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Bautechnisches Prüfamt

Eine vom Bund und den Ländern
gemeinsam getragene Anstalt des öffentlichen Rechts

Mitglied der EOTA, der UEAtc und der WFTAO

National technical approval

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Approval number:
Z-42.3-499

Validity
from: **1 March 2018**
to: **1 March 2023**

Applicant:

Karl Otto Braun GmbH & Co. KG
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Subject of approval:

"BRAWOLINER®" cured-in-place pipes of nominal sizes DN 50 to DN 200 for the rehabilitation of damaged wastewater, rainwater and collection pipes within buildings

The subject of approval named above is herewith granted a national technical approval (*allgemeine bauaufsichtliche Zulassung).*
This national technical approval contains 18 pages and 16 annexes.
This national technical approval replaces national technical approval no. Z-42.3-499 of 25 April 2013.

Translation authorised by DIBt

DIBt

I GENERAL PROVISIONS

1 This decision confirms the fitness for use and application of the subject concerned in accordance with the Building Codes of the federal states (*Landesbauordnungen*).

2 This decision does not replace the permits, approvals and certificates required by law for carrying out building projects.

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

4 Notwithstanding further provisions in the "Special Provisions", copies of this decision shall be made available to the user and installer of the subject concerned. The user and installer of the subject concerned shall also be made aware that this decision must be available at the place of use or place of application. Upon request, copies of the decision shall be provided to the authorities involved.

5 This decision may be reproduced in full only. Partial publication requires the consent of Deutsches Institut für Bautechnik. Texts and drawings in promotional material shall not contradict this decision. In the event of a discrepancy between the German original and this authorised translation, the German version shall prevail.

6 This decision may be revoked. The provisions may subsequently be supplemented and amended, in particular if this is required by new technical findings.

7 This decision is based on the information and documents provided by the applicant. Alterations to this basis are not covered by this decision and shall be notified to Deutsches Institut für Bautechnik without delay.

8 The general construction technique permit (*allgemeine Bauartgenehmigung*) included in this decision also serves as a national technical approval for the construction technique.

II SPECIAL PROVISIONS

1 Subject of approval and field of use

This national technical approval applies to the manufacture and use of the "BRAWOLINER®" cured-in-place pipes (Annex 1) with the epoxy resin system "BRAWO HT®" as well as the polyester fibre liners "BRAWOLINER HT®", "BRAWOLINER HT XT®" and "BRAWOLINER HT 3D®".

The pipe liners are designed to rehabilitate damaged wastewater, rainwater and collection pipes within buildings in accordance with DIN 1986-100[1].

When underground pipes are rehabilitated, the provisions contained in national technical approval no. Z-42.3-362 shall also apply. The present approval applies to the rehabilitation of damaged sewers designed for wastewater in accordance with DIN 1986-3[2]. The wastewater temperature shall not exceed the values specified in DIN EN 476[3].

The cured pipe liners shall meet the requirements for flammable (*normalentflammbar*) building materials of building material class 'B2' in accordance with DIN 4102-1[4].

The "BRAWOLINER®" pipe liners may be used to rehabilitate sewers of circular cross sections of nominal sizes from DN 50 to DN 200 that are composed of asbestos-free fibre cement and cast iron as well as sewers made of GRP, PVC-U, PE-HD and PP plastics, which are used either without pipe penetration seals or with pipe penetration seals not foaming up in case of fire.

The process shall not be used to rehabilitate sewers with pipe penetration seals foaming up in case of fire (e.g. pipe collars).

A resin-impregnated polyester fibre liner is inserted into the damaged sewer and then cured using steam, hot water or ambient temperatures.

In general, vertical downpipes from the roof are rehabilitated through the ventilation duct, underground pipes are rehabilitated through inspection chambers or cleaning openings, and connecting pipes are rehabilitated through connections from sanitary installations. The rehabilitation process can accommodate up to two dimension changes and approx. three deviators or deflections of up to 90 degrees.

A remote-controlled milling unit or other suitable tool is used to open the rehabilitated pipe when connecting pipes and collection pipes are reconnected. A watertight connection is possible without additional connection technology if the pipe liner is adequately bonded to the rehabilitated sewer pipe.

Connection sleeves may also be used to reconnect pipes.

1	DIN 1986-100	Drainage systems on private ground – Part 100: Specifications in relation to DIN EN 752 and DIN EN 12056; issue: 2008-05 DIN 1986-100 Drainage systems on private ground – Part 100: Specifications in relation to DIN EN 752 and DIN EN 12056; issue: 2008-05
2	DIN 1986-3	Drainage systems on private ground – Part 3: Specifications for service and maintenance; issue: 2004-11
3	DIN EN 476	General requirements for components used in drains and sewers; German version EN 476:2011; issue: 2011-04
4	DIN 4102-1	Fire behaviour of building materials and building components – Part 1: Building materials; concepts, requirements and tests; issue: 1998-05 in connection with corrigendum 1; issue: 1998-08

2 Provisions for the construction products

2.1 Properties and composition

2.1.1 Materials of the pipe liner components

2.1.1.1 Materials used for the inversion liners

The materials of the "BRAWOLINER HT®", "BRAWOLINER HT XT®" and "BRAWOLINER HT 3D®" polyester fibre liners with TPU membrane coatings and the materials of the "BRAWO HT®" epoxy resin systems including the fillers, hardeners and other additives used shall correspond to the formulations deposited with Deutsches Institut für Bautechnik.

1) The polyester fibre liners shall have the following properties in accordance with Table 1:

Table 1: Polyester fibre liner properties

Liner designation	Nominal size range [mm]	Weight unit area [g/m²]	Thickness [mm]	Tensile strength [N/mm²]	Transverse strain [%]
"BRAWOLINER HT®"	DN 50	1100 ± 200	≥ 3	> 5	≥ 50
"BRAWOLINER HT®"	DN 70 to DN 200	2300 ± 300	≥ 4	≥ 8	≥ 40
"BRAWOLINER HT XT®"	DN 100 to DN 200	2800 ± 350	≥ 5	≥ 8	≥ 40
"BRAWOLINER HT 3D®"	DN 70 to DN 200	2900 ± 400	≥ 5	≥ 8	≥ 50

2) "BRAWO HT®" resin system

2a) Component A (base) of the epoxy resin system shall have the following properties prior to processing:

- Density at +23 °C: ≈ (1.4 ± 0.1) g/cm³ (DIN 51757[5])
- Viscosity at +23 °C: ≈ (3,900 ± 600) mPa x s (DIN EN ISO 3219[6]/shear rate 100 s^{-1})
- pH value: ≈ 4 ± 1

2b) Component B (curing agent) of the epoxy resin system shall have the following properties prior to processing:

- Density at +23 °C: ≈ (1.0 ± 0.1) g/cm³ (DIN 51757[5])
- Viscosity at +23 °C: ≈ (300 ± 45) mPa x s (DIN EN ISO 3219[6] / shear rate 50 s^{-1})
- pH value: ≈ 8 ± 1

[5] DIN 51757 — Testing of mineral oils and related materials - determination of density; issue: 2011-01

[6] DIN EN ISO 3219 — Plastics – Polymers/resins in the liquid state or as emulsions or dispersions - etermination of viscosity using a rotational viscometer with defined shear rate (ISO 3219:1993); German version EN ISO 3219:1994; issue: 1994-10

2c) The epoxy resin system without polyester fibre cores shall have the following properties in the cured state at a temperature of +23° C and a relative humidity of 50%:

- Density at +23 °C based on DIN EN ISO 1183-1[7]: 1.4 g/cm^3 ± 0.1 g/cm^3
- Flexural modulus based on DIN EN ISO 178[8]: 4,000 N/mm^2
- Bending strength σ_{fB} based on DIN EN ISO 178[8]: 84 N/mm^2
- Tensile strength based on DIN EN ISO 527-2[9]: 45 N/mm^2
- Elongation at fracture based on DIN EN ISO 527-2[9]: ≈ 1.3 %
- Pot life: 49 min ± 6 min

The epoxy resin system shall correspond to the IR spectra deposited with Deutsches Institut für Bautechnik. The IR spectra shall also to be deposited with the external surveillance body.

3) The transparent TPU membrane shall have the following properties:

- Weight unit area in g/m^2: membrane for DN 50: 120 g ± 12 g
  membrane for DN 70: 120 g ± 12 g
  membrane for DN 100: 132 g ± 15 g
  membrane for DN 125: 150 g ± 15 g
  membranes for DN 150 and DN 200: 180 g ± 18 g
- Ultimate stress in longitudinal and transverse directions: ≥ 40 MPa
- Elongation at fracture in longitudinal and transverse directions: ≥ 300 %

2.1.1.2 Material for connection sleeve

The materials for the connection sleeves shall correspond to the formulations deposited with Deutsches Institut für Bautechnik.

The polyester fibre liner "BRAWOLINER HT®" in accordance with Section 2.1.1.1 sub-item 1) and the epoxy resin system "BRAWO HT®" in accordance with Section 2.1.1.1 sub-item 2) shall be used for the connection sleeve.

The epoxy resin system shall correspond to the IR spectra deposited with Deutsches Institut für Bautechnik. The IR spectra shall also to be deposited with the external surveillance body.

2.2 Manufacture, packaging, transport, storage and marking

2.2.1 Standard factory production of the pipe liners

The polyester fibre strands delivered by the upstream supplier shall be manufactured in the applicant's factory into seamless single-layer tubes using the minimum wall thicknesses listed in Section 2.1.1. After the knitted polyester fibre fabric has been produced, the TPU membrane material supplied by the upstream supplier shall be laminated to the liners.

During fabrication, the following production parameters shall be monitored and recorded:

- Flat width
- Basis weight per meter
- Number of stitched rows in 10 cm
- Strain
- Tightness

[7] DIN EN ISO 1183-1 Plastics – Methods for determining the density of non-cellular plastics – Part 1:Immersion method, liquid pyknometer method and titration method (ISO 1183-1:2004); German version EN ISO 1183-1:2004; issue: 2004-05

[8] DIN EN ISO 178 Plastics – Determination of flexural properties (ISO 178:2010); German version EN ISO 178:2010; issue: 2011-04

[9] DIN EN ISO 527-2 Plastics – Determination of tensile properties – Part 2: Test conditions for moulding and extrusion plastics (ISO 527-2:1993 including Cor.1:1994); German version EN ISO 527-2:1996; issue: 1996-07

The applicant shall obtain test reports "type" 2.2 based on DIN EN 10204[10] upon each delivery from the upstream supplier to verify that the properties of the epoxy resin system (components A and B) correspond to the formulations.

Within the scope of the incoming inspection, the following properties shall be verified:

Resin component properties:

- Density
- Pot life

The components supplied by the upstream supplier for on-site resin impregnation shall be stored until further use in suitable airtight containers at the applicant's premises. The storage temperature shall be maintained between ≥ +5 °C and approx. +30 °C. The bunches shall be protected from the direct rays of the sun. The bunches are designed such that they always store components in separate containers.

The relevant accident prevention regulations and the information given in the applicant's procedural manual shall be observed during storage and transport.

2.2.2 Standard factory production of connection sleeve

The polyester fibre strands delivered by the upstream supplier shall be manufactured in the applicant's factory into single-layer connection sleeves of a minimum wall thickness of approx. 3 mm for nominal sizes DN 50 to DN 200.

During fabrication, the following production parameters shall be monitored and recorded:

- Flat width
- Basis weight per meter
- Number of stitched rows in 10 cm
- Strain

The components supplied by the upstream supplier for on-site resin impregnation shall be stored until further use in suitable airtight containers at the applicant's premises. The storage temperature shall be maintained between ≥ +5 °C and approx. +30 °C. The bunches shall be protected from the direct rays of the sun. The bunches are designed such that they always store components in separate containers.

2.2.3 Marking

The polyester fibre liners and the respective resin component transport bunches shall be marked with the mark of conformity (*Ü-Zeichen*') and the approval no. Z-42.3-499 in accordance with the Conformity Marking Ordinances (*Übereinstimmungszeichen-verordnungen*) of the federal states. The mark shall only be applied if the requirements given in Section 2.3 (Confirmation of conformity) are met.

The manufacturer shall apply the hazard symbols and H and P statements to the containers, the packaging, the packing slip or the delivery note in accordance with the Hazardous Substances Ordinance (*Gefahrstoffverordnung*) and EU Directive No. 1907/2006 (REACH) as well as the latest version of the CLP Regulation (EC) 1272/2008[11]. The packaging shall be marked in accordance with the rules of the ADR[12] in the applicable versions.

10	DIN EN 10204	Metallic products – Types of inspection documents; German version EN 10204:2004; issue: 2005-01
11	1272/2008	Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures
12	ADR	European Agreement on the Transportation of Dangerous Goods by Road (ADR) (*Accord européen relatif au transport international des marchandises Dangereuses par Route)*

Additionally, the following information shall be given on the containers used for transporting the polyester fibre liners:

- Nominal size
- Length
- "BRAWOLINER HT®", "BRAWOLINER HT XT®" and "BRAWOLINER HT 3D®"
- Batch number

Additionally, the transport containers for epoxy resin components shall be marked with at least the following information:

- Component designation
- Temperature range
- Bunch content units (volume or weight)

2.3 Confirmation of conformity

2.3.1 General requirements

The confirmation of conformity of the pipe liners und the connecting sleeves (construction products) with the provisions of the national technical approval included in this decision shall be issued for every manufacturing plant in the form of a declaration of conformity of the manufacturer based on factory production control and a certificate of conformity issued by a certification body recognised for these purposes as well as on regular external surveillance carried out by a recognised inspection body, including initial type-testing of the construction products, in accordance with the following provisions.

To issue the certificate of conformity and for external surveillance, including the associated product testing to be carried out in the process, the manufacturer of the construction products shall use an appropriately recognised certification body and an appropriately recognised inspection body.

The declaration of conformity shall be submitted by the manufacturer through marking of the construction products with the national conformity mark including statement of the intended use.

The certification body shall send a copy of the certificate of compliance issued by it to Deutsches Institut für Bautechnik.

A copy of the initial type testing evaluation report shall also be sent to Deutsches Institut für Bautechnik.

2.3.2 Factory production control

A factory production control system shall be set up and implemented in each manufacturing plant. Factory production control shall be understood to be continuous surveillance of production by the manufacturer to ensure that the manufactured construction products satisfy the provisions of the national technical approval included in this decision.

The factory production control shall at least include the measures listed below:

- Specification and verification of the starting material

  The operator of the manufacturing plant shall ensure that for each delivery of components TPU membranes, polyester fibres, resin, curing agents and other additives the requirements given in Section 2.1.1 are met. For this purpose the operator of the manufacturing plant shall obtain the corresponding test reports "type" 2.2 based on DIN EN 10204[10] from the respective upstream supplier. Within the scope of the incoming inspection, the properties specified in Section 2.1.1.1 shall be checked on random samples.

- Checks and tests to be carried out during production:

  The requirements of Section 2.2.1 shall be checked.

– Checking of bunches

  For each resin batch, the marking requirements specified in Section 2.2.3 shall be checked.

The results of factory production control shall be recorded and evaluated. At least the following data shall be recorded:

– designation of the construction products or the starting product and the components,
– type of check or test,
– date of manufacture and testing of the construction products or the starting materials or the components,
– results of the checks and tests as well as, if applicable, comparison with requirements,
– signature of the person responsible for factory production control.

The records shall be kept for at least five years and submitted to the inspection body used for external surveillance. They shall be presented to Deutsches Institut für Bautechnik and the competent supreme building authority upon request.
If the test result is unsatisfactory, the manufacturer shall immediately take the necessary measures to resolve the defect. Construction products which do not meet the requirements shall be handled in such a way that they cannot be confused with compliant products. After the defect has been remedied, the relevant test shall be repeated immediately - where technically feasible and necessary to show that the defect has been eliminated.

2.3.3 External surveillance

The factory production control system at each manufacturing plant shall be inspected regularly, i.e. at least once per half year, by means of external surveillance.

Initial type-testing of the construction products shall be carried out within the framework of external surveillance. Factory production control shall be carried out within the scope of external surveillance by means of spot checks. The requirements of Sections 2.1.1 and 2.2.3 shall be checked in the process.

Additionally, spot checks for compliance with the requirements pertaining to production specified in Sections 2.2.1 and 2.2.2 shall be carried out. These checks shall also include checks of the cure behaviour, density, storage stability and weight unit area as well as the IR spectra.

Sampling and testing shall always the responsibility of the recognised inspection body. The test reports "type" 2.2 in accordance with DIN EN 10204[10] shall also be checked within the scope of external surveillance.

The results of certification and external surveillance shall be kept for at least five years. They shall be presented by the certification or inspection body to Deutsches Institut für Bautechnik and the competent supreme building authority upon request.

3 Provisions for application of the subject of approval

3.1 Planning and design

3.1.1 Planning

An inspection in accordance with DIN EN 1986-3[1] shall be carried out in order to determine whether the damaged wastewater system can be rehabilitated with "BRAWOLINER®". The information provided on the required pipe data shall be checked and documented, e.g. pipe material, pipe layout, pipe length, deviators and nominal sizes, location of ventilation ducts over the roof as well as cleaning openings, hydraulic conditions, any repair measures that were already carried out as well as a determination of any connections that are no longer necessary.

Any available video recordings shall be analysed with regard to the application. The accuracy of the information provided shall be checked on-site. The condition of the existing sewer shall be assessed for determining whether the "BRAWOLINER®" process can be used to carry out the rehabilitation process.

In particular, this assessment shall include a separate assessment of each of the pipe sections to be rehabilitated with regard to fire protection requirements.

The process shall not be used to rehabilitate sewers with pipe penetration seals foaming up in case of fire (e.g. pipe collars). The provisions of the guideline for fire protection requirements of pipe systems (*Richtlinie über brandschutztechnische Anforderungen an Leitungsanlagen*) of the relevant federal states shall be taken into account.

The hydraulic performance of the sewers may not be impaired through introduction of a pipe liner. The corresponding verification shall be provided, if necessary.

3.1.2 Design

3.1.2.1 Wall thicknesses

The wall thicknesses cured under this rehabilitation process come to 2 mm to 6 mm, depending on the system.

3.1.2.2 Reaction to fire

The cured pipe liner complies with the requirements of a flammable (*normalentflammbar)* building material' (building material class B2) in accordance with DIN 4102-1[4].

3.1.2.3 Characteristics of the cured polyester fibre resin composite resulting from thermal analysis (DSC analysis)

The cured polyester fibre resin composite shall have the following limits determined by means of differential scanning calorimetry (DSC):

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

≥ +60 °C

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

≥ +100 °C

3.2 Execution

3.2.1 General requirements

All pipe sections affected must be taken out of service before beginning the rehabilitation project. Before processing components, it is necessary to ensure that components, the wastewater pipe system and their surroundings have the processing temperatures prescribed by the manufacturer.

A resin-impregnated polyester fibre liner is inserted into the damaged sewer and subsequently cured in place.

For this purpose, a polyester fibre liner with an exterior flexible thermoplastic polyurethane membrane (TPU) is impregnated on-site with an epoxy resin. This liner is inverted into the sewer to be restored (host pipe) and expanded by an inverter unit using air or water gravity. Through this inversion, the TPU membrane ends up on the side in contact with the sewage. The curing process shall be carried out using ambient temperatures, hot water or steam.

The process can be used to rehabilitate pipes of nominal sizes from DN 50 to DN 200.

Structural conditions under which the "BRAWOLINER®" CIPP process may be implemented include the following:

a) Rehabilitation of the vertical downpipe from roof through ventilation duct

b) Rehabilitation of underground pipes through inspection chambers or cleaning openings

c) Rehabilitation of connecting pipes through connections from sanitary installations

The process requires that access openings are sufficiently large for the inversion device to be set up.

The rehabilitation process can accommodate up to two dimension changes and approx. three deviators or deflections of up to 90 degrees.

A remote-controlled milling unit or other suitable tool is used to open the rehabilitated pipe when connecting pipes and collection pipes are reconnected. A watertight connection is possible without additional connection technology if the pipe liner is adequately bonded to the rehabilitated sewer pipe. Connection sleeves may also be used to reconnect pipes.

The applicant shall prepare a manual containing procedure instructions and a description of the individual steps for execution of the particular rehabilitation process.

The applicant shall also ensure that the executing parties have been sufficiently familiarised with the process.

The steps required for process execution shall be recorded on log sheets (e.g. Annex 10) for each impregnating and rehabilitation procedure.

The relevant accident prevention regulations shall be observed during all steps in the rehabilitation process.

3.2.2 Equipment and facilities

3.2.2.1 Minimum component, equipment and facility requirements for execution of the rehabilitation process:

- Devices for cleaning small to medium nominal sizes (pipe materials sensitive to abrasives shall be cleaned with appropriate soft attachments like brushes and sponges or high-pressure water jetters)
- Devices for visual inspection
- Locking systems
- Impregnation system (with exhaust unit if necessary) with roller drive and table with conveyor belt or roller table
- Container for residual material
- Climate control cabinet (temperature range: at least +5 °C to +30 C)
- Container with components A and B of epoxy resin system "BRAWO HT®"
- Polyester fibre liners "BRAWOLINER HT®" and/or, "BRAWOLINER HT XT®" and/or "BRAWOLINER HT 3D®" of suitable nominal size (Annex 1)
- Wheather-protected impregnation facility, devices and equipment for mixing resin system
- Power supply
- Vacuum system
- Inverter unit with pressure monitoring systems and ability to connect hot water or steam supply
- Compressor, air hoses, pressure regulator (for air pressure-assisted inversion)
- Inversion scaffold, water hose, hydrant connection and accessories (for water column-assisted inversion) - see Annex 12

- "BRAWO Hotbox" heating system/unit (for hot water-assisted curing) including temperature sensor and unit to monitor and record temperature - see Annex 7
- "BRAWO SteamUnit" steam system with steam-air mixing unit (including control equipment, e.g. steam temperature and pressure) and compressor (minimum 1300 l/min) as well as accessories for steam curing - see Annex 11
- Temperature/pressure-resistant pressure hoses for connection to inverter unit
- Pressure gauge
- Steam outlet device ("BRAWO steam pod")
- Nominal size-based calibration hoses
- Retaining strap
- Inversion brackets (suitable for the respective nominal size)
- Support pipes or hoses for on-site sampling (suitable for the respective nominal size)
- Small tools (e.g. pneumatic cutter)
- Hand tool
- Staff rooms and sanitation facilities (where required)

Should electronic devices such as video cameras (or remote-controlled pipe crawlers) need to be inserted into the host pipe, then they shall be designed in accordance with VDE regulations.

3.2.2.2 Minimum component, equipment and facility requirements for rehabilitating laterals

In addition to those items listed under Section 3.2.2.1, the vehicles of the party which executes the rehabilitation of the laterals shall be equipped with the following for manufacturing the connection sleeve:

- Connection sleeve (top hat) with the appropriate nominal sizes
- Exhaust unit (if necessary)
- Pipe rehabilitation unit
- Inversion bladders in nominal sizes required on-site
- Control unit
- Camera with viewing screen
- Push bars

3.2.3 Rehabilitation project implementation

3.2.3.1 Recording necessary pipe data

Before the work begins, the pipe data required in accordance with Section 3.1.1 shall be recorded with an inspection camera.

3.2.3.2 Preparing and cleaning the pipe system

Since drain traps or entire sanitary installations are dismantled for the rehabilitation project and no odours or germs may get into living spaces, the extraction unit (fan) shall be installed at appropriate ventilation openings over the roof and put into operation. The work area shall be protected from contamination with appropriate covering material. It is necessary to ensure during rehabilitation operations that no wastewater is introduced into the wastewater system to be rehabilitated.

The pipes to be rehabilitated shall then be flushed with warm water. The camera shall be used to monitor this cleaning and assess whether it is adequate for application of the rehabilitation process. Tools for any additional cleaning that may be required shall be selected on the basis of existing sewers (materials, level of contamination and/or corrosion).

The camera shall be used to check the results of the cleaning process. The cleaning process shall be repeated until inner sewer surfaces are free of loose particles.

The actual state of the sewer system shall be documented after the cleaning process using a video recording camera. Holes and cracks which could not be detected before the cleaning process because of deposits or encrustations shall be documented.

The relevant accident prevention provisions shall be observed during all steps in the rehabilitation process.

When steam generators and steam hardening equipment are used, the law on technical equipment (*Gerätesicherheitsgesetz*) and the Ordinance on Steam Boiler Systems (*Dampfkesselverordnung*) shall be observed in particular.

3.2.3.3 Incoming inspection of the process components on-site

The containers used for transporting the process components shall be inspected for the purposes of determining whether the markings specified in Section 2.2.3 are present. The circumference of the polyester fibre tube required for the respective object to be rehabilitated shall be measured again prior to impregnation with resin. A check shall be carried out to ensure that the required storage temperature is maintained prior to resin impregnation.

3.2.3.4 Impregnation of the polyester fibre liner

a) Resin mixing

The resin amount required for resin impregnation of the respective polyester fibre liner shall be determined prior to the start of resin mixing as a function of wall thickness, pipe liner diameter and pipe liner length (Annex 2):

The required number of bunches for resin impregnation shall be removed from the climate control chamber in the rehabilitation vehicle. The epoxy resin system shall be tempered at approx. +13 °C to +15 °C prior to impregnation of the polyester fibre liners. The bunches shall contain components A and B for the epoxy resin system "BRAWO HT®" in separate, individual containers. Components A and B shall be mixed in a ratio of 5:1 (A:B). The mixture shall be homogeneous and free of bubbles. The amounts of components A and B as well as temperature conditions shall be recorded in the log mentioned in Section 3.2.3.1.

b) Resin impregnation (Annex 3)

The polyester fibre liner shall be rolled out on the conveyor table, if necessary be attached to suitable equipment, and then be connected to the vacuum system in the rehabilitation vehicle. A vacuum of approx. 100 mbar to 150 mbar shall be generated to remove a significant amount of the air pockets in the knitted polyester fibre fabric as well as to support the subsequent impregnation process. The resin mixture shall then be poured, using a funnel if necessary, into the pipe liner end without allowing air to enter the liner. The pipe liner shall be passed through a roller drive to ensure uniform distribution of the resin in the knitted polyester fibre fabric. The roller spacing shall be set as specified in Annex 2. The feed rate shall be selected to ensure uniform distribution of the resin in the matrix of the knitted polyester fibre fabric. Should the resin distribution be noticeably uneven, the liner shall be passed through the roller drive again with a smaller distance between rollers. The impregnated pipe liner shall be placed in a layered manner in a container with cold water and soap immediately after being passed through the rollers to reduce friction during the subsequent inversion process and to avoid unnecessarily increasing the temperature.

The curing time and the changes in temperature with time shall be recorded in the log as per the specifications given in Section 3.2.3.1.

3.2.3.5 Inversion of the resin-impregnated polyester fibre liner

3.2.3.5.1 Inversion by means of inverter unit

a) Inversion with closed end (in accordance with Annexes 4 to 6)

The retaining strip shall be connected to the closed end of the impregnated pipe liner, with the heating tube connected in parallel, if necessary. The retaining strip and the heating tube shall be connected to the inverter unit. By means of this retaining strip (with heating tube) the pipe liner is rolled up in the inverter unit (Annex 4).

A pressure hose shall be connected to the inverter unit by means of coupling elements. An appropriate inversion tube for the host pipe shall be fastened to the other end of the pressure hose by means of a coupling element. The pipe liner end shall be pulled through the pressure hose and folded over the inversion tube. This end of the pipe liner shall be secured to the inversion tube using adhesive tape and at least two hose band clips.

The inversion tube with the pipe liner end shall be introduced in front of the start opening and positioned at the start of the host pipe (Annex 5 and 13). An inversion pressure of 0.2 bar to 0.3 bar shall then be generated in the inverter unit. The resin-impregnated pipe liner is pressurised to induce the inversion process. This inversion process shall be continued until the the end point of the host pipe has been reached (Annex 6). Through this process the resin-impregnated inner surface of the pipe liner comes in contact with the the inner surface of the host pipe. This way the TPU coating ends up on the side in contact with the sewage.

1. Hot water-assisted curing (Annex 7):

   The pipe liner shall be filled completely with water via the heating system/unit "BRAWO Hotbox" (Annex 7) to be connected to the inverter unit. Pressure shall be kept constant during the entire filling phase so as to maintain full contact with the inner surface of the host pipe. The water heated in the "BRAWO Hotbox" shall be circulated by means of a pump (Annex 7). The supply water shall be heated to +80 °C. Heating time shall be at least 80 minutes and begins when a return temperature of at least +70 °C is reached. The supply and return temperatures in the heating circuit shall be measured and recorded (Annex 10).

   After curing, the heating water shall be cooled to approx. +10 °C by addition of cold water. Once the water has reached this temperature, it shall be drained.

2. Cold curing:

   The pipe liner can also be cured at ambient temperature (min. +10 °C).

   The curing time for the pipe liner at ambient temperatures (approx. +15 °C) is approx. 20 hours.

3. Steam curing (Annex 11):

   Two variants of applying steam curing are possible:

   1. Via heating tube:

      The process is set up like that of the hot-water-assisted curing process, where the pipe liner is inverted by pulling in a heating tube that is mounted with the retaining strip at the end of the pipe liner. The steam-air mixture flows out of the heating tube at the end of the pipe liner, flows through the pipe liner in the direction of the inverter unit and is regulated to ambient pressure at the outlet of the inverter unit.

A manometer is used to monitor the internal pressure, which is regulated through the outflow valve of the inverter unit in accordance with the procedural manual.

The temperature of the steam-air mixture shall be recorded as it flows in and out and logged (Annex 10).

2. Via "BRAWO steam pod" (Annex 11):

   The "BRAWO steam pod" is integrated into the pipe liner node (using the "open end" variant in the calibrating hose) and inverted with it. Non-condensed steam and air flows out through a bore hole in the pod; a tube in another bore hole is used to remove condensate that has accumulated in the pod.

   A manometer shall be used in accordance with procedure instructions to monitor and regulate the internal pressure that occurs during the curing process, through the volume of inflowing steam-air mixture.

   The temperature of the inflowing steam-air mixture shall be recorded and logged (Annex 10).

A steam-air mixture (+80 °C) shall be made to flow through the inverted, installed pipe liner for a period of at least 100 minutes, until curing is completely finished.

An internal pressure of approx. 0.3 bar to 0.4 bar shall be maintained throughout the curing process. The steam temperature shall not exceed +90 °C during the curing process.

After the curing process is completed, the pipe liner shall be cooled by forcing cold air (with water added if necessary) to flow through it. Care must be taken to avoid any odour nuisances as best as possible while steam curing is being carried out.

The curing time for the pipe liner depends on the resin system used in accordance with Section 2.1.1.1 as well as the temperature of the epoxy resin system, the heating temperature of the water and/or the ambient temperatures, steam temperatures and the time spent on the process. Curing time and pressure as well as steam temperature levels shall be recorded and logged.

b) Inversion with open end (in accordance with Annexes 8 and 9)

If rehabilitation begins at an inspection chamber or start opening and continues in the direction of an inaccessible collection pipe, the pipe liner length shall be defined beforehand to ensure that it does not protrude into the individual pipe or connecting pipe. The pipe liner shall be secured at its end with a rubber band prior to being rolled up in the inverter unit.

The sealed pipe liner shall be rolled up in the inverter unit. The steps described in a), including inversion, shall then be carried out. At the end of the compressed air-assisted inversion process, the rubber band is released and the air escapes from the pipe liner. The pipe liner is not yet pressed against the inner surface of the host pipe.

The pipe liner shall be released from the inversion tube. A calibration hose with a retaining strip connected at the end (additional heating tube or "BRAWO steam pod" may be required depending on variant) shall be rolled into the inverter unit. The starting end of this calibration hose shall be fastened together with the free starting end of the resin-impregnated pipe liner to the deflection bracket. The calibration hose shall then be inverted at the same pressure as stated in a). The calibration hose presses the pipe liner fully against the inner surface of the host pipe.

1. Hot-water-assisted curing:

   The pipe liner is cured as described under paragraph a) item 1.
2. Cold curing:

   The pipe liner is cured as described under paragraph a) item 2.
3. Steam curing:

   The pipe liner is cured as described under paragraph a) item 3.

The curing time for the pipe liner depends on the resin system used in accordance with Section 2.1.1.1 as well as the temperature of the epoxy resin system, the heating temperature of the water and/or the ambient temperatures, steam temperatures and the time spent on the process. Curing time and pressure as well as steam temperature levels shall be recorded and logged.

3.2.3.5.2 Inversion by means of water gravity (Annex 12)

For pipe liner inversion by means of water gravity, an inversion scaffold shall be erected at the start opening. This inversion scaffold shall be sized such that the height corresponds to the required hydrostatic pressure. The open end of the pipe liner shall be securely fastened to the inversion scaffold to enable water to be introduced via a hydrant. The hydrostatic pressure of the water inverts the pipe liner into the host pipe. The end of the pipe liner shall be sealed in an airtight manner and folded up. A retaining strip and, if necessary, a heating tube shall be fastened to the thereby produced 'liner head'. The retaining strip attached to the 'liner head' enables the rate of inversion to be checked. It shall be ensured that inversion is continuous and smooth through control of the amount of water added.

Inversion shall be carried out at a hydrostatic pressure of approx. 2 m to 3 m (0.2 bar to 0.3 bar). Curing shall be carried out at a pressure of approx. 0.3 bar to 0.4 bar.

The inversion process shall be continued until the inspection chamber or the end point of the host pipe is reached. Through this process the resin-impregnated inner surface of the pipe liner comes in contact with the the inner surface of the host pipe. This way the TPU coating of the pipe liner ends up on the side in contact with the sewage. The pipe liner shall be filled completely with water to maintain full contact with the inner surface of the host pipe.

Curing at ambient temperatures or hot water shall be carried out as described in Section 3.2.3.5.1 under paragraph a) item 1. and 2.

3.2.3.6 Finishing work

After the curing process is completed, any protruding parts of the pipe liner that are attached and flush to the given pipe wall, inspection chamber or cleaning opening shall be cut off using pneumatic cutting tools and removed.

The cutting work shall be carried out in compliance with the relevant accident prevention provisions.

3.2.3.7 Lateral reconnection by means of connection sleeve (Annexes 14 to 16)

Connections of connection pipes and collection pipes to downpipes shall be watertight.

A remote-controlled milling unit or other suitable tool is used to open the rehabilitated pipe when connecting pipes and collection pipes are reconnected. A watertight connection is possible without additional connection technology if the pipe liner is adequately bonded to the rehabilitated sewer pipe.

Connection sleeves may also be used to reconnect pipes.

Damaged laterals may be rehabilitated using connection sleeves and the equipment and facilities specified in Section 3.2.2.2.

When manufacturing the connection sleeve, the polyester fibres with the properties specified in Section 2.1.1.2 shall be laid manually over matching moulds corresponding to the possible connection angles and impregnated with resin in accordance with the specifications given in Section 2.1.1.2.

The connection sleeves prepared according to the given local conditions shall be coated with the epoxy resin in accordance with Section 2.1.1.2 on the sides facing the inner surface of the host pipe immediately before installation. This shall be accomplished with minimal generation of air pockets.

The relevant accident prevention provisions and the occupational health and safety requirements shall be complied with during mixing of the resin and impregnation of the connection sleeve as well as during their handling at the construction site.

Using a packer to insert the connection sleeve:

After the connection sleeve is impregnated with the epoxy resin, the sleeve shall be set on the corresponding packer of the pipe rehabilitation unit (Annex 14). The packer is equipped with an inversion bladder corresponding to the nominal size and connection angle of the host connection pipe. The connection sleeve shall be fastened to the packer such that the inversion bladder can be transported in inverted condition to the insertion opening.

The connection sleeve is positioned using push bars while being monitored by a camera installed in the inlet pipe or from the opposite side.

Compressed air is applied to the inversion bladder, causing it to be inverted into the connection pipe (Annex 15). The bladder with the inserted connection sleeve shall be kept pressurised until the resin mixture is cured.

The curing time depends on the resin system used in accordance with Section 2.1.1.2 and on ambient temperatures. The curing time and the applied pressure shall be recorded. After curing, the compressed air shall be released and the pipe rehabilitation unit removed from the sewer (Annex 16).

Should large amounts of resin be left over after insertion and curing, they shall be removed from the pipe by the user; however, small amounts of residue can be left safely in the pipe.

3.2.3.8 Final inspection and leak testing

After the work has been completed, the rehabilitated pipe section shall be visually inspected. It shall be ensured that all residual materials have been removed and no hydraulically disadvantageous wrinkles are present.

The pipe liner shall be checked for leaks after it is cured. This can also be done section-wise. Watertightness can be checked by completely filling rehabilitated pipes.

3.2.4 Testing of samples

3.2.4.1 General

For investigation of the characteristic material properties by means of differential scanning calorimetry (DSC), test samples shall be obtained on-site.

3.2.4.2 Determination of strength properties by means of DSC analysis

A DSC analysis shall be carried out on the samples obtained on-site. The following test procedure shall be used for this:

1. The drill core is cut through with a diamond cutter.
2. The wall thickness of the laminate carrier is measured in three places.
3. A qualitative evaluation of the laminate in the area of the cut is carried out in accordance with DIN 18820-3[13], Section 5.2.
4. A sample is obtained from the laminate for DSC analysis.
5. DSC analysis is carried out in accordance with DIN 53765[14], procedure A-20.
6. The results are evaluated in accordance with the specifications given in Section 9 of DIN 53765[14].

3.2.4.3 Watertightness of samples

The watertightness of the cured pipe liner can be tested on a piece of pipe liner without a protective foil that was obtained from the cured liner without membrane coating. The membrane of this pipe liner section shall either be removed or perforated for test purposes. The laminate shall not be damaged in the process.

Testing of samples can be carried out with an overpressure or an underpressure of 0.5 bar.

For the underpressure test, one side of the sample shall be exposed to water. At an underpressure of 0.5 bar, no water may be observed to exit from the sample side not exposed to water over a test duration of 30 minutes.

In the overpressure test, a water pressure of 0.5 bar shall be applied for a duration of 30 minutes. With this method as well, no water may be observed to exit from the side of the sample not exposed to water.

3.2.5 Declaration of conformity for the rehabilitation measures carried out

Confirmation of conformity of the executed rehabilitation work with the provisions of this national technical approval shall be provided by the executing company by means of a declaration of conformity based on the specifications given in Table 1. The declaration of compliance shall be accompanied by documents providing data on the properties of the process components in accordance with Section 2.1.1 and the results of the tests specified in Table 1.

The rehabilitation project manager or a competent representative of the manager shall be present at the construction site during execution of the rehabilitation work. They shall ensure that the work is carried out properly in accordance with the provisions of Section 4 and, in particular, carry out or organise the tests specified in Table 1. The number and scope of the tests listed there are minimum requirements.

[13] DIN 18820-3 Laminates of textile glass-reinforced unsaturated polyester and phenacrylic resins for load-bearing structural members (GF-UP, GF-PHA); protective measures for load-bearing laminates; issue: 1991-03

[14] DIN 53765 Testing of plastics and elastomers; thermal analysis; DSC-method; issue: 1994-03

Table 1: 'Process-accompanying tests'

Subject of test	**Nature of requirement**	**Frequency**
Visual inspection of pipe	as per Section 3.2.3.1	prior to each rehabilitation
Visual inspection of pipe	as per Section 3.2.3.8	after each rehabilitation
Equipment requirements	as per Section 3.2.2	each construction site
Marking of containers for rehabilitation components	as per Section 2.2.3 and 3.2.3.3	
Watertightness	as per Section 3.2.3.8 and 3.2.4.3	
Resin mixing, resin amount and cure behaviour of each liner	mixing report as per Section 3.2.3.4	
Curing temperature and time	as per Section 3.2.3.5	
Wall structure, wall thickness	as per Section 3.1.2.1	
Check of glass transition temperatures T_{G1} and T_{G2} by means of DSC analysis	as per Sections 2.1.2.3 and 3.2.4.2	

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Drawn up by