Information: DIBt approval Z-42.3-362

Enclosed you will find our DIBt approval Z-42.3-362, valid from 01.06.2020 to 01.06.2025.
Please find attached the translation of this approval into English.

This translation was prepared to the best of our ability and renders the content of the official approval Z-42.3-362 issued by the German Institute for Construction Engineering in English.

This translation has no legal validity and has not been checked by the DIBt. All information without guarantee.

BRAWO® SYSTEMS – KOB GmbH
Blechhammerweg 13-17

67659 Kaiserslautern, Germany

Executive Board:
Dr. Achim Hehl (chairman)

Klaus-Magnus Junginger

Amtsgericht Kaiserslautern
HRB 32894

info@brawoliner.com
T +49 631 20561 100

F +49 631 20561 101

www.brawosystems.com

Approval body for construction products and types of construction

Construction engineering test office

A public agency sponsored jointly by
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Date:	Reference number:
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Number:
Z-42.3-362

Period of validity
from: 1 June 2020
to: 1 June 2025

Applicant:
KOB GmbH
Lauterstraße 50
67752 Wolfstein - GERMANY

Subject of this decision:
Hose liner with the designation "BRAWOLINER" for the rehabilitation of damaged underground waste water pipes in the nominal widths DN 100 to DN 400 and connection collar with the designation "BRAWOLINER connection collar" in the nominal width range DN 100 to DN 150

The aforementioned object of regulation is hereby awarded general building accreditation/approval.
This decision comprises 30 pages and 21 appendices.

I. GENERAL PROVISIONS

1. With this decision, the usability or applicability of the object of the regulation according to the state building regulations is certified.

2. This decision does not replace the permits, approvals and certificates required by law for the execution of construction projects.

3. This decision is issued without prejudice to the rights of third parties, in particular private property rights.

4. Irrespective of further regulations in the "Special Provisions", copies of this decision shall be made available to the user of the object of the regulation. In addition, the user of the object of the regulation needs to be informed that this decision must be available at the place of use or application. Copies shall also be made available to the authorities concerned on request.

5. This decision may only be reproduced in its entirety. Publication in extracts requires the consent of the German Institute for Construction Engineering. Texts and drawings of promotional literature may not contradict this decision, translations must contain the note "Translation of the original German version not checked by the German Institute for Construction Engineering".

6. This decision is revocable. The provisions may be supplemented and amended subsequently, in particular where new technical knowledge so requires.

7. This decision refers to the information and documents provided by the applicant. Any change to these principles is not covered by this decision and must be disclosed to the German Institute for Construction Engineering without delay.

8. The general type approval covered by this decision is also considered to be the general building approval for the type.

II. SPECIAL PROVISIONS

1. Object of regulation and use or application area

This decision applies to the production and use of hose liners with the designation "BRAWOLINER" (Appendix 1) with the epoxy resin systems with the designations "BRAWO I" and "BRAWO III" and the polyester fibre hoses with the designations "BRAWOLINER", "BRAWOLINER HT", "BRAWOLINER XT", "BRAWOLINER HT XT", "BRAWOLINER 3D" and "BRAWOLINER HT 3D" in the nominal widths DN 100 to DN 250 and for the epoxy resin systems with the designations "BRAWO AC" and "BRAWO TC" with the polyester fibre hose with the designation "BRAWOLINER 3D" in the nominal widths DN 300 to DN 400 for renovation or rehabilitation of damaged waste water pipes with circular cross sections.

This decision applies to the rehabilitation of waste water pipes that are intended to drain sewage in accordance with DIN 1986-3[1].

This decision also applies to the restoration of side inlets by means of the connection collar with the designation "BRAWOLINER connection collar" in the nominal widths DN 100 to DN 150 and with the epoxy resin system with the designation "BRAWO RR".

The "BRAWOLINER" hose liners can be used for the rehabilitation or refurbishment of waste water pipes with circular cross-sections made of concrete, reinforced concrete, stoneware, asbestos-free fibre cement, GRP, PVC-U, PE-HD, PP and cast iron, provided that the cross-section of the waste water pipe to be rehabilitated meets the process-related requirements and the structural requirements.

Damaged waste water pipes are rehabilitated by inserting a resin-impregnated polyester fibre hose and subsequently curing this under ambient temperatures or hot water.

In groundwater-saturated zones (groundwater infiltration), a PE protective hose (preliner) must be inserted before inverting the hose liner.

For reconnecting side inlets, only repair or rehabilitation procedures may be used for which general building approvals with the associated type approvals are valid.

2. Provisions applicable to construction products

2.1. Properties and composition

Where applicable, the hose liners described in Section 1 meet the requirements of DIN EN ISO 11296-4[2] and have the specific properties and compositions listed below.

2.1.1. Materials of the hose liner components in the "M" state

2.1.1.1. Materials for inversion hoses

The materials used in the polyester fibre hose "BRAWOLINER", "BRAWOLINER HT", "BRAWOLINER XT", "BRAWOLINER HT XT", "BRAWOLINER 3D" and "BRAWOLINER HT 3D", their coating of polyester urethane film (PU film), PE preliner and the materials used for the epoxy resin systems with the designations "BRAWO I" and "BRAWO III" as well as "BRAWO AC" and "BRAWO TC", including hardeners, must comply with the formulation specifications filed at the German Institute for Construction Engineering.

The polyester fibre hoses for the hose liners have the following values according to table 1:

Table 1: "Properties of the polyester fibre hoses for the hose liners"

Hose designation	Nominal diameter range [mm]	Surface weight [g/m2]	Minimum wall thickness [mm]	Tear strength [N/mm²]	Lateral elongation [%] '
"BRAWOLINER", "BRAWOLINER HT"	DN 100 to DN 250	2,300 ± 300	≥4	≥8	>40
"BRAWOLINER XT", "BRAWOLINER HT XT"	DN 100 to DN 250	2,800 ± 350	≥ 5	≥8	>40
"BRAWOLINER 3D" "BRAWOLINER HT 3D"	DN 100 to DN 200	2,900 ± 400	≥ 5	≥8	≥ 50
"BRAWOLINER 3D"	DN 300 to DN 400	2,900 ± 400	≥8.5	≥8	≥ 50

1 DIN 1986-3 Drainage systems for buildings and land - Part 3: Rules for operation and maintenance; edition:2004-11

2 DIN EN ISO 11296-4 Plastic pipe systems for the rehabilitation of underground pressureless sewer systems (open channel pipes) - Part 4: On-site curing hose lining (ISO 11296-4:2009, corrected version 2010-06-01); German version EN ISO 11296-4:2011; Edition:2011-07

1) The epoxy resins for polyester fibre hoses in Table 1 have the following properties before processing:

- Density at +23 °C according to DIN EN ISO 1183-2[3]
  "BRAWO I" and "BRAWO III": 1.1 kg/dm^3 ± 5 %
- Viscosity of component A (resin) "BRAWO I"
  at +23 °C in accordance with DIN EN ISO 3219[4]: ~ 4,300 mPa x s
- Viscosity of component B (hardener) "BRAWO I"
  at +23 °C in accordance with DIN EN ISO 3219[4]: =510 mPa x s
- Viscosity of component A (resin) "BRAWO III"
  at +23 °C in accordance with DIN EN ISO 3219[4]: = 4,300 mPa x s
- Viscosity of component B (hardener) "BRAWO III"
  at +23 °C in accordance with DIN EN ISO 3219[4]: = 550 mPa x s
- Density at +23 °C according to DIN EN ISO 1183-2[3]
  "BRAWO AC" 1.16 kg/dm^3 ± 5 %
- Density at +23 °C according to DIN EN ISO 1183-2[3]
  "BRAWO TC": 1.23 kg/dm^3 ± 5 %
- Viscosity of component A (resin) "BRAWO AC"
  at +23 °C in accordance with DIN EN ISO 3219[4]: = 4,477 mPa x s
- Viscosity of component B (hardener) "BRAWO AC"
  at +23 °C in accordance with DIN EN ISO 3219[4]: = 651 mPa x s
- Viscosity of component A (resin) "BRAWO TC"
  at +23 °C in accordance with DIN EN ISO 3219[4]: = 4,945 mPa x s

3 DIN EN ISO 1183-2	Plastics - Methods for determining the density of non-foamed plastics - Part 2: Method using a density gradient column (ISO 1183-2:2004); German version EN ISO 1183-2:2004; Edition: 2004-10
4 DIN EN ISO 3219	Plastics - Polymers/resins in liquid, emulsified or dispersed state - Determination of viscosity by means of a rotational viscometer with defined shear rate (ISO 3219:1993); German version EN ISO 3219:1994; Edition: 1994-10

- Viscosity of component B (hardener) "BRAWO TC"
  at +23 °C in accordance with DIN EN ISO 3219[4]: ≈ 261 mPa x s
- Pot life: "BRAWO I" approx. 23 min (In 100 g batch)
  "BRAWO III" approx. 58 min (In 100 g batch)
  "BRAWO AC" approx. 52 min (In 100 g batch)
  "BRAWO TC" approx. 189 min (In 3000 g batch)
- Pot lives depending on the resin quantities with a
  mixing ratio of component A resin to
  component B hardener: 3:1 parts by weight: Appendix 3

The epoxy resin systems correspond to the IR spectra filed at the German Institute for Construction Engineering. The IR spectra must also be filed by the applicant for this decision with the third-party monitoring body.

2) The epoxy resin systems for the polyester fibre hoses in Table 1 have the following properties without a polyester fibre insert in the cured state at a temperature of +23 °C and 50 % humidity:

"BRAWO I":

- Flexural modulus of elasticity according to DIN EN ISO 178[5]: ≈ 3,000 N/mm²
- Tensile strength according to DIN EN ISO 527-2[6]: ≈ 62.0 N/mm²
- Compressive strength according to DIN EN ISO 604[7]: ≈ 100 N/mm²

"BRAWO HI":

- Flexural modulus of elasticity according to DIN EN ISO 178[8]: ≈ 2,650 N/mm²
- Tensile strength according to DIN EN ISO 527-2[6]: ≈ 52.5 N/mm²
- Compressive strength according to DIN EN ISO 604[7]: ≈ 90 N/mm²

"BRAWO AC":

- Flexural modulus of elasticity according to DIN EN ISO 178[5]: ≈ 3,400 N/mm²
- Tensile strength according to DIN EN ISO 527-2[6]: ≈ 76 N/mm²
- Compressive strength according to DIN EN ISO 604[7]: ≈ 48 N/mm²

"BRAWO TC":

- Flexural modulus of elasticity according to DIN EN ISO 178[5]: ≈ 3,900 N/mm²
- Tensile strength according to DIN EN ISO 527-2[6]: ≈ 66 N/mm²
- Compressive strength according to DIN EN ISO 604[7]: ≈ 49 N/mm²

3) The transparent polyester urethane (PU) film for the polyester fibre hoses in Table 1 has the following characteristic properties:

- Surface weight in g/m²of the film for DN 100: 120 g± 12 g
  of the film for DN 125: 150 g± 15 g
  the films for DN 150 and DN 200: 180 g ± 18 g
  of the films for DN 300 to DN 400: 215 g ± 22 g
- Breaking stress in longitudinal and transverse direction: ≥ 40 MPa
- Elongation at break in longitudinal and transverse direction: ≥ 300 %

5 DIN EN ISO 178	Plastics - Determination of flexural properties (ISO 178:2010); German version EN ISO 178:2010; Edition: 2011-04
6 DIN EN ISO 527-2	Plastics - Determination of tensile properties - Part 2: Test conditions for moulding and extrusion compounds (ISO 527-2:1993 including Cor.1:1994); German version EN ISO 527-2:1996; Edition: 996-07
7 DIN EN ISO 604	Plastics - Determination of compressive properties (ISO 604:2002); German version EN ISO 604:2003; Edition:2003-12
8 DIN EN ISO 2811-2	Coating materials - Determination of density - Part 2: Rotating biological contactor method (ISO 2811-2:2011); German version EN ISO 2811-2:2011; Edition: 2011-06

4) PE preliner: minimum wall thickness 150 pm

2.1.1.2. Materials used in the swelling tape (auxiliary material)

Only extruded profiles made of a chloroprene (CR/SBR) rubber and water-absorbent resin may be used for the swelling tape (auxiliary material) in the area of the shaft connection (Appendix 14) of the hose liner. The swelling tapes must show a volume increase of at least 100 % after 72 hours when stored in water.

2.1.1.3. Materials for the connection collar

The materials used for the connection collar must comply with the formulation specifications filed at the German Institute for Construction Engineering.

1) The polyester fibre hose for the connection collar has the following values according to Table 2:

Table 2: "Properties of the polyester fibre hose for the connection collar".

Hose designation	Nominal diameter range [mm]	Surface weight [g/m²]	Thickness [mm]	Tear strength [N/mm²]	Lateral elongation [%]
"BRAWOLINER"	DN 100 to DN 150	2,300 ± 300	≥4	≥8	≥40

2) Components A and B of the epoxy resin system with the designation "BRAWO RR" have the following properties prior to processing:

- Density of component A (resin)
  at +23 °C in accordance with DIN EN ISO 2811-2[8]: 1.157 kg/dm³± 5 %
- Density of component B (hardener)
  at +23 °C in accordance with DIN EN ISO 2811-2[8]: 1.005 kg/dm³ ± 5 %
- Viscosity of component A (resin)
  at +23 °C in accordance with DIN EN ISO 3219[4]: ≈ 2,800 mPa x s
- Viscosity of component B (hardener)
  at +23 °C in accordance with DIN EN ISO 3219[4]: ≈ 390 mPa x s
- Pot life / processing time according to DIN EN ISO 9514[9] at +23 °C, at a mixing ratio of component A resin
  to component B hardener: 3:1 (in a 100 g batch): approx. 4 minutes
- Reaction time (In 100 g batch): approx. 12 minutes

3) The epoxy resin system with the designation "BRAWO RR" has the following properties without a polyester fibre insert in the cured state at a temperature of +23 °C and 50 % humidity:

- Density according to DIN EN ISO 1183-1[10]: 1.166 kg/dm3 ± 5 %.
- Flexural modulus of elasticity according to DIN EN ISO 178[5]: ≈3,000 N/mm²
- Tensile strength according to DIN EN ISO 527-2[6]: ≈50 N/mm²

9 DIN EN ISO 9514 Coating materials - Determination of processing time of multicomponent coating systems - Preparation and conditioning of samples and guidance for testing (ISO 9514:2005); German version EN ISO 9514:2005; Edition: 2005-07

10 DIN EN ISO 1183-1 Plastics - Methods for determining the density of non-foamed plastics - Part 1: Immersion method, liquid pycnometer and titration methods (ISO 1183-1:2012); German version EN ISO 1183-1:2012, Edition: 2013-04

- Shrinkage according to ISO 2577[11]: <0.10%

The epoxy resin system corresponds to the IR spectra filed at the German Institute for Construction Engineering. The IR spectra must also be filed by the applicant for this decision with the third-party monitoring body.

4) The transparent polyester urethane film for the connection collar has the following characteristic properties:

- Surface weight in g/m2:	of the film for DN 100:	120 g± 12 g
	of the film for DN 125:	150 g± 15 g
	of the film for DN 150:	180 g± 18 g
- Breaking stress in longitudinal and transverse direction:		≥ 40 MPa
- Elongation at break in longitudinal and transverse direction:		≥ 300 %

2.1.2. Environmental compatibility

The construction product meets the requirements of the principles for "Assessment of the Effects of Construction Products on Soil and Groundwater" (Version: 2011; Publications by the German Institute for Construction Engineering). This statement only applies if the special provisions of this general building approval are complied with.

The reservation of permission by the competent water authority, in particular in water protection zones, remains unaffected.

2.2. Manufacture, packaging, transport, storage and labelling

2.2.1. Factory production of the hose liners

Seamless hoses are manufactured at the applicant's factory from polyester fibre yarns supplied by the sub-supplier as a single-ply knitted fabric with minimum wall thicknesses according to Table 1 of Section 2.1.1.1. After production of the polyester fibre knitted fabric, the hoses are coated with the polyester urethane film according to Section 2.1.1.1 (3).

During production, the following manufacturing parameters are checked and recorded:

- Surface weight
- Wall thickness
- Tear strength
- Lateral elongation
- Impermeability

The applicant shall have at least factory certificates 2.1 according to DIN EN 10204[12] submitted by the sub-supplier for each delivery in order to check the properties mentioned in Section 2.1.1.1 and the calibration hose (support tube). The applicant shall produce the polyester urethane film as well as the PE preliner according to the characteristics set out in Section 2.1.1.1.

In order to check the properties of the resin systems in accordance with the formulation specifications, the applicant shall have at least factory certificates 2.2 according to DIN EN 1020412 submitted by the sub-supplier for each delivery. As part of the incoming goods inspection, the following properties must be checked according to Section 2.1.1.1 (1) and Section 2.1.1.3:

11 ISO 2577 Plastics - Thermosetting moulding plastics - Determination of shrinkage; Edition: 2007-12

12 DIN EN 10204 Metallic products - Types of test certificates; German version EN 10204:2004; Edition:2005-01

Properties of the resin:

- Density
- Viscosity
- Reactivity

During storage and transport, the relevant accident prevention regulations and the instructions in the applicant's procedure manual must be observed.

2.2.2. Factory production of the connection collar

Connection collars are produced at the applicant's factory from the "BRAWOLINER" polyester fibre hose supplied by the sub-supplier as a single-layer knitted fabric with a minimum wall thickness of 4 mm for the nominal diameter range DN 100 to DN 150 in accordance with Section 2.1.1.3. The polyester fibre hose is coated on the inside with a PU film.

During production, the following manufacturing parameters are checked and recorded:

- Surface weight
- Thickness
- Tear strength
- Lateral elongation
- Impermeability

When producing the connection collar, it must be ensured that it is at least long enough to cover the first sleeve on the side inlet. The minimum wall thickness of the connection collar must be 4 mm.

As part of the incoming goods inspection, the following properties must be checked according to Section 2.1.1.3:

Properties of the resin:

- Density
- Viscosity
- Reactivity

2.2.3. Packaging, transport, storage

The polyester synthetic fibre hoses coated with PU films according to Section 2.1.1 and the connection collars according to Section 2.2.2 must be packed in such a way that the hoses and connection collars are not damaged.

Until further use, the hoses and the connection collar must be stored in a dry place without solar radiation at temperatures between +5 °C and +25 °C.

The resin impregnation components delivered by the sub-supplier to the respective construction site must be stored in suitable, airtight containers on the applicant's premises until further use. The temperature range from > +5 °C to approx. +30 °C must be observed. The containers can be kept for 12 months when sealed at the factory and must be protected from direct sunlight. The containers are designed so that they always contain (epoxy resin and hardener ("BRAWO I", "BRAWO III", "BRAWO RR", "BRAWO AC" and "BRAWO TC") in separate individual receptacles.

During storage and transport, the relevant accident prevention regulations and the instructions in the applicant's manual must be observed.

2.2.4. Labelling

The polyester fibre hoses, the connection collar and the respective transport containers for the resin components must be labelled with the conformity mark (Ü mark) in accordance with the conformity mark regulations of the countries, including the decision number Z-42.3-362. The labelling may only be carried out if the conditions set out in Section 2.3 Certificate of Conformity are fulfilled.

The manufacturer must indicate the hazard symbols and H and P phrases in accordance with the Hazardous Substances Ordinance and EU Regulation No. 1907/2006 (REACH) as well as the current version of CLP Regulation (EC) 1272/2008[13] on the containers, packaging, package insert or on the delivery note. The packaging must be labelled in accordance with the CMR[14] rules in the versions currently in force.

In addition, the following must be specified on the transport containers used for the polyester fibre hoses for the hose liners:

- Nominal diameter
- Length
- Wall thickness
- Designations "BRAWOLINER", "BRAWOLINER HT", "BRAWOLINER XT", "BRAWO- LINER HT XT", "BRAWOLINER 3D" and "BRAWOLINER HT 3D"
- Batch number

In addition, the transport containers for resins and hardeners for the hose liners must be labelled at least as follows:

- Resin designation "BRAWO I", "BRAWO III", "BRAWO AC" and "BRAWO TC"
- Component designation A (resin) and B (hardener)
- Temperature range
- Container contents (volume or weight)

In addition, the following must be specified on the transport containers for the polyester fibre hoses used for the connection collar:

- Nominal diameter
- Connection bracket
- Length
- Designations "BRAWOLINER connection collar".
- Batch number

In addition, the transport containers for resins and hardeners for the connection collar must be labelled at least as follows:

- Resin designation "BRAWO RR"
- Component designation A (resin) and B (hardener)
- Temperature range
- Container contents (volume or weight)

[13] 1272/2008 — Regulation (EC) No. 1272/2008 on classification, labelling and packaging of substances and mixtures

14 CMR — European Convention on the Contract for the International Carriage of Goods by Road (Accord européen relatif au transport international des marchandises Dangereuses par Route)

2.3. Certificate of conformity

2.3.1. General

The certificate of conformity for the construction products with the provisions of the general building approval covered by the decision must be made for each manufacturing plant with a declaration of conformity based on a factory production control and a certificate of conformity from a certification body recognised for this purpose as well as regular external inspection by a recognised inspection body including initial testing of the construction products in accordance with the following provisions.

For the issue of the certificate of conformity and external monitoring, including the product tests to be carried out, the manufacturer of the construction products must involve a certification body recognised for this purpose and a monitoring body recognised for this purpose.

The declaration of conformity shall be issued by the manufacturer by marking the construction products with the conformity symbol (Ü symbol) indicating the intended use.

A copy of the certificate of conformity issued by the certification body shall be made available to the German Institute for Construction Engineering by the certification body.

The German Institute for Construction Engineering must also be provided with a copy of the initial test report.

2.3.2. In-house production control

An in-house production control shall be set up and carried out in each manufacturing plant. In-house production control means the continuous monitoring of production to be carried out by the manufacturer to ensure that the construction products that it manufactures comply with the provisions of the general building approval covered by this decision.

The in-house production control shall include at least the measures listed below:

– Description and verification of the starting material

a) <u>For the hose liner materials and connection collars:</u>

For each delivery of the components comprising PU film, polyester fibres, resin and hardener, the operator of the manufacturing plant must ensure that they comply with the required properties in accordance with Section 2.1.1. For this purpose, the operator of the manufacturing plant must have the relevant factory certificates 2.2 according to DIN EN 10204[12] submitted by the respective supplier. As part of the incoming goods inspection, the properties mentioned in Section 2.1.1 shall also be checked by random sampling.

For the connection collars, the shrinkage shall also be checked by random sampling in accordance with Section 2.1.1.3 on at least three test specimens according to ISO 2577[11] or by determining the loss of mass in accordance with DIN 16946-1[15]. The test shall be carried out on test specimens after conditioning for 24 hours at +23 °C ± 2 °C. The use of a collapsible metal mould is recommended for the production of the test specimens.

[15] DIN 16946-1 Reaction resin moulding materials; Casting resin moulding materials; Test methods; Edition: 1989-03

b) For the swelling tapes (auxiliary materials):

For each delivery of the swelling tapes, the applicant shall have the properties specified in Section 2.1.1.2 confirmed to it by the sub-supplier by submitting works certificates 2.2 in accordance with DIN EN 1020412.

Compliance with the geometric requirements (profile shape and dimensions) of the swelling tapes shall be checked visually and by random sample remeasurement as part of the incoming inspection.

- Checks and tests to be carried out during manufacture:

  The requirements under Sections 2.2.1 and 2.2.2 shall be verified.

- Checking the containers:

  For each batch of resin, the labelling requirements shall be checked in accordance with Section 2.2.4.

The results of the in-house production control shall be recorded and evaluated. The records shall contain at least the following information:

- Name of the construction products or the starting materials and components,
- Type of check or test,
- Date of manufacture and testing of construction products and starting materials or components,
- Result of the checks and tests and, where applicable, comparison with the requirements,
- Signature of the person responsible for in-house production control.

The records shall be kept for at least five years and shall be submitted to the inspection body responsible for external monitoring. They must be submitted to the German Institute for Construction Engineering and the responsible highest building supervisory authority upon request.

If the test result is unsatisfactory, the manufacturer shall immediately take the necessary measures to remedy the defect. Construction products which do not meet the requirements shall be handled in such a way as to avoid confusion with conforming products. Once the defect has been remedied - insofar as this is technically possible and necessary to prove that the defect has been remedied - the relevant test shall be repeated without delay.

2.3.3. External monitoring

At each manufacturing plant, the in-house production control must be regularly inspected by an external monitoring body, but at least once every six months.

Within the scope of external monitoring, an initial test of the construction products shall be carried out. The in-house production control shall be carried out within the scope of external monitoring by random sample checks. The requirements of Sections 2.1.1 and 2.2.2 shall be verified in this respect.

In addition, the manufacturing requirements according to Sections 2.2.1, 2.2.2 and 2.2.4 shall be checked at random. This also includes checking the curing behaviour, density, storage stability and surface weight, as well as IR spectroscopy.

Sampling and testing shall be the responsibility of the recognised monitoring body. The factory certificates 2.2 in accordance with DIN EN 10204[14] must also be checked during external monitoring.

The results of the certification and external monitoring shall be kept for at least five years. They must be submitted by the certification body or the monitoring body to the German Institute for Construction Engineering and the responsible highest building supervisory authority upon request.

3. Provisions for the application of the object of regulation

3.1. Planning and dimensioning

3.1.1. Planning

The details of the necessary pipe data must be checked, e.g. line layout, depth, position of side inlets, shaft depths, groundwater, pipe connections, hydraulic conditions, inspection openings, cleaning intervals. Existing video recordings must be evaluated in relation to the application. The correctness of the information shall be verified on site. The assessment of the condition of the existing waste water pipe of the property drainage system with regard to the applicability of the rehabilitation procedure shall be carried out.

The hydraulic effectiveness of the waste water pipes must not be impaired by the installation of a hose liner. Corresponding evidence is to be kept if necessary.

3.1.2. Dimensioning

3.1.2.1. Hose liner in "I" state

3.1.2.1.1. Wall thickness and wall construction

Depending on the system, resin-impregnated polyester fibre liners are used for rehabilitation measures, which have a minimum wall thickness of 3 mm after inversion and curing.

With hose liners of the wall thickness mentioned, waste water pipes may be rehabilitated whose load-bearing capacity is given alone (without support of the surrounding soil), i.e. no cracks (except hairline cracks with crack widths less than 0.15 mm or, in the case of reinforced concrete pipes, less than 0.3 mm) are present. The nominal stiffness must not fall below SN > 500 N/m^2.

If the old pipe ground system alone is no longer capable of bearing loads, such waste water pipes with hose liners of the wall thicknesses listed in Table 3 may only be rehabilitated if the static loads to be absorbed by the hose liner are verified by a static calculation in accordance with worksheet DWA-A 143-2[16].

For the calculated values of the short-term ring stiffness SR of the cured hose liner, the wall thicknesses in Tables 3 and 4 must be observed.

[16] DWA-A143-2 German Association for Water Management, Waste Water and Waste e. V. (DWA) - Worksheet 143: Rehabilitation of drainage systems outside buildings - Part 2: Static calculations for the rehabilitation of waste water pipes and sewers with lining and assembly method; Edition:2015-07

Table 3: "Minimum wall thicknesses and nominal stiffness SN1 of cured hose liners"

Nominal diameter DN	Resin system	Minimum wall thickness			
in mm		3 mm	4 mm	5 mm	5.5 mm
DN 100	"BRAWO I" and BRAWO III"	5,850 N/m²	13,867 N/m²	27,083 N/m²	-
DN 125	"BRAWO I" and BRAWO III"	2,995 N/m²	7,100 N/m²	13,867 N/m²	-
DN 150	"BRAWO I" and BRAWO III"	1,733 N/m²	4,109 N/m²	8,025 N/m²	s
DN 200	"BRAWO I" and BRAWO III"	... 731 N/m²	1,733 N/m²	3,385 N/m²	-
DN 250	"BRAWO I" and BRAWO III"	-	887 N/m²	1,733 N/m²	-
DN 300	"BRAWO AC"	-	638 N/m²	1,258 N/m²	1,683 N/m2
DN 300	"BRAWO TC"	-	576 N/m²	1,136 N/m²	1,520 N/m2
DN 400	"BRAWO AC"	-	-	524 N/m²	700 N/m2
DN 400	"BRAWO TC"	-	-	-	632 N/m2

[1] Calculation of the nominal stiffnesses with the short-term modulus of elasticity E=2,600 N/mm² of the nominal diameters DN 100 to DN 250 with the resin systems "BRAWO I" and "BRAWO III" and E=3,100 N/mm2 with the resin system "BRAWO AC" as well as E=2,800 N/mm² with the resin system "BRAWO TC" according to DIN EN 1228

Table 4: "Nominal stiffnesses SN and short-term ring stiffnesses SR"

Nominal stiffness SN in N/m²	Short-term ring stiffness SR in N/mm²
500	0.0040
630	0.0050
830	0.0065
1,250	0.0100
2,500	0.0200
5,000	0.0400

The hardened wall thickness must not fall below the minimum of 3.0 mm.

The following relationships apply to the nominal stiffnesses SN and short-term ring stiffnesses SR:

The following applies to SN:

$$SN = \frac{E \cdot s^3}{12 \cdot s_m^3}$$

The following applies to SR:

$$SN = \frac{E \cdot s^3}{12 \cdot s_m^3}$$

(SN = nominal stiffness according to DIN 16869-2[17])

For the groundwater loading condition, the hose liner must be dimensioned with regard to dents in accordance with worksheet DWA-A 143-2[16] (see also Section 3.1.2.1.4).

[17] DIN 16869-2 Glass-fibre reinforced polyester resin (UP-GF) pipes, centrifugally cast, filled - Part 2: General quality requirements, testing; Edition:1995-12

If the waste water pipe to be rehabilitated is located in the groundwater-saturated zone, the pipe liners have a three-layer wall structure due to the PE protective film (preliner) to be retracted. This consists of the PE protective film, the polyester fibre layer and the PU film (Appendix 1). The protective film is not required in soil conditions where there is no ground water. In this case, the hose liners have a two-layer wall construction made of polyester fibre layer and PU film.

3.1.2.1.2. Physical characteristics of the cured hose liner

After curing the polyester fibre layer impregnated with resin and hardener (without PE preliner and inner coating), these must have the following characteristic values:

a) Nominal hose liner diameters DN 100 to DN 250

- Density at +23 °C according to DIN EN ISO 1183-23: 1.163 kg/dm^3 ± 5 %
- Hardness according to DIN EN 59[18]: ≥ 80 IRHD
- Short-term modulus of elasticity according to DIN EN 1228[19]: ≥ 2,600 N/mm^2
- Flexural modulus of elasticity according to DIN EN ISO 11296-4[2] or DIN EN ISO 178[5]: > 2,200 N/mm^2
- Bending stress ore according to DIN EN ISO 11296-4[2] or DIN EN ISO 178[5]: ≈ 40 N/mm^2

b) Nominal hose liner diameters DN 300 to DN 400 with the "BRAWOLINER 3D" and the resin systems "BRAWO AC"

- Density at +23 °C according to DIN EN ISO 1183-2[3]: 1.135 kg/dm^3 ± 5%
- Hardness according to DIN EN 59[18]: ≥ 17
- Short-term modulus of elasticity according to DIN EN 1228[19]: ≥ 3,100 N/mm^2
- Flexural modulus of elasticity according to DIN EN ISO 11296-4[2] or DIN EN ISO 178[5]: ≥ 2,200 N/mm^2
- Bending stress ore according to DIN EN ISO 11296-4[2] or DIN EN ISO 178[5]: ≈ 30 N/mm^2

c) Nominal hose liner diameters DN 300 to DN 400 with the "BRAWOLINER 3D" and the resin systems "BRAWO TC"

- Density at +23 °C according to DIN EN ISO 1183-2[3]: 1.217 kg/dm^3 ± 5 %
- Hardness according to DIN EN 59[18]: ≥ 17
- Short-term modulus of elasticity according to DIN EN 1228[19]: ≥ 2,800 N/mm^2
- Flexural modulus of elasticity according to DIN EN ISO 11296-4[2] or DIN EN ISO 178[5]: ≥ 2,300 N/mm^2
- Bending stress OfB according to DIN EN ISO 11296-4[2] or DIN EN ISO 178[5]: ≈ 29 N/mm^2

[18] DIN EN 59 — Glass fibre reinforced plastics; determination of hardness with the Barcol hardness tester; Edition: 1977-11

[19] DIN EN 1228 — Plastics piping systems - Glass-fibre reinforced thermosetting plastic (GRP) pipes - Determination of specific initial ring stiffness; German version EN 1228:1996; Editions 1996-08

3.1.2.1.3. Properties of the cured hose liner based on thermal analysis (DSC analysis)

The cured polyester fibre resin composite has the following limit values, which were determined by means of Differential Scanning Calorimetry (DSC)

Glass transition temperature T_{G1}	(actual state of the reaction resin system; first heating phase)
– "BRAWO I":	≥ +45 °C
– "BRAWO III":	≥ +45 °C
– "BRAWO AC":	≥ +73 °C
– "BRAWO TC":	≥ +63 °C
Glass transition temperature TG2	(resin system in fully cured state; second heating phase)
– "BRAWO I":	≥ +87 °C
– "BRAWO III":	≥ +80 °C
– "BRAWO AC":	≥ +117°C
– "BRAWO TC":	≥ +83 °C

3.1.2.1.4. Static calculation of the cured hose liner

If a static calculation is required for rehabilitation measures, the stability must be determined according to worksheet DWA-A 143-2[16] of the "German Association for Water Management, Waste Water and Waste e. V. (DWA) before execution.

In the static calculation, a partial safety factor of γ_M = 1.35 must be taken into account for the hose liner material.

The reduction factor A for determining the long-term values was determined according to

DIN EN 761[20] and must be taken into account for the static calculation.

The following values are to be taken into account for the static calculation:

a) Nominal hose liner diameters DN 100 to DN 250 with the resin systems "BRAWO I" and "BRAWO III"

– Short-term bending stress σ_{fB} according to DIN EN ISO 11296-4[2] or DIN EN ISO 178[5]:	40 N/mm²
– Long-term bending stress σ_{fB}:	≥ 25 N/mm²
– Short-term modulus of elasticity according to DIN EN 1228[19]:	2,600 N/mm²
– Long-term modulus of elasticity:	1,800 N/mm²
– Reduction factor A after 10,000 hours:	1.44

b) Nominal hose liner diameters DN 300 to DN 400 with the "BRAWOLINER 3D" with the resin systems "BRAWO AC"

– Short-term bending stress σ_{fB} according to DIN EN ISO 11296-4[2] or DIN EN ISO 178[5]:	30 N/mm²
– Long-term bending stress σ_{fB}:	≥ 16 N/mm²
– Short-term modulus of elasticity according to DIN EN 1228[19]:	3,100 N/mm²
– Long-term modulus of elasticity:	1,694 N/mm²
– Reduction factor A after 4.500 hours:	1.83

[20] DIN EN 761 Plastic piping systems - Glass-fibre reinforced thermosetting plastic (GRP) pipes - Determination of creep factor in the dry state; German version EN 761:1994; Edition: 1994-08

c) Nominal hose liner diameters DN 300 to DN 400 with the "BRAWOLINER 3D" with the resin systems "BRAWO TC"

- Short-term bending stress σ_{fB} according to DIN EN ISO 11296-4[2] or DIN EN ISO 178[5]: 29 N/mm²
- Long-term bending stress σ_{fB}: $\geq$ 12 N/mm²
- Short-term modulus of elasticity according to DIN EN 1228[19]: 2,800 N/mm²
- Long-term modulus of elasticity: 1,176 N/mm²
- Reduction factor A after 4.600 hours: 2.38

3.1.2.2. "BRAWOLINER connection collar"

3.1.2.2.1. Physical characteristics of the cured connection collar

- Density at +23 °C according to DIN EN ISO 1183-2[11]: approx. 1.1 kg/dm³
- Adhesive tensile strength according to DIN EN 1542[21] on stoneware: > 3.4 N/mm²
- Adhesive tensile strength according to DIN EN 1542[21] on PVC: > 2.5 N/mm²

The hardened wall thickness must not fall below the minimum of 3.0 mm.

3.1.2.2.2. Properties of the cured connection collar based on thermal analysis (DSC analysis)

The connection collar has the following limit values, which were determined using Differential Scanning Calorimetry (DSC):

Glass transition temperature T_{G1} (actual state of the reaction resin system; first heating phase)

- "BRAWO RR": $\geq$ +56 °C

Glass transition temperature T_{G2} (resin system in fully cured state; second heating phase)

- "BRAWO RR": $\geq$ +87 °C

3.2. Execution

3.2.1. General

Damaged waste water pipes are rehabilitated by inserting and subsequently curing a resin-impregnated polyester fibre hose.

For this purpose, a polyester fibre hose, which is enclosed on the outside with a flexible polyester urethane film, is impregnated with epoxy resin (EP resin) on site. This hose is inserted (inverted) into the pipe to be rehabilitated by means of water gravity or compressed air using a pressure drum and installed. This inversion causes the polyester urethane film to reach the side facing the waste water. The compressed air or water pressure is maintained until the resin-impregnated polyester fibre hose has cured. Curing can be accelerated by hot water circulation using a device called the "BRAWOLINER-HOTBOX".

In the groundwater-saturated zone (groundwater infiltration), a PE protective hose (preliner) is pulled in before the resin-impregnated polyester fibre hose is inverted.

Side inlets are restored by means of a pipe rehabilitation device. In this case, side inlets are opened by means of a remote-controlled milling unit or other suitable tools. By means of an inversion bladder adapted to the respective nominal diameter of the side inlet, this "BRAWOLINER connection collar" impregnated with the epoxy resin "BRAWO RR" is pushed into the side inlet pipe up to the first sleeve connection. Curing takes place at ambient temperatures or with the addition of steam or hot water.

[21] DIN EN 1542 Products and systems for the protection and repair of concrete structures - Test methods - Measurement of bond strength in a pull-off test; German version EN 1542:1999; Edition: 1999-07

The "BRAWOLINER" hose liners can be used for the following structural conditions:

a) from the starting shaft to the target shaft

b) from an inspection opening to the target shaft

c) from the starting shaft to the inspection opening

d) from an inspection opening or starting shaft to the waste water collection sewer

e) from the starting shaft or an inspection opening to a defined point in the waste water pipe to be rehabilitated

f) from the sewer to a defined point of the waste water pipe being rehabilitated Between the respective starting and finishing points, several shafts can be crossed, including the crossing of shafts with channel deflections. Up to a channel deflection of 90°, crossing is possible without creases.

If creasing occurs, it must not be greater than that specified in DIN EN ISO 11296-4[2].

The side inlets are restored from the collecting pipe by means of the "BRAWOLINER connection collar" using rehabilitation robots.

However, side inlets can also be restored either in open construction or by means of a repair or rehabilitation procedure for which general building approvals with the associated type approvals are valid.

The applicant must provide the executing company with a handbook describing the individual steps of the procedure in relation to the type of execution used for the rehabilitation procedure.

The applicant shall also ensure that those executing the work are adequately acquainted with the procedure. The sufficient expert knowledge of the executing company can be documented by an appropriate quality seal issued by Güteschutz Kanalbau e. V. [22].

3.2.2. Devices and equipment

3.2.2.1. The components, equipment and facilities required as a minimum for the execution of the rehabilitation procedure:

- Devices for sewer cleaning
- Devices for sewer inspection (DWA-M 149-2[23])
- Equipment for the production vehicles:
  - Impregnation point, if necessary with suction device
  - Container for residual materials
  - Climate controlled cabinet for the resin systems (temperature range at least +5 °C to +20 °C)
  - Container with resin and hardener "BRAWO I" or "BRAWO III" or "BRAWO AC" or "BRAWO TC
  - Polyester fibre hoses "BRAWOLINER", "BRAWOLINER HT", "BRAWOLINER XT", "BRAWOLINER HT XT", "BRAWOLINER 3D" and "BRAWOLINER HT 3D" in the appropriate nominal diameters (Appendix 1)
  - Roller drive

[22] Güteschutz Kanalbau e. V.; Linzer Str. 21, Bad Honnef, Phone: (+49 (0)2224) 9384-0, Fax: (+49 (0)2224) 9384-84

[23] DWA-M 149-2 German Association for Water Management, Waste Water and Waste e. V. (DWA) - data sheet 149: Status detection and assessment of drainage systems outside buildings - Part 2: Coding system for optical inspection; Edition: 2013-12

- Table with conveyor belt or roller table
- Power supply
- Vacuum system
- Nominal diameter-related PE preliners
- Nominal diameter-related pressure hoses for connection to the pressure drum
- Pressure drum with pressure monitoring devices and hot water connection
- Compressor, compressed air hoses, compressed air regulator (for inversion by means of pressure)
- Inversion frame, cold water hose, hydrant connection and accessories (for inversion by means of water gravity) (Appendix 12)
- Heating system/unit designated 'HOTBOX' (for hot water curing) (Appendix 9 and 12)
- nominal size related calibration hoses
- Ropes
- Inversion bends (suitable for the respective nominal diameter)
- Sealing bags (suitable for the respective nominal diameter)
- Support tubes or support hoses for sample collection on the construction site (suitable for the respective nominal diameter)
- Temperature sensor
- Temperature monitoring and recording apparatus
- Small devices (e.g. compressed air cutting tools)
- Hand tools
- communal and sanitary rooms if necessary

If electrical devices, e.g. video cameras (or so-called long-distance sewer eyes) are brought into the pipeline to be rehabilitated, they must be supplied in accordance with VDE regulations.

3.2.2.3. Additional components, devices and equipment required at least for the rehabilitation by means of a connection collar

- "BRAWOLINER connection collar" in the appropriate nominal diameters
- if necessary, suction device
- Pipe rehabilitation device / packer
- Inversion bladders in the nominal diameters required on site
- Control unit
- Camera with screen
- Sliding rods

3.2.3. Implementation of the rehabilitation measure

3.2.3.1. Preparatory measures

Before commencing work, the waste water pipe to be rehabilitated must be cleaned to such an extent that the damage can be detected faultlessly on the monitor. If nec. obstacles to inverting the hose must be removed (e.g. root intrusions, protruding side inlet pipes, tar build-ups, etc.). When removing such obstacles, it must be ensured that this is only done with suitable tools so that the existing waste water pipe is not additionally damaged.

Before starting the inversion it must be ensured that the relevant pipe is not operated; if necessary, set appropriate sealing bags and divert the waste water.

Persons may only enter shafts of the waste water pipes to be rehabilitated if it has been checked beforehand that no flammable gases are present in the pipe section. The same applies to devices used for the rehabilitation procedure which are to be introduced into the pipeline section to be rehabilitated.

The corresponding sections of the following regulations must be observed:

- GUV-R 126[24] (previously GUV 17.6)
- DWA-M 149-2[23]
- DWA-A 199-1 and DWA-A 199-2[25]

The accuracy of the information referred to in 3.1.1 shall be verified on site. For this purpose, the pipe section to be rehabilitated must be cleaned with conventional high-pressure flushing equipment to such an extent that the damage on the monitor can be detected faultlessly during the optical inspection in accordance with data sheet DWA-M 149-2[23].

When persons enter the shafts of the waste water pipes to be rehabilitated and during all steps of the rehabilitation procedure, the relevant accident prevention regulations must also be observed.

The steps required to carry out the process shall be recorded for each impregnation, using the record sheet in Appendix 19.

3.2.3.2. Incoming inspection of the process components on the construction site

The transport containers used for the process components shall be checked to ensure that the markings referred to in Section 2.2.4 are present. The circumference of the polyester fibre hose in relation to the object to be rehabilitated must be measured before impregnation with resin. Check that the storage temperature to be maintained before resin impregnation is complied with.

3.2.3.3. Arrangement of support tubes and support hoses

Before the PE protective hose (preliner) is pulled in, support tubes or support hoses may have to be positioned to extend the waste water pipe to be rehabilitated or in the area of intermediate shafts so that samples can be taken at these points to complete the rehabilitation measure.

3.2.3.4. Positioning of the swelling tapes (auxiliary materials)

Before the preliner is inserted, one or two swelling profiled tapes should be placed at an interval of approx. 10 cm to 20 cm from the beginning of the pipeline to be rehabilitated. These must be positioned by hand. Placing the swelling tapes is also necessary in the same way for each shaft passed through and at the end shaft.

In areas where swelling tapes cannot be used for structural design reasons, the watertight formation of the connection areas between the hose liner and the shaft can also be carried out in accordance with Section 3.2.3.11.

[24] GUV-R126 Safety regulations: Work in enclosed spaces of waste water treatment plants (previously GUV 17.6); Edition: 2007-06

[25] DWA-A 199-1 German Association for Water Management, Waste Water and Waste e. V. (DWA) - Worksheet 199: Service and operating instructions for sewage plant personnel, - Part 1: Service instructions for sewage plant personnel; Edition:2011-11

DWA-A 199-2 German Association for Water Management, Waste Water and Waste e. V. (DWA) - Worksheet 199: Service and operating instructions for sewage plant personnel - Part 2: Operating instructions for sewage and rainwater treatment system personnel; Edition:2007-07

3.2.3.5. Inserting the PE protective hose (preliner)

In groundwater saturated zones, a preliner must always be inserted.

The PE protective hose must be inserted into the waste water pipe to be rehabilitated in such a way that damage is avoided. The PE protective hose must be inserted by means of inversion. The PE protective hose must be inserted into the waste water pipe to be rehabilitated using the "pressure drum" by means of compressed air. The swelling tapes to be used for the watertight connection of the hose liner must be positioned in the area of the shaft connections when the PE protective hose is installed (Appendix 14 and 15).

3.2.3.6. Impregnation of the polyester fibre hose

a) Resin mixture

Prior to mixing the resin, the contractor must determine whether the epoxy resin "BRAWO I", "BRAWO III", "BRAWO AC" or "BRAWO TC" is to be used for the specific rehabilitation measure. The specifications or diagrams in Appendix 2 must be observed for the selection process.

The epoxy resins must be brought to a temperature of approx. +13 °C to +15 °C before impregnating the polyester fibre hoses.

The quantity of resin required for impregnating the respective polyester fibre hose with resin shall be determined before the beginning of resin mixing depending on the wall thickness, the hose liner diameter and taking into account an excess quantity of resin according to the following equation (Appendix 4)

Resin quantity [kg] = (tt x hose liner diameter [m] x wall thickness [mm] x hose liner length [m] x 0.9) + excess resin [kg].

The containers cooled to the processing temperature of approx. +15 °C, consisting of component A resin and component B hardener, are to be mixed homogeneously and without bubbles in the required quantities in a mixing ratio of 3:1 (resin:hardener).

Resin and hardener quantities, resin mixture and hardening behaviour as well as the temperature conditions shall be recorded in the log (Appendix 19) according to Section 3.2.3.1.

b) Resin impregnation (Appendix 5)

The polyester fibre hose is to be rolled out on the conveyor table in the production vehicle, if necessary also attached to suitable equipment and then connected to the vacuum system. A vacuum of approx. 100 mbar to 150 mbar must be created in order to largely eliminate air inclusions from the polyester fibre knitted fabric and support the subsequent impregnation. The mixed resin quantity is then filled into the hose liner through a funnel in such a way that no air gets into the hose. To evenly distribute the resin in the polyester fibre knitted fabric, the hose liner must be passed through a roller device. The roller spacing must be set to approximately twice the wall thickness of the respective hose liner (Appendix 4). The feed rate must be selected so that the resin is distributed as evenly as possible in the matrix of the polyester fibre knitted fabric. If the resin distribution is noticeably uneven, the hose may have to be passed through the roller device again with a narrower distance between the rollers. To reduce friction during the subsequent inversion and to avoid unnecessary temperature increases, the impregnated hose liner should be placed in layers in a container with cold water and soap detergent immediately after passing through the rollers.

The curing time and the temperature curve for both inverting with closed end and inverting with open end shall be recorded in the log according to Section 3.2.3.1.

3.2.3.7. Inverting the resin impregnated polyester fibre hose

3.2.3.7.1. Inverting by means of a pressure drum

a) Inverting with closed end (Appendices 6 to 8)

The pull-in rope must be attached to the closed end of the impregnated hose liner and the heating hose to this. The pull-in rope and the heating hose must be connected to the pressure drum. By means of this rope (with heating hose) the hose liner is rolled up in the pressure drum (Appendix 6).

A nominal diameter-related pressure hose is to be connected to the pressure drum by means of coupling elements. At the other end of the pressure hose, an inversion pipe matched to the pipe to be rehabilitated must be attached by means of a coupling element. The end of the hose liner must be pulled through the pressure hose and turned inside out at the inversion pipe. This hose liner end must be firmly connected to the inversion pipe by means of adhesive tapes and, if necessary, metallic tensioning straps.

The inversion pipe (inversion bend) with the hose liner end is to be inserted in the starting shaft or in front of the inspection opening and positioned in the PE protective hose (preliner) at the beginning of the pipe to be rehabilitated (Appendix 7). An inversion pressure of 0.2 bar to 0.3 bar must then be applied to the pressure drum. The resin-impregnated hose liner is pressurised with compressed air and this causes the turning inside out process. This inversion process continues until the target shaft, the inspection opening or the target point of the waste water pipe to be rehabilitated is reached (Appendix 8). This process brings the resin-impregnated inside of the hose liner either into contact with the inside of the PE protective hose or directly into contact with the inner surface of the waste water pipe to be rehabilitated. In this way, the polyester urethane coating reaches the side facing the waste water.

Hot water curing:

The compressed air must be slowly released at the pressure drum while the hose liner is being filled with water. Via the "HOTBOX" heating system/unit to be connected to the pressure drum, the hose liner must be completely filled with water so that it fits snugly against the inner surface of the waste water pipe to be rehabilitated and is held there. The water heated in the "HOTBOX" is to be pumped in the heating circuit (see Appendix 9). The circulating water must be heated to +55 °C in the feed. The feed and return flow temperature in the heating circuit must be measured and recorded. For the nominal diameter-related heating and holding times, the specifications in Appendix 13 must be observed. After completion of the curing process, the heating water must be cooled down to approx. +10 °C by adding cold tap water. The water must be drained once this temperature level is reached.

Cold curing:

The curing of the hose liner can also take place under ambient temperatures (minimum +10 °C). The resin systems "BRAWO I", "BRAWO III" and "BRAWO AC" are "cold-curing" epoxy resins.

The following curing times for the hose liner under ambient temperatures must be observed:

"BRAWO I":	13 hours at +10 °C
"BRAWO III":	24 hours at +10 °C
"BRAWO AC":	24 hours at +10 °C

The curing time for the hose liner depends on the epoxy resin system used according to Section 2.1.1.1, the heating temperature of the water (Appendix 13) and/or the ambient temperatures. The curing time and the applied pressure must be recorded.

b) Inverting with open end (Appendix 10 and 11)

If the rehabilitation is carried out from a start shaft or an inspection opening in the direction of an inaccessible waste water collection sewer, the hose liner length must first be determined so that the hose liner does not protrude into the collection sewer. The end of the hose liner must be sealed with a retaining rubber before it is rolled up in the pressure drum.

The hose liner sealed in this way must be rolled up in the pressure drum. After that, the same steps as described in paragraph (a) shall be carried out, including inversion. At the end of the inversion process supported by compressed air, the retaining rubber loosens and the pressure in the hose liner is released. The hose liner is not yet placed against the inner surface of the pipe to be rehabilitated or against the PE protective pipe (preliner) previously installed.

The hose liner must be detached from the inversion pipe. A calibration hose with connected heating hose must be rolled into the pressure drum. The other end of this calibration hose shall be attached to the U-bend together with the exposed end of the resin impregnated hose liner. Then the calibration hose must be inverted at the same pressure level as mentioned in paragraph (a). The calibration hose ensures that the hose liner fits snugly against the inner surface of the pipe to be rehabilitated or the PE protective hose.

Hot water curing:

The hose liner must then be cured as described in paragraph a) using hot water circulation via the "HOTBOX" and the pressure drum. After completion of the curing process, the heating water must be cooled down to approx. +10 °C by adding cold tap water. The water must be drained off after reaching this temperature level and the calibration hose removed.

Cold curing:

Curing is carried out as described in Section 3.2.3.7.1 a).

3.2.3.7.2. Inverting by means of water gravity (Appendix 12)

In order to invert the hose liner into the pipe by means of water gravity, an inversion frame must be erected at the start shaft. The height of this inversion frame must be dimensioned according to the required hydrostatic pressure and the shaft depth. The open end of the hose liner must be fixed to the inversion frame and fastened in such a way that water can then be introduced via a hydrant. The hydrostatic pressure of the water causes the inversion of the hose liner into the waste water pipe being rehabilitated. The end of the hose liner must be sealed airtight and folded up. A safety rope and, if necessary, a heating hose must be attached to the resulting "liner head". The safety rope attached to the "liner head" is used to control the inversion speed. It must be ensured that by controlling the amount of water added, the inversion is continuous and not intermittent.

Inversion is to be carried out with a water column of approx. 2 m to 3 m (corresponding to a hydrostatic water pressure of 0.2 bar to 0.3 bar). Curing must be carried out at approx. 0.3 bar to 0.4 bar.

The inversion process continues until the target shaft, the inspection opening or the target point of the waste water pipe to be rehabilitated is reached. This process brings the resin-impregnated inside of the hose liner into contact with the inside of the previously inserted protective hose (preliner) or directly with the inner surface of the waste water pipe to be rehabilitated. In this way, the polyester urethane coating on the hose liner reaches the side facing the waste water. The hose liner must be completely filled with water so that it fits snugly against the inner surface of the waste water pipe to be rehabilitated and is held there.

Curing is performed as described in Section 3.2.3.7.1 under a) and b).

3.2.3.8. Final work

After curing, the resulting inner pipe on the respective shaft wall must be cut off and removed using compressed air-powered cutting tools in the start and target shafts. In the intermediate shafts, the upper half-shell of the resulting pipe must be removed until it touches the floor of the shaft.

The pipe sections (circular rings) are to be taken from the support tubes or support hoses also to be removed (see Section 3.2.4) for the following tests.

When carrying out cutting work, the relevant accident prevention regulations must be observed.

3.2.3.9. Reconnection of side inlets by means of connection collar (Appendices 16 to 18)

To reconnect the side inlets, the pipe rehabilitated with the hose liner is opened using a remote-controlled milling unit or other suitable tools.

The repair of damaged side inlets can be carried out by means of a 'connection collar' using the equipment and devices mentioned in Section 3.2.2.3.

The factory-produced "BRAWOLINER connection collar" with the properties according to Section 2.1.1.3 and corresponding to the possible connection angles must be impregnated with "BRAWO RR" resin according to Section 2.1.1.3. When producing the "BRAWOLINER connection collar", it must be ensured that it is at least long enough to cover the first sleeve on the side inlet if possible.

To do so, the "BRAWO RR" containers cooled to the processing temperature of approx. +15 °C, consisting of component A resin and component B hardener, are to be mixed homogeneously and without bubbles in the required quantities in a mixing ratio of 3:1 (resin:hardener). The maximum processing time is 30 minutes

Immediately prior to installation, the connection collar, which is adapted to the respective local conditions, must be impregnated with the epoxy resin according to Section 2.1.1.3 from the side facing the inside of the pipe to be rehabilitated. In doing so, air inclusions should be minimised as far as possible.

When mixing the resin and impregnating the connection collar, as well as when handling it on the construction site, the relevant accident prevention regulations and the specifications of the health and safety regulations must be observed.

Inserting the connection collar with a packer:

After the connection collar has been impregnated with the epoxy resin, it must be placed on the respective packer of the pipe rehabilitation device (Appendix 16). The packer is equipped with an inversion bladder according to the nominal diameter being renovated and the connection angle of the side inlet. The connection collar is to be fastened to the packer in such a way that the inversion bladder can be transported up to the insertion opening by turning it inwards. Only packers equipped with rollers or runners may be used for repairs.

The connection collar is positioned by means of sliding rods under observation by a camera, which is inserted into the side inlet pipe or from the opposite side.

By means of compressed air (approx. 0.3 bar to 0.4 bar) the inversion bladder is pushed into the connection pipe (Appendix 17). The bladder with the inserted connection collar is left under pressure until the resin mixture has cured (approx. 6 hours at +10 °C sewage pipe temperature). The curing process can be accelerated by adding heat (water or steam).

The curing time depends on the resin system used according to Section 2.1.1.3 and on the ambient temperatures. The curing time and the applied pressure must be recorded. After curing, the compressed air must be released and the pipe rehabilitation device removed from the pipe (Appendix 18).

It must be ensured that no excess resin leaks out.

The resin impregnation and installation process must be fully documented (Appendix 19).

During handling on the construction site, the relevant accident prevention regulations and the specifications of the health and safety regulations must be observed.

Resin and hardener quantities, resin mixture and hardening behaviour as well as the temperature conditions must be recorded in the log according to Section 3.2.3.1.

The watertight restoration of side inlets can also be carried out in open or closed construction with repair or rehabilitation procedures, for which general building approvals with the associated type approvals are valid.

3.2.3.10. Shaft connection

Shaft connections must be watertight using swelling auxiliary tapes (Appendix 14), which must be positioned in the area of the shaft connections before the PE protective hose (preliner) is pulled in.

The resulting protrusions (see also Section 3.2.3.8 - Final work) of the cured inner pipe facing the front wall of the shaft (so-called mirror) and the transitions to the flow channel in the start and target shaft must be made watertight both in the respective start and, if necessary, also in the target shaft, as well as in the intermediate shafts (Appendix 15).

In areas where swelling tapes (auxiliary tapes) cannot be used for structural design reasons, the watertight formation of the connection areas between the hose liner and the shaft after curing the hose liner can also be carried out as follows:

a) Levelling the transitions using reaction resin filler, for which a general building approval is valid,

b) Levelling the transitions using mortar systems for which a general building approval is valid,

c) GRP laminates for which a general building approval is valid,

d) Grouting with polyurethane (PU) or epoxy (EP) resins for which a general building approval is valid,

e) Installation of hose liner end collars for which a general building approval is valid.

The proper execution of the watertight transitions must be ensured.

3.2.3.11. Inscription in the shaft

The following inscription should be applied in the start or end shaft of the rehabilitation measure in a permanent and easily legible manner:

- Type of rehabilitation
- Designation of the pipe section
- Nominal diameter
- Wall thickness of the hose liner
- Year of rehabilitation

3.2.3.12. Final inspection and leak test

After completion of the work, the rehabilitated pipe section must be inspected visually. It must be determined whether any material residues have been removed and whether there are any hydraulically detrimental folds.

After curing the hose liner, including restoration of the side inlets, a check for leaks must be carried out, if necessary including the shaft connection areas (Appendix 20). This can also be done in sections.

The rehabilitated pipes must be tested for leaks using water (method "W') or air (method "L") according to DIN EN 1610[26]. When testing with air, the specifications in table 3 of DIN EN 1610[26], test method LD for damp concrete pipes and all other materials must be observed. Side inlets that have been rehabilitated by means of a connection collar can also be tested separately for water tightness using suitable sealing bags.

3.2.4. Tests on samples taken

3.2.4.1. General

Circular rings or segments are to be removed from the hose liner on site (certificate accompanying sample Appendix 21).

If it turns out that the test specimens are unsuitable for the tests mentioned under Section 3.2.4.2 a) or that sampling of circular rings or segments is not possible, then for **side inlet pipe liners up to DN 200**, a DSC analysis according to Section 3.2.4.2 b) can be performed as an alternative.

For the connection collar, the DSC analysis can be performed according to Section 3.2.4.2 b).

For the investigation of the characteristic material properties by means of Differential Scanning Calorimetry (DSC), test specimens are to be taken from the segment on the construction site. These are to be removed by means of core drilling. The diameter of the sample should be at least 2.5 cm.

3.2.4.2. Strength properties

a) Determination of the strength properties after 3-point flexural and long-term ring stiffness testing

The flexural modulus of elasticity and the flexural stress are to be determined from the samples taken.

During these tests, the short-term value, the 1-h value and the 24-h value of the flexural modulus of elasticity and the short-term value of the flexural stress are to be recorded.

During the test, it must also be determined whether the creep tendency according to DIN EN ISO 899-2[27] is complied with in accordance with the following relationship or from Diagram 1:

$$K = \frac{E_{1h} - E_{24h}}{E_{1h}} \, x \, 100$$

The creep tendency depends on the subsequent cross-linking of the resin, and therefore, taking into account the age of the sample, can be taken from Diagrams 1 to 3.

[26] DIN EN 1610 Installation and testing of waste water pipes and sewers; German version EN 1610:2015; Edition:2015-12

[27] DIN EN ISO 899-2 Plastics - Determination of creep behaviour - Part 2: Creep rupture flexural test under three-point loading (ISO 899-2:2003); German version EN ISO 899-2:2003; Edition:2003-10

Diagram 1: "Assessment of creep tendency depending on sample age" with the resin systems "BRAWO I" or "BRAWO III"

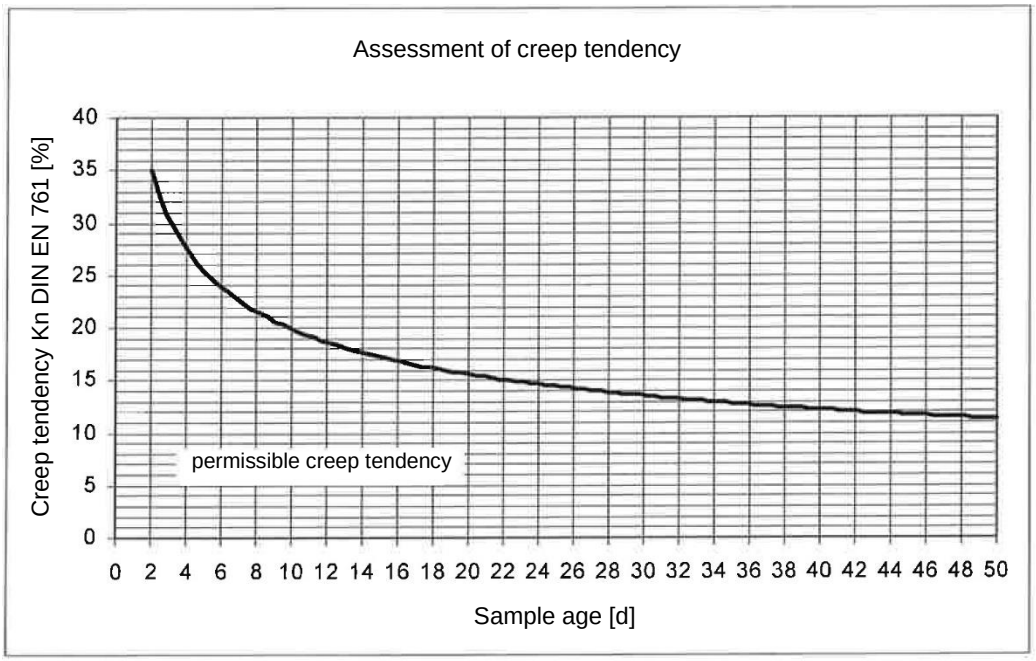


Diagram 2: "Assessment of creep tendency depending on sample age" with the "BRAWO AC" resin system

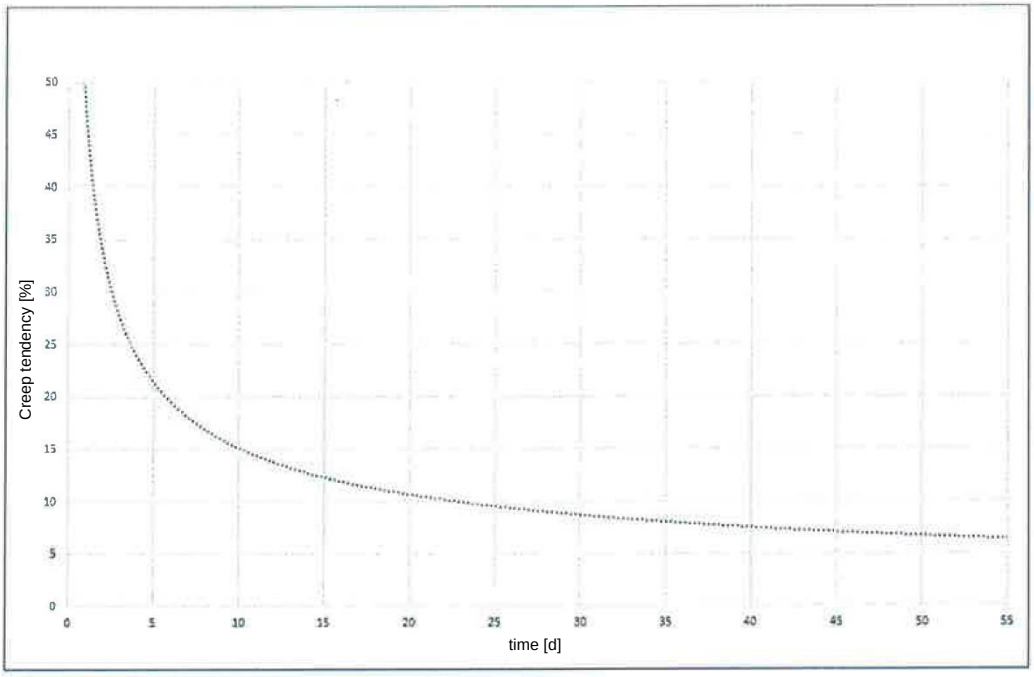
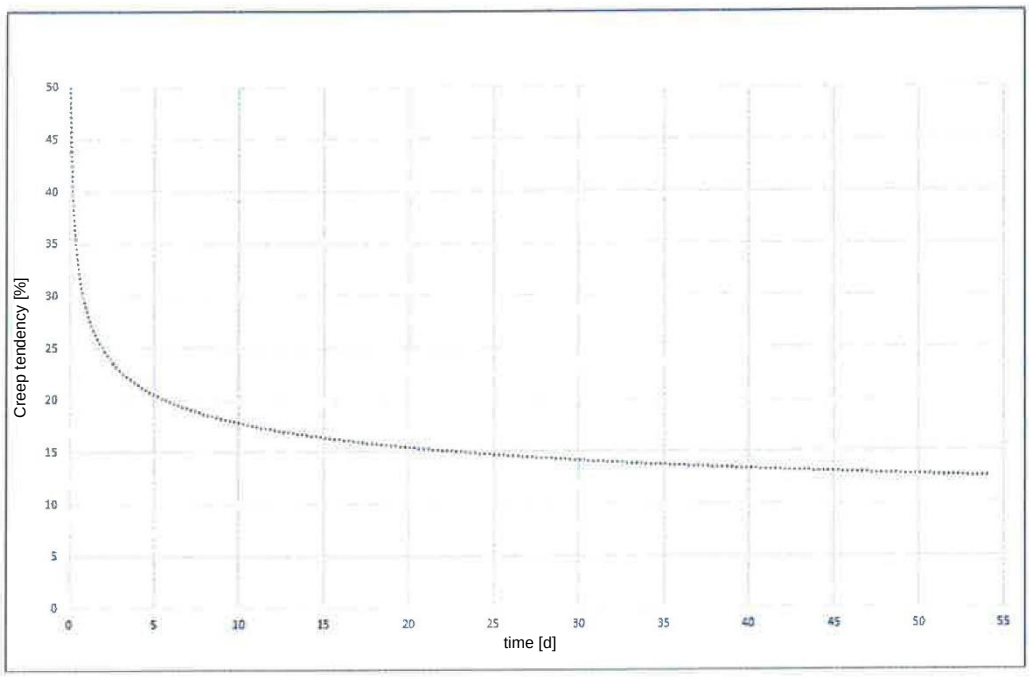


Diagram 3: "Assessment of creep tendency depending on sample age" with the "BRAWO TC" resin system



The creep tendency determined in the test on the sample taken at the construction site must not exceed the value of the creep tendency from Diagrams 1 to 3, depending on the age of the sample.

To determine the curing, the hardness mentioned in Section 3.1.2.1.2 shall also be checked.

In addition, the flexural modulus of elasticity and the flexural stress σ_{fB} must be determined on the cured hose liner in accordance with DIN EN ISO 11296-4[2] or DIN EN ISO 178[5] (three-point flexural test), using curved test bars from the corresponding circular profile, which should have a minimum width of 50 mm in the radial direction. When testing and calculating the modulus of elasticity, the span measured between the support points of the test bar shall be taken into account.

The determined short-term values of the moduli of elasticity and flexural stresses Ara must be equal to or greater than the value specified in Section 3.1.2.1.2 and Section 3.1.2.1.2.

b) Determination of the strength properties by means of DSC analysis

for side inlet hose liners up to DN 200 and connection collar

For connection collars and, if sampling of circular rings or segments is not possible for the hose liners, a DSC analysis can be performed on the samples taken at the construction site as an alternative.

To do so, the following test procedure must be followed:

1. Cutting through the drill core with a diamond cutter
2. Measurement of the wall thickness of the supporting laminate at three points

3. Qualitative assessment of the laminate in the area of the saw cut according to DIN 18820-3[28], Section 5.2
4. Removal of the sample for DSC analysis from the laminate
5. DSC analysis according to DIN EN ISO 11357-2[29] half step height method
6. Evaluation of results according to Section 10

3.2.4.3. Watertightness of the samples

The watertightness of the cured hose liner and the connection collar is to be tested on test specimens taken from the cured hose liner without preliner and without film coating in accordance with the criteria of DIN EN 1610[26].

Testing on test specimens may be carried out either with overpressure or a vacuum of 0.5 bar.

During the vacuum test, water shall be applied to one side of the sample. At a vacuum of 0.5 bar, no water leakage shall be visible on the unloaded side of the sample for a test period of 30 minutes.

In the overpressure test, a water pressure of 0.5 bar shall be applied for 30 minutes. With this method, too, no water leakage must be visible on the unloaded side of the sample.

3.2.4.4. Wall thickness and wall construction

The average and total wall thickness as well as the wall construction according to the conditions in Section 3.1.2.1.1 shall be checked on cut surfaces, e.g. using a light microscope with approx. 10-fold magnification. The thickness of the pure resin layer must also be checked. In addition, the average area of any shrink hole points shall be checked in accordance with DIN EN ISO 7822[30].

3.2.4.5. Physical characteristics of the cured hose liner and the connection collar

The characteristic values specified in Sections 3.1.2.1.2, 3.1.2.1.3, 3.1.2.2.1 and 3.1.2.2.2 shall be checked on the samples taken.

3.2.5. Declaration of compliance with the rehabilitation measure carried out

The confirmation of conformity for the rehabilitation work carried out with the provisions of the general type approval recorded by this decision shall be made by the operating company with a declaration of conformity on the basis of the specifications in Tables 5 and 6. The declaration of conformity shall be accompanied by documentation of the characteristics of the process components referred to in Section 2.1.1 and by the results of the tests referred to in Table 5 and Table 6.

The manager of the rehabilitation measure or a competent representative of the manager for the rehabilitation must be present on the construction site during the execution of the rehabilitation. He shall ensure the proper execution of the work in accordance with the provisions of Section 3.2 and, in particular, carry out the tests in accordance with Table 5 or arrange for them and the tests in accordance with Table 6 to be carried out.

The tests on samples in accordance with Table 6 shall be performed by an inspection body recognised by the building supervisory authority (see list of inspection, testing and certification bodies in accordance with the state building regulations, Part V, No. 9).

[28] DIN 18820-3 Laminates made of textile glass reinforced unsaturated polyester and phenacrylate resins for load-bearing components (GF-UP, GF-PHA); protective measures for the load-bearing laminate; Edition: 1991-03

[29] DIN EN ISO 11357-2 Plastics - Differential scanning calorimetry (DSC) - Part 2: Determination of glass transition temperature and glass transition height (ISO 11357-2: 2013), German version EN ISO 11357-2:2014; Edition: 2014-07

[30] DIN EN ISO 7822 Textile glass reinforced plastics - Determination of the amount of shrink holes present - Annealing loss, mechanical decomposition and statistical evaluation methods (ISO 7822:1990); German version EN ISO 7822:1999; Edition:2000-01

Once every six months, the sampling from a hose liner of an executed rehabilitation measure must be carried out by the aforementioned monitoring body. The latter shall also review the documentation of the work carried out according to Table 5 of the rehabilitation measure.

Table 5: "Procedure-accompanying tests"

Object of the test	**Type of requirement**	**Frequency**
optical inspection of the pipe	according to Section 3.2.3.1 and DWA-M 149-223	before every rehabilitation
optical inspection of the pipe	according to Section 3.2.3.12 and DWA-M 149-223	after every rehabilitation
Instrumentation	according to Section 3.2.2	every construction site
Marking of the containers for the rehabilitation components	according to Section 2.2.4 and 3.2.3.2	
Air and watertightness	according to Section 3.2.3.12	
Resin mixture, resin quantity and curing behaviour per hose and per connection collar	Mixed protocol according to Sections 3.2.3.6 (a) and 3.2.3.9	
Curing temperature and curing time	according to Sections 3.2.3.7 and 3.2.3.9	

The tests listed in Table 6 shall be initiated by the manager of the rehabilitation measure or his expert representative. For the tests specified in Table 3, samples shall be taken from the sample hoses described.

Table 6: "Tests on samples

Object of the test	Type of requirement	Frequency
Short-term flexural modulus of elasticity, Short-term flexural stress ore and creep tendency on pipe sections or on circular rings	according to Sections 3.2.4.1 and 3.2.4.2. a)	every construction site, min. every second hose liner
Density and hardness (hose liner) of the sample without preliner and without coating film	according to Sections 3.1.2.1.2, 3.2.4.2 and 3.2.4.5	
Density (connection collar)	according to Section 3.1.2.2.1	
Watertightness of the hose liner sample without preliner and without coating films	according to Section 3.2.4.3	
Watertightness of the connection collar	according to Section 3.2.4.3	
Wall thickness and wall construction	according to Section 3.2.4.4	
Checking the glass transition temperature Tgi and Tgz by means of DSC analysis 1 for side inlet hose liners up to DN 200 and connection collar	according to Section 3.1.2.1.3, 3.1.2.2.2 and 3.2.4.2 b)	
Creep tendency on pipe sections or cut-outs	according to Section 3.2.4.2. a)	if the short-term modulus of elasticity mentioned in Section 3.1.2.1.4 is not reached and min. 1 x hose liner per half year

[1] Provided that compliance with the glass transition temperatures Tgi and TG2 specified in Section 3.1.2.1.3 and 3.1.2.2.2 has been demonstrated by means of DSC analysis on the samples taken at the construction site, this shall also be regarded as evidence of compliance with the physical characteristic values of the cured polyester fibre resin composite specified in Section 3.1.2.1.2 and 3.1.2.2.1.

The test results shall be recorded and evaluated; they shall be submitted to German Institute for Construction Engineering on request. The number and scope of the specifications listed in Tables 5 and 6 are minimum requirements.

Maja Tiemann [Signature] [Stamp]
Head of Department