Provisional Translation, December 18 2023

RSV factsheet 1.3

Sewer rehabilitation of drinking water pipes with pressure hose liners

(August 2021)

Rohrleitungssanierungsverband e.V.
Ericusspitze 4 | 20457 Hamburg
Phone: +49 40 21074167 | www.rsv-ev.de

Preface

The use of flexible hose methods for sewer renovation has successfully established itself on the pipeline renovation market over the past 45 years. By using systems that curing on site, damaged pipelines can be rehabilitated without or with minimal trenching, even where access is difficult and with complex pipe runs.

The normative basis for the use of pressure hose liners is available. DIN EN ISO 11295 classifies plastics piping systems for renovation and renewal and provides initial information on planning and installation. DIN EN ISO 11298-4 specifies requirements and test methods for "hose liner systems curing on site" for the sewer rehabilitation of water supply networks. The use of "cured-in-place pipes with adhesive backing" in water pipes is regulated in DVGW worksheet manhole (shaft/chamber) 330 and worksheet GW 327.

Operators of water supply networks, engineering offices, manufacturers and installation companies are often faced with questions regarding the sewer renovation of drinking water pipes that are currently not adequately answered in the existing rules and regulations. This factsheet 1.3 "Sewer rehabilitation of drinking water pipes with pressure hose liners" is intended to close these gaps. It serves as a comprehensive guide that not only lays down the existing normative basis, but also defines the requirements for materials, techniques and procedures, particularly with regard to drinking water quality. It also describes the basic principles of planning, tendering and implementation.

The factsheet shows solutions for the joint of the pressure hose liner to the drinking water network and for making connections; junctions; contacts. Taking into account typical operating conditions in a pressurised pipe system, the requirements for quality assurance are defined.

We would be delighted if you could tell us about your experiences of using this factsheet.

Hamburg,
August 2021

RSV - Rohrleitungssanierungsverband e.V.

Guide for special labels

In this factsheet, we draw attention to special content at various points. These are graphically labelled with symbols.

Symbol	Meaning
	**Information on the internet** Further information can be found on the Internet at www.rsv-ev.de or on a corresponding website. The symbol with the link is stored in the PDF.
	**General content** This information is not specific to this factsheet, but also applies to other areas of sewer renovation.
	**Need for regulation** The content published here points to regulatory gaps that should be remedied in future regulations.
	**Comment** These are comments on existing regulations. These may contain deviating statements.
	**Exclusive information** Here you will find exclusive content and information that can be seen as an addition to existing rules and regulations.
	**Recommodation** This is a recommodation of the RSV, which deserves special attention from users.
	**Quote** At this point we quote other factsheets or refer to them. If you have any further questions, we recommodation you to consult us.

1 Range of application

This factsheet applies to the rehabilitation of predominantly underground drinking water pipes and specifies the requirements for the plastic pipe systems used, which are manufactured using the cured-in-place pipe lining method or pipe lining with adhesive backing.

Drinking water pipes are used to transport and distribute drinking water from the supply points with a pumping station or elevated tank through the pressurised pipes to the points of use. This factsheet also deals with sections of such drinking water pipes that require sewer rehabilitation and can also be used for raw and service water pipes in the water supply sector.

The factsheet is based on DIN EN ISO 11295 and DIN EN ISO 11298-4. ***Figure 1*** lists the "cured-in-place pipe lining" and "pipe lining with adhesive backing" (fabric hose) technology families contained in this factsheet in accordance with DIN EN ISO 11295 under the term "sewer rehabilitation".

This factsheet applies to pressure cured-in-place pipes of classes A, B and C in accordance with DIN EN ISO 11295 and covers the entire system consisting of the cured-in-place pipe including joints and connections; junction; contacts. It is applicable up to a pressure rating of PN16.

Class D liners in accordance with DIN EN ISO 11295 are not part of this factsheet. It also does not apply to negative pressure drainage.

In drinking water systems, old pipe materials made of steel, cast iron, plastic, fibre cement, GRP, stoneware, concrete - with and without internal coating - are present and can be rehabilitated using pressure hose liners, depending on the system.

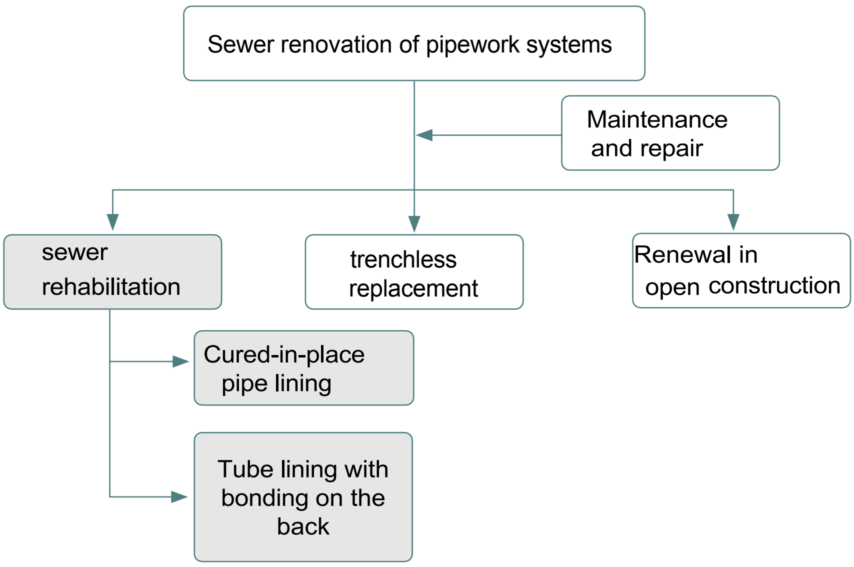


Figure 1*: Technology families based on DIN EN ISO 11295*

2 Definitions

Pressurised pipeline (in the sense of this factsheet) Pipe for transporting drinking water, raw water or process water under pressure

Pressure pipe liner Generic term for plastics piping systems for the renovation of underground pressure pipes, regardless of the type of renovation process (analogous to DIN EN ISO 11295)

Pressure hose Flexible hose made of carrier and/or reinforcement material, including all foils, which is impregnated with a reactive resin system and is suitable for use in the sewer renovation of pressure lines (referred to as liner in DIN EN ISO 11298-4)

Pressure hose liner Fully installed and hardened pressure hose; the result is a socketless cured-in-place pipe that conforms positively-locking to the inside of the existing pipeline and can be joined to it (referred to as a CIPP product in DIN EN ISO 11298-4)

Pressure hose liner system Pressure hose liner including all connections; junction; contact required for renovation

Pressure hose lining Procedure for the production of a pressure hose liner

Enthalpy Energy that a system releases or extracts as heat from the environment at constant pressure

Fitting Pipe fitting consisting of one or more parts

Foil Definitions based on DIN EN ISO 11298-4

- **Permanent membrane:** Inner and/or outer liner designed to remain intact during the insertion of the pressure hose and the curing of the resin system and to maintain its functions for the entire operational life of the pressure hose liner.
- **Temporary membrane:** Internal and/or external surface that only performs functions during installation and is removed during or after installation.

Glass transition Temperature range in which a material shows the greatest change in deformability, e.g. from a deformable to a curing state

Hand laminate A manually produced unit made of fibre-reinforced plastic.

Curing The process of resin polymerisation that is triggered by heat or light or accelerated by heat.

Resin system Resin including the curing agent and all fillers or other additives in specified proportions

Impregnation	Insertion of the resin system into the carrier and/or reinforcement material
Composite	Combination of cured resin system, substrate and/or reinforcement, exclusively inner and/or outer liners (cf. laminate)
Laminate	Hardened composite made of carrier and/or reinforcing material and reactive resin; corresponds to the composite in accordance with DIN EN ISO 11298-4 in the wall structure of the pressure hose liner
Useful life	Period during which a pressure line renovated using a pressure hose liner can be used for operational purposes.
Polymerisation	Synthesis reactions in which monomers (small basic molecules) are converted into polymers (large macromolecules); reaction type for the formation of plastics
Tube lining with bonding on the back	Lining with a reinforced hose that is bonded to the existing pipeline to prevent it from collapsing. Also known as lining with fabric hoses to be glued in.
Substrate	Flexible hose that absorbs the liquid resin system during insertion into the pipe to be sewer rehabilitated and forms part of the pressure hose liner after curing.
Cured-in-place pipe lining	Lining with a flexible hose impregnated with a reaction resin system. After curing, a pipe is formed.
Wall thickness	Definitions based on DIN EN ISO 11298-1/-4:

- **Nominal wall thickness ($_s$):** Wall thickness of the cured-in-place pipes in the uncured state, which corresponds to the manufacturing dimension.
- **Design thickness:** required wall thickness of the composite, determined by static calculation
- **Composite thickness ($_{ec}$):** Wall thickness of the combination of cured resin system, carrier and/or reinforcement material, excluding all foils
- **Total wall thickness ($_{etot}$):** Thickness of the pressure hose liner, consisting of the composite and all semi-permanent and permanent membranes
- **Composite thickness ($_{em}$):** The composite thickness is calculated from the total wall thickness by subtracting the thicknesses of the inner liner, outer liner, pure resin layers and reinforcements as an installation aid. (Composite thickness is not used in accordance with DIN EN ISO 11298-4 and corresponds to the definitions of design thickness)

3 Pressure hose lining

DIN EN ISO 11295 categorises pressure pipe liners into classes A to D. ***Table 1*** defines the associated properties.

Table 1: Static classification of pressure pipe liners analogue to DIN EN ISO 11295:2018-06

Properties of the liner	Class A	Class B	Class C	Class D
Can withstand internal or external failure (bursting, bending or cracking) of the existing pipeline	+	-	-	-
Long-term nominal pressure > highest permissible component operating pressure (PFA)	+	-	-	-
Inherent ring stiffness a)	+	+	- b)	- b)
Long-term bridging of holes and joint gaps at the highest permissible component operating pressure (PFA)	+	+ c)	+ c)	-
Provides internal corrosion protection d)	+	+	+	+

+ applies
- Does not apply

a) The minimum requirement for a liner is that it must be self-supporting when the pipe depressurises.
b) The liner is based on an adhesive bond with the existing pipeline in order to be self-supporting in the event of a pressure drop.
c) The liner conforms sufficiently tightly, either during installation or for a short period of time after the initial application of the operating pressure, so that the internal pressure load can be transmitted radially to the existing pipeline.
d) The liner serves as a barrier against corrosion, abrasion and/or the formation of uneven structures from corrosion products / flaking of the existing pipe as well as against contamination of the pipe contents by the existing pipe; it generally also reduces the surface roughness, which improves the flow capacity.

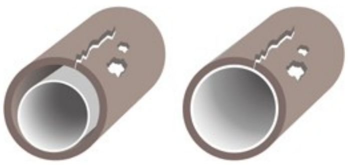
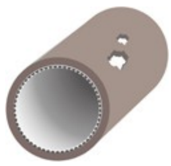
3.1 Classification

Depending on the classification, the pressure hose liner can be designed independently of the existing pipeline or interactively with the existing pipeline (see ***Table 2***).

According to the definition in DIN EN ISO 11295, an independent class A pressure hose liner is capable of withstanding all internal or external contamination on its own over its entire planned useful life without failure. It is not dependent on the radial support of the existing pipeline. A pressure hose liner is considered independent if, when tested, it has a long-term internal pressure resistance independent of the existing pipe. This must be equal to or greater than the highest permissible operating pressure of the rehabilitated pipeline. The pressure hose liner must be able to absorb all loads acting on the cured-in-place pipes from the outside.

By definition, an interactive (class B or C) pressure hose liner is not capable of withstanding all contamination over its entire planned useful life without failure. It is therefore supported radially, so to speak, on the existing pipeline.

Table 2: Static classification of pressure pipe liners and relationship between the technology families within the scope of DIN EN ISO 11295:2018-06

<table>
<tr><th colspan="2">Class A</th><th>Class B</th><th>Class C</th><th>Class D</th></tr>
<tr><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">independent</td><td colspan="3">interactive</td></tr>
<tr><td colspan="2">Fully resilient</td><td colspan="2">Semi-static loadable</td><td>Not resilient</td></tr>
<tr><td>lining with continuous pipes</td><td colspan="3">-</td><td rowspan="6">This document is not applicable</td></tr>
<tr><td>lining with discrete pipes</td><td colspan="3">-</td></tr>
<tr><td rowspan="3">-</td><td colspan="2">lining with close-fit pipes</td><td></td></tr>
<tr><td colspan="3">Curing on site hose liner</td></tr>
<tr><td colspan="2"></td><td>Hose liner with adhesive backing</td></tr>
<tr><td>-</td><td>-</td><td>lining with sprayed polymeric materials</td><td>-</td></tr>
<tr><td colspan="5">Note 1: Lining with retracted hoses is still to be classified, as product standards for this family of technologies have yet to be developed.
Note 2: The dots in the illustrations of classes C and D represent the adhesive joint.</td></tr>
</table>

Class A and B pressure hose liners have their own ring stiffness. This must be taken into account in order to determine the buckling strength under the effect of hydrostatic loads from outside and/or negative pressure loads.

The following list summarises the classification into classes A, B, C for pressure cured-in-place pipes within the range of application of this factsheet:

- Class A: independent, fully static load-bearing, conforms closely
- Class B: own ring stiffness, interactive, semi-static load-bearing capacity
- Class C: based on an adhesive bond, interactive, semi-static load-bearing capacity

In accordance with DIN EN ISO 11295, the pressure hose liner is characterised by the fact that it conforms tightly. In practice, it is possible in individual cases to use the class A pressure hose liner with a loose fit. Special technical requirements must be taken into account here (see chapter 8.8).

An overview of the static actions to be applied depending on the classification can be found in Chapter 8.7.

3.2 Technology overview and materials, areas of application and limits

Pressurised hoses for drinking water applications comprise the following components:

- resin system
- Support and/or reinforcement material
- Inner liner (permanent)
- Outer liner* (permanent, semi-permanent or temporary)

* not for pressure hose lining with adhesive backing

The inner liners of drinking water pressure liners are always permanent membranes. Temporary foils that are removed after installation are technically possible, but not common at the time of publication of the factsheet.

EXKLUSIV

The relationship between these components is **shown** in **Figure 2**. The various components can have functions related either to the end product or to the installation, depending on the specific procedure used.

The systems currently available on the market can be differentiated in terms of the liner materials used, areas of application and limitations as ***shown*** in ***Table 3.***

The possible pipe lengths depend on the project and system; possible pressure levels depend on the diameter and system.

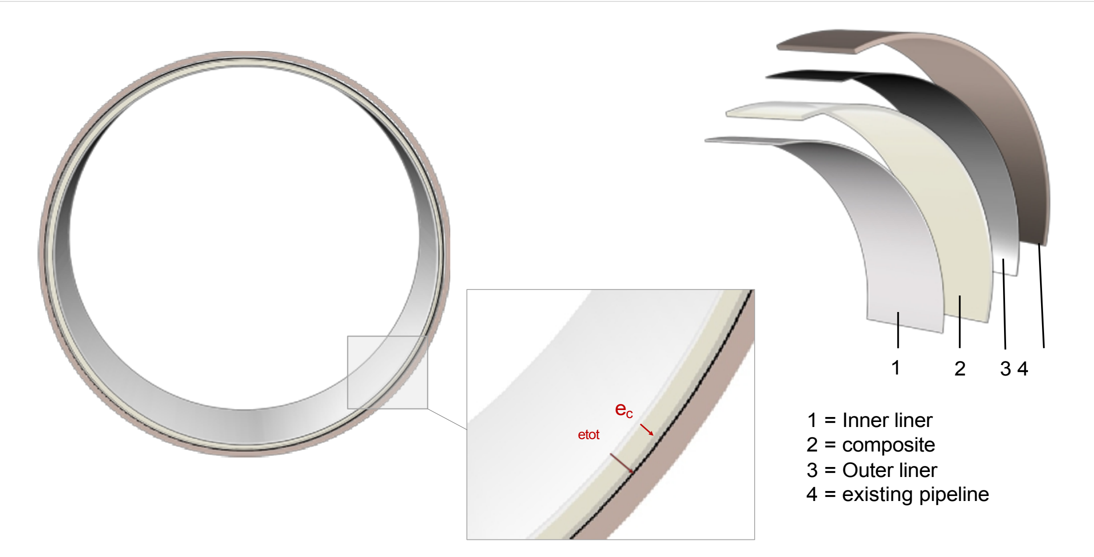


Figure 2*: Typical wall construction of a pressure hose*

Table 3: Technical overview of pressure hose liners, areas of application and limits

	Fabric tube liner	needled felt liner	Fabric hose with reinforcement	Glass fibre reinforced needled felt liner	glass fibre liner
Classification DIN EN ISO 11295 (depending on design)	C	A, B	A, B, C	A, B, C	A, B
DN range [mm]*	DN 80 - DN1200	DN 100-DN 1600	DN 100-DN 1200	DN 100-DN 1600	DN 150-DN 1500
Composite thickness [mm]*	2 to 5	4 to 30	3 to 25	5 to 15	4 to 15
resin type**	EPOXY RESIN, PU	EPOXY RESIN, UP	EPOXY RESIN	EPOXY RESIN, UP	UP, VINYL ESTER REIN
installation method	inversion	Inversion, combination retraction/inversion			Move-in
pipe bend mobility	Heat curing (water/steam) Ambient temperature	Heat curing (water/steam)			UV combination curing
Arc mobility (depending on radius)*	≤ 45° (larger bends with radii > 6D possible with restrictions)				≤ 10°

* The values stated are typical scopes; individual characteristic values for the different pressure cured-in-place pipes can be found in the manufacturer's specifications.
** EP - epoxy, UP - unsaturated polyester, vinyl ester rein, PU - polyurethane

4 Connection technologies

The pressure hose liner or the existing pipeline rehabilitated using a pressure hose liner must be handed over to the network operator ready for connection.

A completed sewer renovation therefore not only includes the pressure hose liner itself, but also the corresponding connection options to the pressure pipe network.

DIN EN 11298-4: 2020 (E) differentiates between

- Joints using flange adapters or couplings directly onto the pressure liner - independent of the existing pipeline
- Joints by sealing against the existing pipeline (only for interactive liners) and by sealing against a new fitting. The new fitting is either joined to the existing pipeline or anchored independently of the existing pipeline.

For class A, the standard requires the coupling or flange adapter to be attached independently of the existing pipeline. If a longitudinal frictional connection is required, it must be checked how this can be ensured and whether the existing pipeline can be used as an abutment.

The technical options for joints between the pressure hose liner and the existing pressure pipe network can be categorised into three types:

- Joints via the existing pipeline (class B, C)
- Joints via a fitting (class A, B)
- Joints via the pressure hose liner (class A)

EXKLUSIV

The rehabilitated pipe section is thus provided with jointable spigot ends or flange joints in accordance with DIN EN 1092-1.

The connection technologies must be selected in accordance with the local requirements of the network operator and depending on the pipe condition, material and pressure hose liner.

4.1 Joints via the existing pipeline

If the condition and material of the existing pipeline allow it, the end of the old pipe can be used as a joint. To do this, the pressure hose liner in the existing pipe is cut back and sealed against the inner surface of the old pipe using a liner end sleeve (LEM). Depending on the existing pipe material, welding neck flanges or couplings can be used as connectors (fittings), which are attached to the existing pipeline (***Fig. 3***). Welding neck flanges must be fitted in advance of the liner installation.

The LEM is used for sealing and joints between rehabilitation systems and the existing pipeline. Adhesive systems (class C) are an exception. Here, the use of a liner end collar is not mandatory. Tightness is achieved by bonding the systems themselves. With bonded fabric hoses, the LEM only serves as an inflow protection. The LEM must not be used to ensure the tightness of the system, as this must be guaranteed by secure bonding.
The longitudinal frictional locking of the joint depends on the longitudinal frictional locking of the existing pipeline. The LEM is exclusively a sealing element.

The existing pipeline spigot end of the rehabilitated pipe section may only be integrated into the network using mechanical couplings: Welded connections are not possible after installation of the liner.

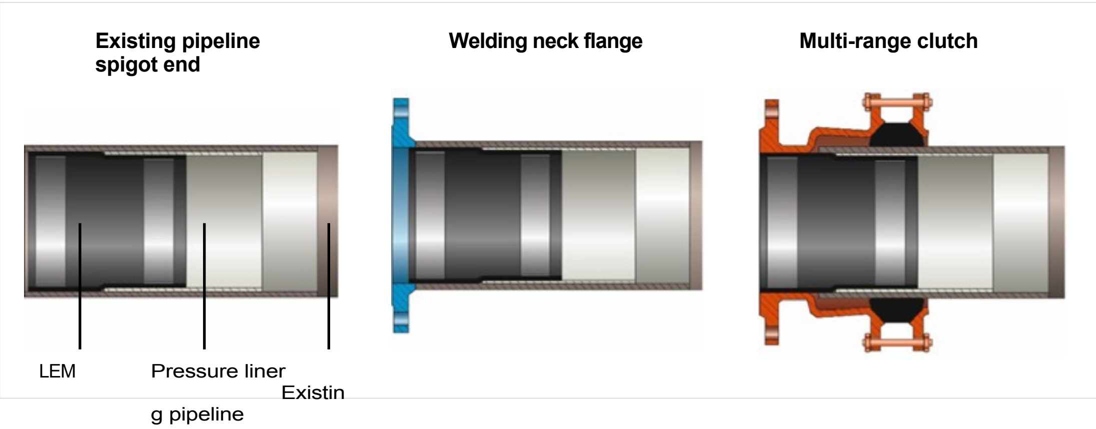


Figure 3: Joints via the existing pipeline (liner class B, C)

Requirements:
Mechanical couplings, flanges and cuffs used here must be approved for use with drinking water and tested in their combination for the area of application. They must be designed for the corresponding pressure rating of the pressure hose liner or existing pipeline pressure hose liner system.
Care must be taken to ensure that the sealing surfaces (existing pipeline and liner inner surface) do not have any unevennesses that would prevent sealing. The exact dimensioning of the LEM is crucial for sealing. Careful measurement of the internal circumferences in the area to be sealed in the existing pipeline and in the liner is essential.
Damage to the existing pipeline when cutting back the liner must be avoided and damaged surfaces must be repaired. Damage to the liner itself must also be prevented when cutting back.

> **Note:** As the LEM seals via a permanent radial pressure, it can only be used with existing pipelines made of plastics with a high creep tendency (e.g. polyethylene, PVC) if the bedding is sufficiently dense (e.g. liquid soil). In this case, the bedding must counteract the radial forces and thus prevent creep.

4.2 Joints via a fitting

With this type of joint, a new pipe fitting of the same internal diameter ($diOld_{pipe} = _{diFitting}$) is placed in front of the existing old pipe before the hose is installed. The joints between the existing pipeline and the fitting are made by welding or coupling, depending on the existing pipe material and condition. In the case of existing pipelines that are not longitudinally force-fit, it may b e sufficient to simply secure the position without a force-fit joint.

Once the liner has been installed, it is cut back inside the fitting and sealed against the inner surface of the fitting using a liner end sleeve (LEM) (***Fig. 4***). The longitudinal frictional locking of the joint depends on the longitudinal frictional locking of the existing pipeline. The LEM is exclusively a sealing element.

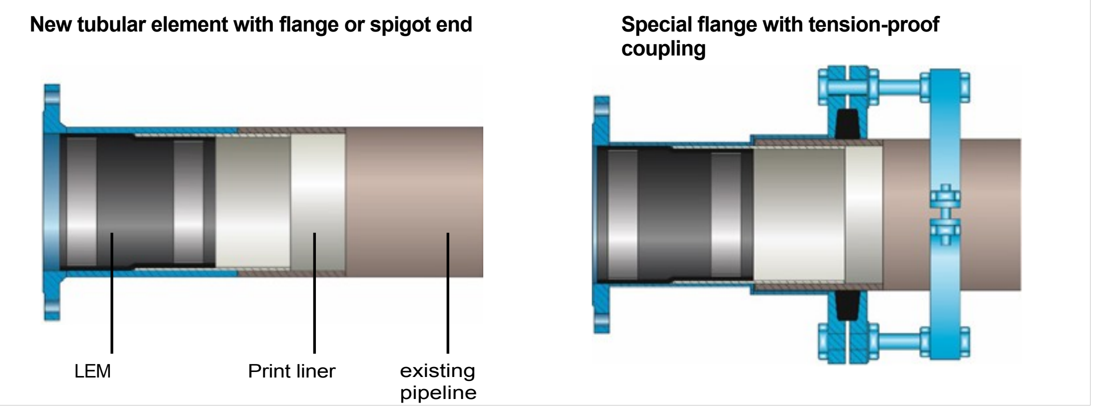


Figure 4: Joints via a fitting (liner class A, B)

Requirements:
The mechanical couplings, flanges and cuffs used here must be approved for use with drinking water and tested in their combination for the area of application. They must be designed for the corresponding pressure rating of the pressure hose liner or existing pipeline pressure hose liner system.
Care must be taken to ensure that the sealing surfaces (fitting and liner inner surface) do not have any unevennesses that would prevent sealing. The exact dimensioning of the LEM is crucial for sealing. Careful measurement of the inner circumferences in the area to be sealed in the fitting and in the liner is essential. Damage to the fitting when cutting back the liner must be avoided and damaged surfaces must be repaired. Damage to the liner itself must also be prevented when cutting back.
The information on the LEM in section 4.1 must be observed accordingly.

4.3 Joints via the pressure hose liner

Joints via the pressure hose liner are only possible with independent class A pressure hose liners. In this case, the connection fitting is arranged directly on the liner, using bonded joints (GRP flanges) or couplings (***Fig. 5***).

Grp flanges can be bonded to the pressure hose liner either during the curing of the liner or afterwards. The resulting joints are independently longitudinally force-fit.

For fittings that are retrofitted, a suitable liner spigot end must first be produced. To do this, the liner is either cured in a suitable formwork or the existing pipeline is cut back to the appropriate length after installation. The fitting is then glued or mounted on the liner.

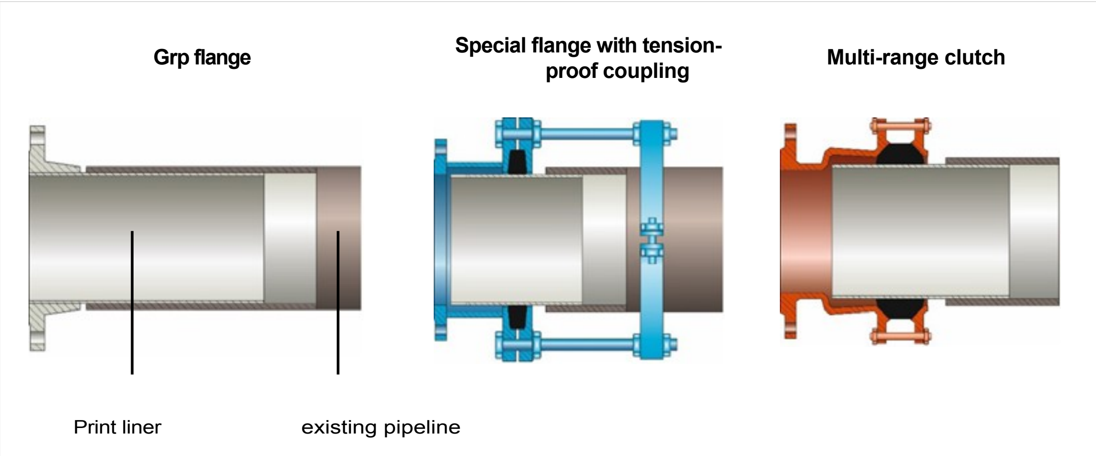


Figure 5: Joints via the pressure hose liner (liner class A)

When installing couplings, it should be noted that it is only possible to clamp them to the liner to create a longitudinal frictional connection if this has been approved by the system manufacturer. If necessary, the longitudinal frictional connection must be established via a suitable abutment (e.g. the existing pipeline).

The cut edge of the pressure hose liner must be sealed in accordance with the system manufacturer's specifications.

Requirements:
The mechanical couplings, flanges and cuffs used here must be approved for use with drinking water and their combination must be tested for the area of application. They must be designed for the corresponding pressure rating of the pressure hose liner or existing pipeline pressure hose liner system.
Care must be taken to ensure that the sealing surface (liner outer surface) does not have any unevennesses that would prevent sealing. Ovalities in the production of the liner spigot ends must be prevented by using suitable formwork.
To reduce stress peaks caused by differences in stiffness in the transition area between the grp flange and the exposed liner, an outlet; outfall transition can be created, e.g. using hand laminates. The system manufacturer's specifications must be observed.

5 Connection techniques

Common connections; junctions; contacts to drinking water pipes are fittings (e.g. valves, gate valves, hydrants) or other pressurised pipes (e.g. house connections). An essential aspect of sewer renovation is to reliably restore these connections and enable new connections; junction; contact. The state of the art of connection techniques for pipes that are rehabilitated using pipe lining is shown below.

5.1 Making connections; junction; contact via Connection fittings

EXKLUSIV

Lateral pipes (house connections) as well as aeration and venting valves can be restored via connection fittings depending on the system. These must be developed for liner-restored pipelines and tested with the pressure hose liner system. They seal directly onto the liner installed in the pipe or its inner liner with the help of an internal saddle and are fixed to the existing pipeline or a counter mould with an external saddle. For class A pressure liners, the external saddle can also be attached directly to the liner (***Fig. 6, left***).
After installation of the liner, the inner saddle is inserted into the rehabilitated pipe from the inside, guided through a drilled hole and fixed from the outside via an external saddle (***Fig. 6 below***). The inner saddle must be manufactured in such a way that it is adapted to the curvature of the liner.

is adapted. The external saddle can be used universally by using various compensating rubbers. If shear forces occur, the connection fitting must be secured using a pipe clamp.

Note: Connection fittings are currently being developed in which the inner saddle can be fed through the hole from the outside. Work is also underway on a connection that can be used for pipes that have been renovated and are in operation. It is being developed on the basis of commercially available tapping fittings that are approved for drinking water.

Note: In the case of bonded fabric hoses (class C), branches can be newly created or restored without additional measures using conventional pipework construction tools. Existing and operationally safe branches can be opened from the inside without the need for a grave, e.g. using a milling robot. New outlets are created from the outside using a tapping tool (with a drill bit) and the connection; junction; contact is installed using classic connection fittings or moulded parts. Tightness is ensured by bonding the liner to the existing pipeline. Branches from DN 12 can be opened (no maximum DN). As a rule, branches are at least one dimension smaller than the pipe diameter of the rehabilitated pressure pipe.

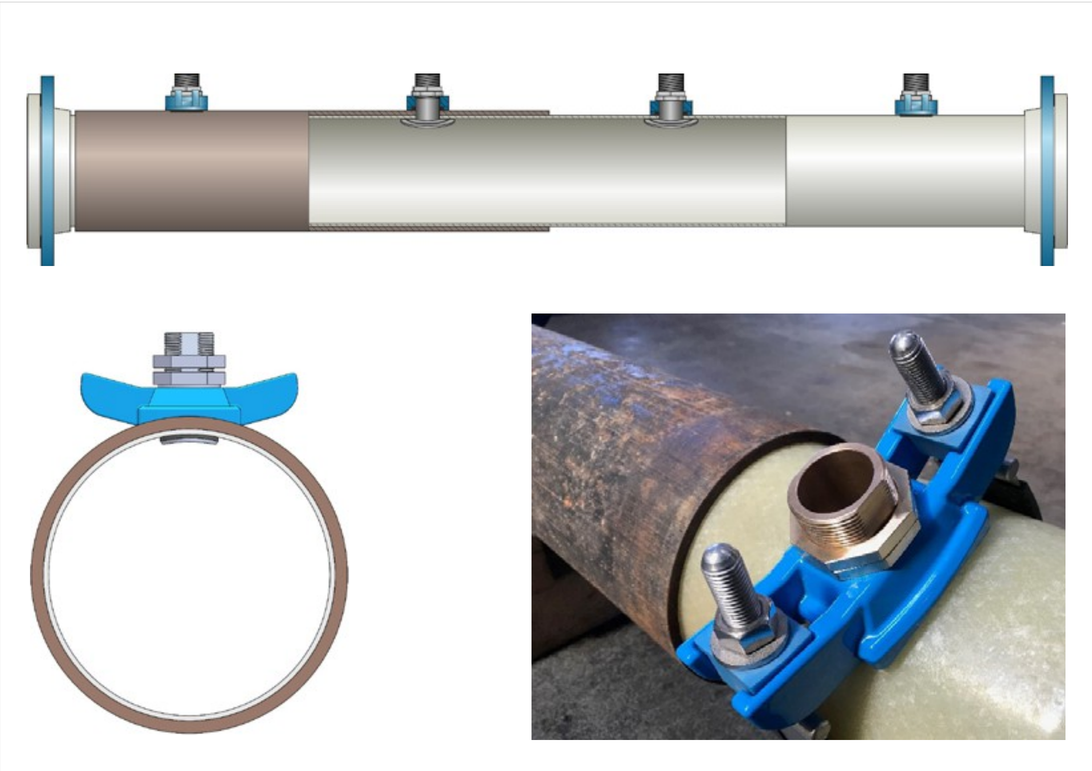


***Figure 6**: Connection fitting with internal seal consisting of an internal and external saddle - on the renovated pipe (left) or directly on the liner (right)*

5.2 Making connections; junction; contact using Fitting piece

The connections; junction; contact must be removed prior to the installation of the pressure hose liner in open construction. The resulting gap in the pressure pipe to be renovated must be closed using a fitting piece for the duration of the sewer rehabilitation. It may also be possible to use low expansion capacity fabric as a reinforcement hose to prevent critical overexpansion of the liner during installation and curing. No protection against overexpansion is necessary when using fabric hoses. After successful installation of the pressure hose liner, it must be separated in the area of the removed connection; junction; contact and tied in both pipe ends in accordance with chapter 4. The connection; junction; contact is reinstalled between the fittings. ***Figure 7 shows*** two connection options.

EXKLUSIV

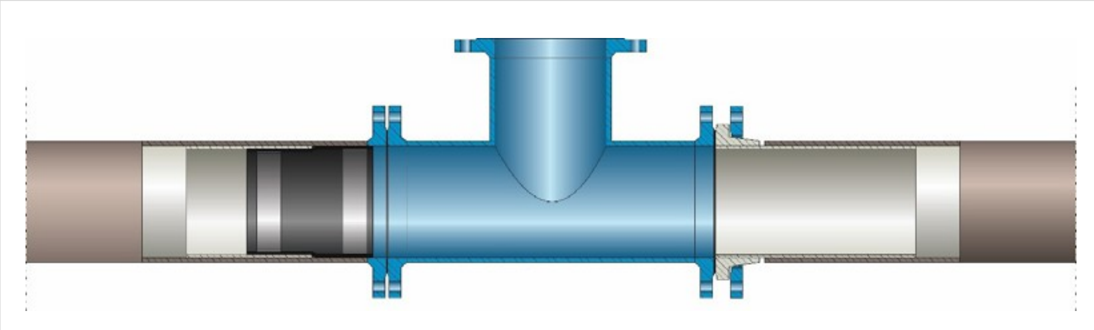


***Figure 7**: Example of making connections; junction; contact via the existing pipeline with welding neck flange and LEM (left - connection via the pressure hose liner with grp flange, right - connection via the pressure hose liner with grp flange)*

6 Requirements for Pressure hose lining

All components, materials and processes for pressure hose lining must be quality-tested and harmonised. The reproducibility of the process steps must be guaranteed. As part of extensive suitability tests, the procedure demonstrates its applicability for the sewer rehabilitation of pressure pipes and the areas of application are defined (see chapter 6.4).

The defined and suitability-tested pressure hose lining must have proof of suitability for drinking water hygiene in accordance with the "Assessment basis for plastics and other organic materials in contact with drinking water" (KTW-BWGL) (see chapters 7.1, 7.2).

> **Comment:** For the confirmation of conformity by a certification body in accordance with the KTW-BWGL, a transitional regulation of the Federal Environment Agency (UBA) applies until 21 March 2023, which allows the use of test reports in accordance with the KTW coating guideline and DVGW W 270.

6.1 Requirements for the materials

The components of the pressure hose liner are shown in chapter 3.2. ***Table 4*** summarises the liner components and requirements.

The material specifications from DIN EN ISO 11298-4 are deliberately not used here, as not all material combinations specified there adequately fulfil the requirements for the durability of pressure hose liners.

Table 4: Materials for pressure hose components

Pressure hose component	Materials*
resin type	EPOXY RESIN, UP, VINYL ESTER REIN, PU
Filler type	without, chemically inert inorganic or organic
pipe bend mobility	Heat curing, UV light curing, combination UV/hot curing, curing at ambient temperature (for class C liners)
Substrate/ reinforcement	• inert plasticiser-free polymer fibres e.g. poly(ethylene terephthalate) • Corrosion-resistant glass fibres of the "E-CR" type in accordance with DIN EN ISO 2078 and DIN 1259, which comply with the specifications of DIN EN 14020 Parts 1-3 • Combinations of the above fibres
Foils	• No specifications for temporary membranes • For permanent membranes, the material requirements are based on the necessary function (proof of suitability) • Foils must not have a negative impact on the operation of the pipe, materials e.g. TPU, PP, polyethylene
*Other materials can in principle be tested in accordance with this factsheet.	

For class A and B liners, resin types according to ***Table 5*** are preferred.
used.

Table 5: Preferred resin types for class A and B drinking water hose liners

UPResin	• DIN 18820-1* Group 3 or according to DIN EN 13121-1 Group 4** • DIN 16946-2 at least type 1130 (thermal and mechanical requirements)
Epoxy resin	• DIN 16946-2 Type 1020, Type 1021, Type 1040 (thermal and mechanical requirements)
vinyl ester rein	• DIN 18820-1* Group 5 or according to DIN EN 13121-1 Group 7** or Group 8 • DIN 16946-2 at least type 1310 (thermal and mechanical requirements)
* DIN 18820-1 withdrawn ** halogenated resin systems are excluded	

The test principles of **DVGW GW 327** apply to class C fabric hose processes. The verification of the properties of the materials used and the finished product, i.e. the fabric hose bonded to the pipe wall, is regulated in the DVGW W 330 Technical Test Specification. This is the basis for the certification of bonded fabric hoses for lining water pipes. It defines requirements for the peel resistance and the adhesive strength of the coating on the fabric as well as the resistance to negative pressure.

In the fabric hose process, the resins have a bonding rather than a load-bearing function and are therefore referred to as adhesives in the rules and regulations. Epoxy resins and PU resins are used.

The liner manufacturer must document that suitable materials are used for liner production in accordance with the specification. For this purpose, acceptance test certificates 3.1 in accordance with DIN EN 10204 must be available and suitable self-monitoring must take place.
The requirements of DIN 18200 for factory production control and external monitoring apply.

6.2 Requirements for the system technology

EXKLUSIV

The system technology for pressure hose lining includes:

- Dosing and mixing technology for resin systems
- Impregnation technology
- Installation technology
- Hardening technology

All technical equipment must be in perfect technical condition and must be checked and maintained in accordance with the manufacturer's instructions. It may only be operated by qualified personnel.

6.2.1 Dosing, mixing and impregnation technology

The storage of the resins and the non-impregnated carrier and/or reinforcement materials as well as the mixing of the resins must always take place under defined and controlled ambient and material temperatures. The process-relevant data of the dosing (e.g. weight, volume) and mixing (e.g. volume flow, mixing times) of the resin components must be automatically documented and stored. The impregnation must ensure complete wetting of the carrier and/or reinforcing material. The use of vacuum to deaerate the material must be controlled and carried out in accordance with the manufacturer's specifications.

6.2.2 Installation technology

The equipment technology required depends on the installation method of the pressure hose liner system and the manufacturer's specifications. There are three different procedures: the inversion method (crimping), the retraction method and the combination of inversion and retraction methods.

The requirements for the installation technology for the inversion method - pressure drum or inversion water column - are:

- Pressurisation according to manufacturer's specifications
- Gentle inversion, as continuous as possible
- Print control and documentation.

The inversion of the pressure hose is facilitated by the use of suitable lubricants, e.g. neutral liquid soap. For water inversion of pressure

For class A and B hoses from approx. DN 500, it must be assumed that these can no longer be installed without the use of a conveyor belt.

The inversion speeds and pressures in accordance with the manufacturer's specifications must be observed.

The requirements for the installation technology for the retraction method are:

- Electronic measurement and recording of the retraction forces
- Possibility of tractive force limitation

The retraction of the pressure hose is facilitated by the use of sliding foils in the sole area and lubricants. Depending on the product, the sliding foils may be part of the pressure hose structure. The pull-in forces specified by the manufacturer must be observed.

After pulling in, the pressure hose is inflated in accordance with the manufacturer's specifications by pressurising with air. The pressure must be checked and recorded. The correct positioning of the pressure hose must be visually checked and recorded.

6.2.3 Hardening technology

The following pipe bend mobility is possible: heat curing, uv light curing, combination uv/heat curing, curing at ambient temperature.

A hardening check in the outer laminate (between the liner and the existing pipeline) is essential in drinking water applications.

The requirements for heat curing are as follows:

- Sufficient heating capacity
- Sufficient circulation capacity or vapour throughput
- Automatic pressure monitoring and logging during curing (water column height for hot water curing; pressure manometer for steam curing)
- Temperature monitoring and recording at the flow and return as well as in the outer laminate (between the pressure hose and existing pipeline, at least in the sole) at least at the start and finish points, if possible also at intermediate points; logging as a data record, not just as a graphic
- Condensate drainage during steam curing

The requirements for the curing technique for uv light curing and combination curing are:

- suitable light sources, lamps and a liner approved by the liner manufacturer.

-performance (see below for details), including logging with details of the manufacturer

- Electronic logging* of the pass-through speed of the UV light sources and the illuminant function
- Electronic logging* of the internal pressure
- Temperature control and recording* on the surface of the pressure hose,

- For combination curing and system/project-dependent for uv light curing, electronic control* of the temperature in the outer laminate (between hose and existing pipeline, at least in the sole) at least at the start and finish points, if possible also at intermediate points
- Electronic control* of the curing in the outer laminate at least at the start and finish points, if possible also at intermediate points, using impedance spectroscopy (EIS, see chapter 13.3)
- The lamps must not have any visible damage and must be free of surface pollution or reflections (dark glass body).

* Logging as a data record, not just as a graph or diagram

For the light source used (light core or light chain), the manufacturer must provide speed tables for each pressure hose with the following minimum specifications for the hardness, depending on the dimension and wall thickness:

- Clear designation of the light sources
- Power specification for the lamps used
- Pass-through speeds
- Separate specifications for the start and stop phase (ignition intervals, pull-through speed)

Light sources that have not been verified by the pressure hose manufacturer must not be used for curing pressure hoses.

The types of light sources used in the light sources must be approved by the pressure hose manufacturer. It must be possible to clearly identify each lamp, e.g. by means of a serial number that enables the manufacturer to be identified. The time of commissioning must be documented.

EXKLUSIV

An intensity measurement of the lamps must be carried out regularly (for the first time after 200 operating hours at the latest, repeat test after 150 operating hours at the latest). If the light intensity is below 75 % compared to the reference, the lamps must be replaced. It should be noted that the intensity of the lamps depends on the light sources and the power of the generator. The test must be documented.
Information on proof of hardening can be found in chapter 7.4.

6.3 Requirements for the execution of installation

EXKLUSIV

Complete documentation of all relevant process steps must be prepared for every construction measure carried out with pressure hose liners. These records must be kept so that the cause of any defects can be identified and suitable corrective measures can be taken. Retention periods are at least five years.

In the case of impregnation in the factory, the delivery note must contain at least the following information:

- Wall thickness of the supplied liner (Note: The supplied wall thickness of the impregnised cured-in-place pipes leads to the resulting composite thickness $_{ec}$ or composite thickness $_{em}$ in the installed and cured product. For UV curing, the specification of the supplied wall thickness must correlate with the specifications in the speed tables).

- Pressure hose identification or production number
- Date of manufacture
- Transport and storage conditions (storage period and temperature range)
- Customer
- Site and installation location / renovation section
- DN
- Length
- Weight
- pipe bend mobility
- If necessary, conditions for handling such as: do not stack, do not expose to direct sunlight or frost

Thermal recorders must be enclosed with the pressure hose (at least for hot or combination curing) in order to check compliance with the delivery and storage temperatures. If the hose is delivered in ice-cooled transport containers, the thermal recorders can be dispensed with. The liner must also be provided with ice between the layers to ensure reliable cooling. Depending on the system and ambient conditions, on-site impregnation requires the pressure hose to be cooled, e.g. by means of a water or water-ice bath. The current storage conditions (temperature) of the pressure hose must be documented at least at the start of installation.

For UV or combination curing, the pressure hose manufacturer must specify the maximum possible pass-through speed depending on the light sources and pressure hose. This is done on a project-specific basis for each delivery or as standard using table values tested for drinking water applications. For heat curing, the required heating specifications must be specified as a function of the laminate temperature (outside).

On arrival at the site, the pressure hose must be checked at least as follows:

- Checking the delivery documents
- Visual inspection of the pressure hose
- Check that the flat dimension matches the specified diameter

The documentation of the work on the site must include at least:

- Video recordings of the visual inspection by pressure pipe inspection or inspection before and after the renovation measure
- If necessary, calibration record (see chapter 8.8)
- Installation and curing protocols, which include the following parameters, among others:
  - Process-dependent continuous documentation of the pressure, temperature and/or UV light parameters as well as the tensile forces occurring during retraction of the pressure hose

  - UV curing: documentation of the testing of light sources and lamps in accordance with chapter 6.2.3 before each installation
  - Curing at ambient temperature (cold curing without energy supply for class C liners): Shore D hardness measurement at a suitable position of the installed pressure hose under local curing conditions
- construction site daily reports
- leak test report

For on-site impregnation additionally

- Dosing and mixing log, impregnation log; for pressurised hoses of class A or B, logging must be carried out automatically

All process parameters to be documented must be recorded at such a frequency, depending on the process, that even events of short duration are recorded which may have an influence on the properties of the pressurised hose liner, such as
z. e.g. pressure parameters or exothermic temperature peaks.

The company carrying out the installation must ensure that the installation guidelines for the selected and tested pressure hose lining method are followed exactly and checked using internal and external monitoring mechanisms.

6.4 Requirements for the pressure hose liner system (suitability tests)

The pressure hose liner system must be tested in accordance with the requirements of DIN EN ISO 11298-4. Table 2 and Table 3 specify requirements for short-term and long-term characteristics for class A and B pressure hose liners. Requirements for class C pressure hose liners are contained in **DVGW manhole (shaft/chamber) 330.**
The flushing jet resistance of the pressure hose liner must be verified in accordance with DIN 19523 Chapter 4.3 Procedure 2 "Practical test".

The specifications for curing are defined as part of the suitability test (see chapter 7.4.3). Glass transition temperatures and, if necessary, enthalpies are determined. This has proven itself in practice with epoxy resin systems. For resin systems with reactive solvents (e.g. styrene, acrylate for UP and vinyl ester rein resins), the content of residual monomers is determined.

The ability of pressure hose liners to negotiate bends varies greatly and depends primarily on the carrier/reinforcement material, the foils used and the pipe bend mobility. The system manufacturer must prove that it is possible to cross bends. The decision on the ability to rehabilitate always depends on the project, as the arrangement and shape of bends can vary greatly.
The requirements are to ensure low wrinkling that does not jeopardise the operation of the pressure pipe (piggable cross-section, freedom from obstacles) and that the liner conforms as fully as possible to the outside of the bend. When passing through a bend in a non-load-bearing existing pipeline, the static requirements for

EXKLUSIV

must be taken into account accordingly in the planning. This can be done, for example, by backfilling the outside of the arch so that a radial "support" is subsequently ensured. This requires a case-by-case assessment with the relevant expert structural engineer.

To evaluate the overall system against dynamic pressure load changes (pressure surges, e.g. due to switching operations, see chapter 8.4), a system verification is available via a pressure pipe load change test (DLT) based on ISO 15306 and DIN 50100. Here, class A and B pressure hose liners are subjected to a pressure cycling stress test (positive and negative pressure range) specifically with connections; junctions; contacts, so that an evaluation of the overall system is possible. If no DLT is required for the negative pressure range because pressure surges can essentially be ruled out, the suitability of the overall system must still be tested in the positive pressure range. The load change then takes place in the positive pressure range. For the pressure hose liners, the connections; junction; contacts (see chapter 4) and connections (see chapter 5) to be used in the system must always be tested with the liner. This can be done via a system test using a pressure pipe load change test (DLT).

EXKLUSIV

6.5 Qualification of the company

Service providers for the construction, renovation, inspection or cleaning of water, drinking/ potable pipes must provide evidence of the necessary expertise, performance and reliability as well as quality monitoring - consisting of external and internal monitoring. DVGW-certified specialist companies for trenchless pipe construction in accordance with **DVGW Code of Practice GW 302** are authorised to carry out the work (R5 for cured-in-place pipe lining (n.v.), R1 for pipe lining with bonding on the back).

The crew commissioned to carry out the remedial action must consist of specialists and instructed persons in accordance with DVGW GW 301. Training measures and instructions for the hose lining procedure used, including the hygiene measures to be observed, must be carried out and documented.

The requirements of DVGW W 491 apply to companies that fulfil inspection, maintenance and other preliminary work.

7 Drinking water hygiene Requirements

The German Drinking Water Ordinance (TrinkwV) defines requirements for systems for the production, treatment or distribution of drinking/potable water. According to this ordinance, materials and substances in contact with drinking water must not reduce the protection of human health, adversely change the odour or taste of the water or release substances into the drinking water beyond what is unavoidable if the generally recognised rules of technology are observed.

Additional requirements and tests can be defined by the network operator.

The drinking water hygiene assessment is carried out separately for the pressure hose liner and for its connections.

7.1 Testing in accordance with UBA assessment principles

The requirements of the Drinking Water Ordinance are concretised by the Federal Environment Agency (UBA) in material-specific assessment principles. The requirements for organic materials are regulated in the "Assessment basis for plastics and other organic materials in contact with drinking/potable water (KTW-BWGL)". The KTW-BWGL currently applies to plastics, organic coatings and lubricants. Other materials such as elastomers, silicones, etc., for which guidelines and transitional recommendations currently exist, are also to be transferred to the KTW-BWGL in the future (as of 06.2020).

The layer in contact with water is decisive for the assessment, which is why pressure cured-in-place pipes are generally assessed according to the KTW-BWGL. According to the KTW-BWGL, pressurised hose liners are to be regarded as multi-layer systems, as they are made up of several firmly bonded layers. The individual layers must be assessed on a material-specific basis in accordance with the annexes to the assessment basis and the migration restrictions of all layers must be evaluated.

The drinking water hygiene assessment of pressure hose liners is carried out as a suitability test for the drinking water hose liner by a certification body that is accredited for materials in contact with drinking water. This involves a review of the formulation, which requires the following information:

- Description of the exact structure of the product/unit
- Designation of the material type(s)
- List of all starting materials for the manufacture of the product (monomers, additives, auxiliaries and other starting materials) with the chemical designations, trade names, CAS numbers, technological functions, quantities used, suppliers and safety data sheets.

The recipe check is used to determine whether the composition requirements are met. When checking the formulation of multi-layered products, the formulation is checked individually for each layer.

After a positive formulation evaluation, the practical migration test is carried out in the laboratory on the actual product (pressure hose liner). The test pipe should have a high substance release compared to the actual product. This is a pipe in the small diameter range (largest surface-to-water volume ratio) and the minimum curing to be achieved in rehabilitation practice. The samples for the

Migration tests are generally carried out on a sample construction site - using the manufacturing process defined for the pressure hose liner.

As part of this sample construction site, the RSV also recommodates taking test specimens to determine the curing in the laminate and testing them in an accredited laboratory to compare the residual monomer content and the glass transition temperatures (see chapter 6.4).

7.2 Proof of conformity

The assessment principles do not contain any specifications on how the conformity of a tested product with the requirements can be confirmed. To supplement the assessment principles, the Federal Environment Agency has drawn up a recommendation for confirming the drinking water hygiene suitability of products. The assessment and verification of compliance with the drinking water hygiene requirements for products in contact with water, drinking/potable water are carried out in analogy to Regulation (EU) No. 305/2011 according to System 1+. This means that conformity is confirmed by a certification body. The tasks of the certification body are as follows:

- Initial inspection of the factory and factory production control
- Type testing of the product
- Ongoing monitoring, assessment and evaluation of factory production control
- Audit-testing.

Ongoing monitoring, assessment and evaluation of the factory production control is carried out as part of the annual external surveillance carried out by the certification body or an authorised surveillance body at the manufacturer's premises. External monitoring includes annual on-site monitoring of the manufacturing process and the off-cutting of samples on sites or sample construction sites. The samples are subjected to a migration test and assessed.

Comment: For the confirmation of conformity by a certification body in accordance with KTW-BWGL, a transitional regulation of the UBA applies until 21 March 2023, which allows the use of test reports in accordance with the KTW coating guideline and DVGW manhole (shaft/chamber) 270.

7.3 Hygiene during the rehabilitation procedure and handling

All tools, equipment and work clothing that come into contact with the drinking water systems after the sewer renovation or before an interim recommissioning may only be used in drinking water systems.

The requirements of DVGW worksheets W 400-2 and W 291 and DIN EN 805 must be observed.

Annex 13.12 contains an overview plan of the required degree of hygiene depending on the activities to be carried out on the supply network.

EXKLUSIV

> **Note:** When recording the condition using camera inspection, care must be taken to prevent germs from entering the pipe. The camera system used must be thoroughly cleaned and disinfected beforehand. When moving the camera system from one pipe to another, ensure that PPE (especially protective gloves) is worn to prevent contamination of the trolley.

All fittings and valves must be protected against pollution.

7.4 Proof of curing

With regard to possible migration into the water, drinking/potable water, the hardening control of the pressure hose liner is essential. This is carried out using test pieces from the liner laminate in the laboratory via the glass transition temperaturs reached using DSC or DMA analysis, the determination of enthalpies using DSC analysis and, depending on the resin system, via the determination of residual monomers (see chapters 10.2, 13.1, 13.2, 13.7). Curing control during the sewer renovation is carried out via control measurements in the outer laminate between the liner and the existing pipeline (furthest away from the energy source). Temperature measurements (especially for heat curing resin systems) and electrical impedance spectroscopy (especially for UV and combination curing systems) can be carried out using sensors on the outside of the liner. For systems curing at ambient temperature, curing is monitored over time a s a function of temperature.

7.4.1 Temperature measurement in the outer laminate as in situ curing control

Monitoring the temperature development in the liner during the curing process is a reliable indicator of the successful cross-linking of heat curing resin systems, as the time and level of temperature exposure allow conclusions to be drawn about the degree of curing. Thermocouples are positioned directly between the liner and the existing pipeline. Measuring cables that allow temperature control over the entire pipe section to be renovated are also available. The disposable sensors remain in the rehabilitation product after the measurement.

7.4.2 Impedance spectroscopy as in situ curing control

EXKLUSIV

Electrical impedance spectroscopy or dielectric analysis (see section 13.3) allows conclusions to be drawn about the curing behaviour of the resin system by measuring the ion viscosity. For this purpose, a flat disposable sensor is applied to the outside of the print liner before curing, which is in direct contact with the resin. This continuously determines the ion viscosity and the temperature of the outside during curing. The disposable sensors remain in the restoration product after the measurement.

7.4.3 Proof of hardening on material samples

Specifications for curing are defined as part of the suitability test (see chapter 6.4). The glass transition temperaturs are determined for epoxy resins. The glass transition temperature is directly correlated to the degree of curing of the matrix system. For UP and vinyl ester rein resins, the residual monomer content is determined. Depending on the system, glass transition temperaturs and enthalpies can also be defined. The curing achieved is determined using material samples from the rehabilitated pipe and compared with the values determined in the suitability test (see chapter 10.2.). This provides direct proof of the hardening of the liner.

7.5 Cleaning, disinfection, hygiene testing after installation

The cleaning and disinfection of the rehabilitated drinking water pipe is tendered in the same way as for a newly laid drinking water pipe. DVGW worksheet W 291 (cleaning and disinfection of water distribution systems) and DIN EN 805 are primarily used for this.

Section 3 "Treatment and disinfection", § 11 of the **Drinking Water Ordinance** contains a list of treatment substances and disinfection processes. DVGW Code of Practice W 291 specifies the necessary control tests such as the off-cut of water samples (after rinsing), microbiological examinations; investigations, pH value checks and turbidity measurements. The specification values for the examination; investigations of test water are derived from the Drinking Water Ordinance (TrinkwV), in particular section 2.

The pipeline must be disinfected and flushed before commissioning the rehabilitated pipe. Proof of microbiological safety must be provided. The disinfectants and procedures listed in the TrinkwV, DIN EN 805 and DVGW W 291 must be used.

In preparation for disinfection, the pipe is flushed with water, drinking/ potable water, whereby sufficient flow velocities of at least 2 m/s to 3 m/s must be maintained. Depending on the pipe cross-section, three to five times the pipe volume should be provided as flushing water volume.

The procedures for cleaning and disinfection as well as the associated disinfectants should be specified in the tender, adapted to the local conditions. The operator's specifications and, for example, the options for disposing of the rinsing water etc. must be taken into account. During disinfection, it must be ensured that no disinfectant additive enters the drinking water network. According to DVGW W 400-3, disinfection is recommended together with the internal pressure test.

In connection; junction; contact with the disinfectant, the pipe is flushed again with at least one times the pipe volume until the remaining disinfectant in the pipe has been sufficiently rinsed out. After 24 hours, the (first) bacteriological sample is taken off-cut (see section 10.3).

8 Planning

8.1 Condition survey

In the case of pressurised pipes, no regular inspections are generally carried out in the form of camera inspections. Sewer rehabilitation is therefore either triggered by known cases of damage or an accumulation of such cases, or a precautionary repair is carried out due to the age, particular risk situation of the pipe, material (e.g. asbestos-cement pipe), pressure loss or similar.

It is advisable to use old pipe sections, e.g. from burst pipes, as the basis for recording the condition for the rehabilitation planning. These are used, among other things, to assess the surface condition, any existing deposits and internal coatings, the internal pipe diameter and the wall thickness. The network operator's damage register should include this information.

As part of the planning of a pressure pipe renovation, a cleaning including removal of incrustations and a visual inspection are carried out. It may already be necessary to set up an emergency supply for this, see chapter 8.5. The need for this must be checked via the water supplier's network operation.

Note: If no decommissioning, cleaning and inspection of the pipe is carried out as part of the planning, these processes are shifted to the rehabilitation process. It must be taken into account that the planned pressure hose measure may have to be adapted and may take longer than planned.

The pipe condition can be recorded in accordance with DWA M 149-5, whereby additional quantitative statements can be made on the following points:

- Hole diameter [mm]
- Socket gap width [mm]
- Offsets [mm] and angles [degrees] within a straight pipe section (e.g. underbends, culverts)
- Angle [degrees], radius [x DN] and type of bends
- Position and size of any protruding obstacles (connections; junction; contact, plugs, etc.)
- Position and type of outlets, connections; junctions; contacts, fittings, aeration and venting valves, moulded parts, etc.

Typical damage patterns of pressurised pipes are:

- Corrosion: surface corrosion or pitting (from the outside to the inside, less frequently from the inside to the outside), stress corrosion cracking
- Abrasion
- incrustation
- Deflection (static overload, lack of bedding)
- Mechanical damage (from construction or operation)
- Cracking

- Leaking pipe connection
- Damaged interior coating

In the case of crack formation, it must be determined whether this is due to previous damage caused by e.g.
B. Corrosion. If no previous mechanical damage is recognisable as the cause of the damage, cracking can also indicate operational problems due to a lack of aeration or deaeration or pressure surges. If it is established that operational problems result from an unsuitable pipe run (unplanned high and/or low points), this must be taken into account during the planning stage and the structural defects must be rectified (smoothing of the pipe run or installation of a ventilation valve).

A pressure test of the existing pipe is generally not required.

Depending on the static classification and the material and condition of the pipe, it may be necessary to measure the wall thickness. The actual wall thickness must be determined if a class B or C pressure hose liner is planned and it is suspected that the old pipe wall thickness has been reduced due to corrosion and/or abrasion. A non-destructive determination of the wall thickness is generally carried out using ultrasonic testing. The surface of the pressure pipe to be examined; investigation must be professionally prepared (removal of coatings, rust, etc.).

8.2 Preparation of the existing pipeline, Cleaning

As part of the planning, specifications must be made for the possible cleaning of the existing pipeline. Depending on the condition, existing deposits and material of the pipe, the following cleaning methods can be used for pressurised pipes:

- surge flushing
- Pigs
- Air-water flushing
- High water pressure
- Maximum water pressure
- Different mechanical cleaning methods (e.g. scraping, sandblasting)

The cleaning parameters must be adjusted to the conditions on site. There is a risk of damage during cleaning, especially with old polyethylene, PVC, grey cast iron and fibre cement pipes.
The cleaning target is determined by the requirements from the classification of the pressure hose liner and its installation:

- Class A and Class B: free cross-section, no loose parts, free of protruding obstacles and incrustations
- Class C: as above, additionally free of separating substances (adhesive substrate)

EXKLUSIV

For this purpose, information on the location, length, height and arrangement of cleaning openings must be provided in the planning. If necessary, structural measures necessary to enable cleaning. Excavations can already be constructed for cleaning, which are used for later installation.

The supply of water for cleaning must be described in the planning. Furthermore, the handling of the cleaning water/material and, if applicable, the conditions for discharge or disposal (discharge authorisation, sedimentation container, sampling of the cleaning water, disposal of cleaning residues, etc.) must be taken into account. The respective environmental regulations must be observed (see chapter 15.4).

Based on the cleaning carried out for the planning, the necessary cleaning effort for the tender and later installation can be estimated. For particularly pronounced incrustations, the use of high-pressure water or a milling robot should be planned. These services should be tendered on a time and material basis and a realistic estimate of the time required should be made (see chapter 8.8). Bonding systems (class C) always require the use of ultra-high water pressure and, if necessary, sandblasting (see section 8.2).

The cleaning result is evaluated by visual inspection. Instructions for cleaning with maximum water pressure are given in Annex 13.13.

8.3 Information on the existing pressure line

The planning must at least take into account the following information on the existing pressure pipe:

- Material, age of the pipe, possibly existing internal and/or external protection
- Operating pressure, nominal pressure (PN), test pressure
- DN; di, da; diameter change if necessary
- Length: total and individual sections
- Arches, inspections, aeration and ventilation valves, other installations, connections/junctions, culverts, valve shafts if necessary, compensators
- Topographical features (high and low points)
- Design of the cable connection: tension-proof, plugged, abutment
- if known: construction method used
- Bedding of the pressure pipe, above-ground installation if necessary
- Groundwater level above top of pipe

Furthermore, the height and position of the existing pipework is an important basis for the planning and execution of installation. In very few cases can this be reliably determined from as-built plans. Determination by means of an XYZ position measurement represents a considerable effort. It must therefore be decided during the planning stage how detailed the position can and should be determined. Whenever operational problems are known and a reliable pressure surge calculation appears necessary, precise position measurement is essential.

Depending on the selected static system, information on the bedding of the existing pipeline is also required. If necessary, a determination of the soil

The planning of the project must include the determination of the characteristic values and, if necessary, the preparation of a geotechnical report.

The more information available on the existing pressure pipe, the more reliable the planning will be. If not all the necessary information is available, it must be collected and evaluated during project implementation.

8.4 Determination of operational boundary conditions

The operational boundary conditions for pressure pipes are largely determined by the pump operation and must be comprehensively determined during planning. They must be taken into account in the preliminary structural analysis and as part of the pressure surge calculation. The decisive operational parameters are the maximum operating pressure and the maximum rated pressure.

> **Note:** A drinking water pressure pipe generally reaches its maximum rated pressure as a result of pressure surges, e.g. due to the rapid closing of valves, the withdrawal of extinguishing water or the rapid start-up of pumps. Pressure surges should generally not occur during normal operation.

Existing installations (e.g. aeration and venting valves, slide valves, pigging sluices, cleaning opening) must also be determined and it must be clarified on the operational side whether they are functional or whether they need to be replaced or repaired.

8.5 Maintaining operations (emergency supply)

The planning for securing the supply must contain at least the following information:

- Drinking water demand to be provided
- Extinguishing water supply (according to local specifications)
- Length and diameter of any necessary replacement pipes
- Take-off and discharge points incl. geodetic heights
- Structural features of the pipe route (underfloor installation, elevation, etc.)

A concept must be drawn up that contains all the necessary information for the decommissioning of the drinking water pipe to be sewer renovated. This may include information on shutting down the pumping station, relocating or shutting off pipes, commissioning emergency supply lines, etc.

8.6 Planned rehabilitation procedure

The space required for the sewer renovation must be determined in advance. This concerns the size and arrangement of the excavations, including bracing and, if necessary

necessary further measures such as lowering the groundwater level in the excavations. The construction site facilities for the renovation process must be planned and the necessary installation areas for the plant technology, material storage and, if necessary, the disposal area must be determined in terms of size and location. The following minimum space requirements for the plant technology can be assumed:

- Drive: depending on the process, minimum installation area for the renovation technology plus working space
- Target pit: process-dependent, working area for inversion methods, additional installation area for winches, compressors, etc. for retraction methods.

These space requirements must be taken into account and agreed in advance when obtaining permits and for coordination with affected third parties (e.g. neighbouring residents, tradespeople, property owners, other utilities and waste disposal companies).

The necessary permits must be obtained as part of the planning process (e.g. water permits, crossing agreements) or agreed in advance with the authorising bodies if the final approval can only be granted after the contract has been awarded (e.g. night work permits, traffic permits). The authorisations may result in support, e.g. work in certain time windows, work up to a certain noise level, which must be included in the tender.

The renovation work must be scheduled taking into account the requirements of the necessary authorisations and the operational requirements of the network operator. As a result, a preliminary construction schedule with the basic work steps must be drawn up.

8.7 Requirements for the static calculation

The liner class to be used must be decided at the planning stage. Depending on the classification, the following actions must be taken into account for the structural analysis (***Table 6***):

EXKLUSIV

***Table 6**: Actions on the pressure hose liner depending on the pressure hose liner class and load case as a basis for the static calculation*

Classification according to DIN EN ISO 11295	Load case according to DWA A 143-2	Effects from inside	External influences
Class A Fully statically loadable*	Load case II Existing pipeline bears in the long term not with	Internal pressure (boiler mould and bridging of socket gaps and holes) Negative pressure	External water pressure Earth and traffic loads**
Class B, C Semi-static loadable	Load case I Existing pipeline carries	Internal pressure (only bridging of socket gaps and holes) Negative pressure	External water pressure
			Taking into account existing imperfections

* in straight pipe sections
** Depending on its condition, the existing pipe may not bear the internal pressure in the long term, but as an existing pipe soil system it can bear the earth and traffic loads so that these do not have to be taken into account in the liner statics.

In DIN 18326, chapter 0 "Instructions for the inflation of the performance description" in section 0.2.16, VOB/C requires the specification of static requirements for the lining pipe and the resulting wall thickness. Consequently, it is the planner's task to create a preliminary structural analysis for all possible liner systems in order to determine the wall thickness of the respective system required for a tender. For this purpose, the use of GSTT Information 20-2 (n.v.) is recommended, taking into account DWA-A 143-2 and DWA-A 127-2.

The final structural analysis must be prepared for the execution of installation for the selected pressure hose system or the preliminary structural analysis must be confirmed. In particular, the boundary conditions assumed in the planning, such as the dimension of socket gaps or holes to be bridged, pre-deformations, local imperfections, bends or angles, must be checked and adjusted if necessary.

In addition, preliminary structural analyses are required for civil engineering measures such as abutments, excavations and the like. This part of the planning will not be discussed further here.

8.8 Tender

VOB/C (DIN 18326) Chapter 0 "Instructions for the inflation of the service description" must always be observed. Additional information and further explanations for the sewer rehabilitation of pressure pipes are provided below:

- Maintenance of operation/supply: this is of particular relevance for pressurised pipes, see chapter 8.5
- Cleaning: see chapter 8.2. The planning must at least provide information on the type of cleaning, accessibility and installation areas, supply and disposal of rinsing water. If cleaning cannot be ensured via existing cleaning openings, the planning must include access options via

Provide excavations, preferably arranged so that they can be used later for the installation of the liner. If sufficiently good information about the degree and type of pollution can be provided, the cleaning should be tendered in [m]. If no information is available on the nature of the contamination, the cleaning should be tendered in [d] or [h]. For class C pressure hose liners, cleaning is installed differently depending on the process. Therefore, the cleaning target "free of separating substances" should be tendered in [m].

- Visual inspection: The planning must provide for a visual inspection at the start of construction and after completion of the preparatory work. The former serves to finalise the actual scope of the necessary preparatory work between the construction company carrying out the installation and the construction supervisor. The latter is necessary to check the success of the preparatory work and to verify or adjust the assumptions made in advance regarding the condition of the pipe in relation to the statics and the installation of the liner.

- Calibration: After completion of the preparatory work, a continuous calibration of the pipe must be carried out if there are indications of existing diameter fluctuations.

- The arrangement and size of excavations must be specified in the tender. Furthermore, accessibility and set-up areas must be specified. Sufficient areas for vehicles (sewer renovation and service vehicles) and equipment (e.g. winch, conveyor belt, pressure drum) must be provided on both sides of the renovation route, particularly for the installation of the pressure hose.

- The handling of fittings such as gate valves, valves, etc. must be specified. They should generally be removed before installation of the pressure hose and then replaced (see chapter 5). Ideally, the necessary excavations for the installation of the pressure hose should be located at these points. Suitable fitting and connecting pieces should be provided here. The usability of connection fittings (see chapter 5.1) for lateral pipes and valves must be checked and provided in accordance with the condition of the existing pipeline.

- For class C pressure hose liners, the possibility of connections without additional measures must be considered and, if necessary, a trenchless opening from the inside using a milling robot must be checked (see chapter 5.1).

- It must be determined how to proceed with bends, as these have an influence on the static load-bearing capacity of the pressure hose liner. Depending on the diameter and radius of the procedure and pressure hose, bends can also be renovated (see ***Table 3***). In addition, bends must generally be removed before the installation of the pressure hose and then replaced. Ideally, any excavations required for the installation of the pressure hose should be located at these points.

- In the event of diameter changes in the pipe run (e.g. repair points), a class A pressure hose liner can be used in areas with a larger internal diameter.

The liner should be provided with a loose fit for installation. In this case, it is necessary to provide a suitable reinforcement hose or support tube to prevent the liner from overstretching during installation and to ensure that the laminate is compacted during curing. A separate structural analysis is required for this type of installation. The resulting annulus must be filled in accordance with the static requirements. The loose-fitting pressure hose must be positionally secured so that no forces can be transmitted to connections; junctions; contacts.

- The type of joint for the finished liner must be specified taking into account the condition of the existing pipeline (see chapter 4). Suitable sealing elements must be tendered. If the pipe ends cannot be made plane-parallel to each other, suitable wedge ring seals must be used.

- The planning must include information on the required quality tests on the construction site. In addition to material tests, these include in particular the visual inspection after installation of the liner and production of the joint as well as the pressure test (see Chapters 10.1, 10.2). The specifications for the pressure test must be defined individually, especially if, for example, fittings between connected rehabilitation sections and installations lead to changing materials with different expansion properties and therefore cannot be tested clearly in accordance with DIN or DVGW rules and regulations. If necessary, a section-by-section test is preferable here. The off-cut of a representative material sample must be defined (see chapter 10.2.1), for example by installing suitable sample support pipes in the excavation.

9 Rehabilitation procedure

9.1 Construction site sequence planning

EXKLUSIV

The key points for preparing the renovation measure are:

- Obtaining the necessary authorisations
- Pressure hose pre-ordering: This is generally carried out on the basis of the information from the planning. If available, reference pipe sections (e.g. stored pipe breaks) can be used if it is ensured that the reference reflects the condition of the entire pipe.
- Checking the arrangement and size of the planned excavations
- Check that there is sufficient building clearance
- Scheduling the disconnection and emptying of the section to be renovated (see chapter 8.5)
- Once the pipe has been decommissioned, the data supplied from the planning is checked by means of a visual inspection of the pipe to be renovated. All necessary data such as length, geometry, changes in direction, damage pattern and obstacles are recorded.
- Determine the wall thickness to be ordered, see chapter 8.7.
- Final pressure hose order: Old inner tube diameter and variations

The specifications, length of pipe of the existing pipeline to be rehabilitated, statically required wall thickness of the pressure hose and design must be submitted to the manufacturer well in advance of installation so that fabrication can be carried out in good time.
- Ordering other required materials (aids, moulded parts, cuffs, etc.) based on the measured values
- Possible precautions for tempering the materials depending on the expected ambient conditions

If it is determined during the course of the sewer renovation that data deviates from the planning, the client must be informed immediately and the renovation concept adjusted if necessary.

9.2 Preparatory work

9.2.1 Creating the excavations

The excavations must be constructed in accordance with **DIN 4124** and the requirements of the pressure hose liner method. It must be ensured that the excavations are dry and clean and that the excavation invert is at least 0.5 m away from the pipe bedding. The bracing must be designed in such a way that it does not hinder the installation of the liner. The base of the excavation must be provided with a clean layer. A pump sump may be required.

9.2.2 Disconnecting the pipe

The cut-out between the pipe ends must be selected so that there is sufficient free space for the installation of the liner and the selected type of connection. The pipe ends must be designed in such a way that the liner cannot be damaged during installation.

9.2.3 Cleaning and removal of obstacles

After decommissioning, a visual assessment of the pipe condition is carried out to finalise a suitable cleaning procedure. After carrying out the cleaning, the cleaning result must be checked (see chapter 9.2.4) and the cleaning repeated if necessary or further measures taken.

If there are obstacles such as solid deposits or incrustations, grouting compounds, etc., these must be removed using suitable procedures (see chapter 8.2)

9.2.4 Optical inspection

Before installation of the liner, the pipe is visually examined; investigation. This inspection serves to document the degree of cleaning and the final proof that the pipe can be rehabilitated.

9.3 Installation of the pressure hose liner

The requirements for the system technology and execution of installation can be found in Chapters 6.2 and
6.3. The basic outlet of a pressurised hose liner installation is described below. It must be ensured that all components of the rehabilitation technology used during installation, curing and reworking comply with the hygiene requirements for work on drinking water systems.

9.3.1 Impregnation of the liner

The dosing and mixing of the resin components as well as the impregnation of the liner with the resin system is carried out either in the factory or on site (see sections 6.2 and 6.3).

9.3.2 Installation procedure

The cured-in-place pipes can be installed in various ways:

- Inversion (rolling up/process of turning)
- Retraction
- Combination of retraction and inversion

Either water or air is used as the inversion or set-up medium. The liner should inflate completely during the inversion process. Collapse must be avoided. Adhesive systems (class C) must conform completely to the old pipe wall during installation.

9.3.2.1 Inversion

In the inversion method, the liner is rolled in under pressure, taking into account the respective installation conditions and installation instructions.

> **Note:** During the inversion method, the outer side of the liner, which faces the medium after inversion, must be specially protected and kept clean.

9.3.2.2 Retraction

In the retraction method, the compressed air hose is pulled into the pipe using a cable connection and winch and then inflated with compressed air.

9.3.2.3 Combination of retraction and inversion

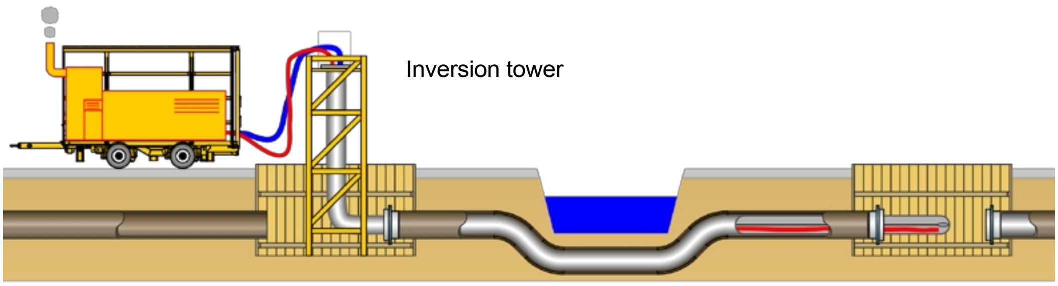
In the combined procedure, a pressure hose is first retracted into the pipe to be rehabilitated and then a second pressure hose is inverted into the retracted hose. The individual work steps are carried out as described above.

9.3.2.4 curing

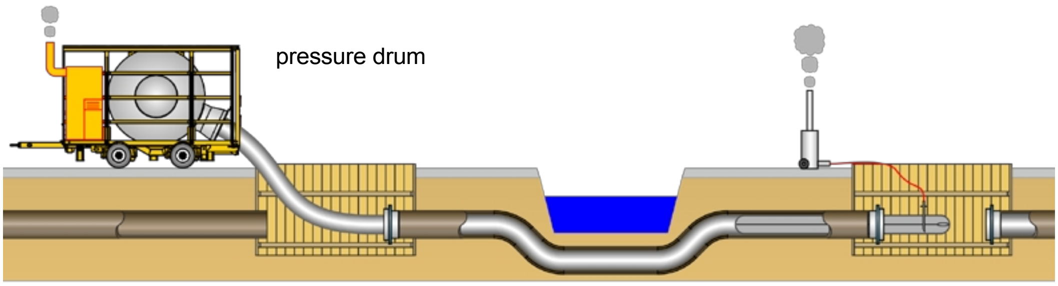
Curing is achieved by

- Heat curing or
- UV light curing or
- Combination curing (UV light curing and heat curing) or
- Curing at ambient temperature (cold curing without energy supply).

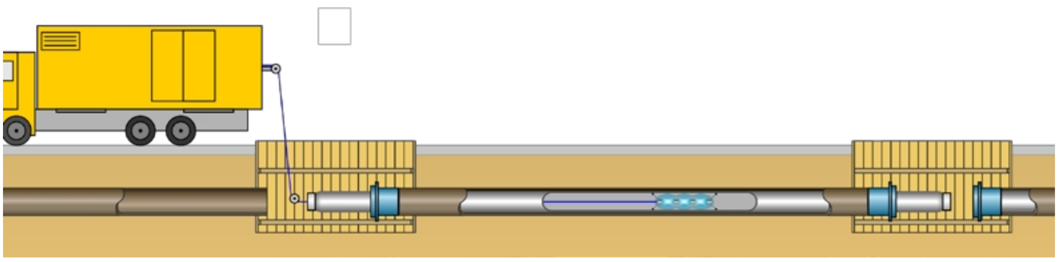
For curing requirements, see chapter 6.2.3.



a) Heat curing with water



b) Heat curing with steam



c) Uv light curing

***Figure 8**: Schematic representation of the hardening process*

9.4 Finalising work

After curing is complete, the liner ends must be cut off and, depending on the connection technology, formed in accordance with chapter 4. When cutting the liner, care must be taken to ensure that no cutting dust gets into the rehabilitated pipe.

Other necessary work must be carried out depending on the project, e.g:

- Making connections; junction; contact according to chapter 5
- Insertion of fitting pieces
- External corrosion protection of the existing pipeline and all other installations
- Production of abutments
- Creation of pipe bedding and excavation of excavation pits
- Restoration of the surfaces
- Dismantling the emergency supply

All cable ends must always be securely closed between work steps and before leaving the site.

10 Quality inspection of the end product

Pipe liner systems based on reaction resin systems that are cured on site only become the end product on site. Material tests on construction site samples are required to check the quality achieved. The recommended requirements for quality testing are discussed in this chapter.

The pipe can only be released if the quality inspection of the end product has been completed and the results fulfil the defined requirements. The contractually agreed tests of the end product must be carried out.

10.1 Visual inspection, Pressure test

The renovated pipe must be visually inspected and documented.

EXKLUSIV

For the pressure testing of class A and B pressure hose liners, the requirements in accordance with DIN EN 805 and DVGW worksheet W 400-2 apply in principle. It must be taken into account that the system consisting of the existing pipeline, pressure hose liner and installations is tested. The table values for the individual materials cannot be used for the pre-test times (see chapter 8.8).

For class C fabric hoses, a leak or pressure test of the renovated pipe is usually carried out in accordance with DVGW GW 327, section 4.7.4, taking into account that the non-renovated pipeline must also withstand the test pressure. The following procedures can be used, for example:

- Leak test in connection; junction; contact or during curing with a minimum duration of 20 minutes. The maximum test pressure for this is curing pressure.
- Testing in accordance with DVGW W 400-2

The test can be carried out before opening the connections; junctions; contacts, provided that the pressure hose liner is not overloaded as a result.

For all liner classes, a visual examination of the pressurised pressure line must be carried out on the exposed pipework parts after connection to the network. Visual, leak and pressure tests must be recorded.

10.2 Material testing

A material sample must be taken from the installed pressure hose liner on site and submitted to an accredited laboratory for further examination; investigation.

10.2.1 Class A and B pressurised hose liners

A representative sample must be taken. Accordingly, it must be ensured that the liner in the sampling area has the same expansion ratios and installation and hardening conditions as in the pipe to be renovated.

Preferably a complete ring of at least 400 mm width should be removed. When off-cutting a ring section, it must have a length of at least 350 mm and a width in the circumferential direction of at least 20 times the wall thickness.

The material characteristics are checked in accordance with the provisions in chapter 13 At least the following checks must be carried out:

- Verification of material properties by flexural test or apex pressure test
- Proof of curing by determining the glass transition temperatur and, if necessary, enthalpies by using differential scanning calorimetry (DSC analysis) and/or dynamic mechanical analysis (DMA).
- Detection of residual monomer content for UP and vinyl ester rein resins (e.g. styrene, for acrylates according to existing classification)
- depending on the system, proof of the watertightness; waterproof of the laminate (leak test of the material sample for non-permanent inner liners)

The test results must be compared with the information from the respective suitability test and drinking water approval (see chapter 7.4.3).

Note: The off-cut of a representative sample for the rehabilitated pipe must be prepared prior to the installation of the pressure hose liner, for example using suitable sample support pipes. It is not usually possible to take a sample directly from the rehabilitated pipe in the case of pressure pipes.

10.2.2 Class C pressure hose liner

An essential process control for the installation of class C pressure hose liners (hose lining with bonding on the back) is the testing of the required bonding in the peel test in accordance with DVGW GW 327 or DIN 30658-1. For this purpose, a test piece must be taken after curing, usually from the end of a lining section. The required length of the test piece should be at least 500 mm.

If it is not possible to take a sample directly from the renovated pipe, a support pipe must be installed in advance on the pipe to be renovated, which is also renovated and later serves as a sample. The material and surface preparation of the support pipe must correspond to the pipe to be renovated.

Direct curing control is not currently regulated for class C pressure hose liners. Proof of curing can be provided by determining the glass transition temperature. This is determined using differential scanning calorimetry (DDK or DSC analysis) for epoxy resins or using dynamic mechanical analysis (DMA) for UP and vinyl ester rein resins.

10.3 Hygiene testing and approval

In connection; junction; contact with the neutralisation or rinsing out of the disinfectant (see chapter 7.5), a test run of the entire rehabilitated pipe with drinking/potable water is carried out. At this point, water samples must be taken for hygiene testing in accordance with DVGW manhole (shaft/chamber) 291.

In accordance with the hygiene regulations, the locations and intervals at which samples are taken for microbiological examination; investigation must be specified. Off-cut sampling is recommodated at least at the feed from the network for filling the pipe (reference) and at the end of the rehabilitated pipeline section. The examination; investigation of the samples is carried out by an accredited laboratory. The limit values of the Drinking Water Ordinance apply as well as any conditions defined by the operator in the tender.

With proof of hygienic safety, the rehabilitated sewers should be connected to the water supply network as soon as possible in order to minimise the risk of contamination due to retention time. If the test results exceed the required limit values, a new disinfection (see section 7.5) must be carried out and the off-cut sampling repeated until microbiological safety is achieved. Only then can the rehabilitated pipe be put into operation.

The pipe is always approved by the operator on the basis of the conditions specified in the tender.

11 Operation of the renovated pipe

The pressure hose liner must be designed for the operating conditions (see chapter 8). Provided this is the case, the renovated pipe can be operated as usual.

For long-term, damage-free operation, it is important that the assumptions made in the design are compared with the actual operating conditions or that the latter are adjusted in such a way that overloading of the rehabilitated pipe is prevented. This applies in particular to pump operation. Here, the maximum pressures and the number of load cycles are estimated during planning. If the actual operating conditions deviate significantly from the assumptions made, e.g. due to changes in pump operation, it may be necessary to review the structural design or adjust the expected technical useful life (see chapter 12).

In order to be able to implement all operating instructions in practice, good documentation of the stock and appropriate labelling in the register is essential. At least the following points should be visible in the cadastre:

- Labelling of the pressure hose liner, position in the pipe run
- Type of joints between the pressure hose liner and the existing structure
- exact location of the LEM, if available
- If necessary, operational instructions for cleaning (max. pressure, pigging only, etc.)

In addition to the as-built plans, the documentation should also contain documents showing the operating pressures and pump clearances for which the liner is designed (liner structural analysis).

11.1 Cleaning the refurbished pipe

In general, cleaning with soft pigs or air-water flushing is sufficient for cleaning the renovated pipe, as the pressure hose liner has a very low roughness and little incrustation occurs.

The pressure hose liner is designed to withstand high levels of abrasion (high flow velocities across the entire cross-section). However, its resistance to high pressure jetting is low, as this is rarely used in pressurised pipes (see chapter 6.4).

EXKLUSIV

If high pressure jetting is required in individual cases, the pressure should be set as low as possible. The nozzle must be pulled continuously through the pipe; static flushing must be avoided. The use of scrapers and brushes is not permitted. Personnel must be familiarised with the cleaning of pressure hose liners.

11.2 Use of robotic and camera systems

When using robot and camera systems for visual inspection after sewer renovation, for subsequent connections of connecting pipes or for repairs, care must be taken to ensure that the devices used do not introduce any contamination/germs (see chapter 7.3) or cause any damage to the cured-in-place pipes.

The vehicles must be equipped with drive wheels that do not damage the liner surface. The use of sharp or very rough wheel surfaces (e.g. granulate coatings) to improve the friction of the wheels is not permitted.

11.3 Repair work

EXKLUSIV

If a localised repair is required for a rehabilitated pipeline, this is carried out using the sealing and connection technologies from Chapter 4 (***Fig. 3*** and ***Fig. 5***) and Chapter 5. The joints required for this should be provided accordingly.

For this work, the renovated existing pipeline is cut in front of and behind the repair point using a cutting tool and rejoined with a fitting piece. Suitable cutting tools include pipe cutters, cut-off grinders and window cutters. Care must be taken to ensure that the liner is not pushed away from the existing pipeline during cutting. By using a cutting depth limiter, the liner in the existing pipeline can be cut back or exposed without causing damage. Cutting torches must not be used.

It should be noted that non-glued liners must always be sealed - either with the help of a liner end sleeve or an edge seal.

The mechanical couplings, flanges and collars used must be tested and approved for the area of application. They must be designed for the corresponding pressure rating of the pressure hose liner or the existing pipeline pressure hose liner system.

> **Note:** The use of grp hand laminates and repair clamps is technically possible for localised repairs to class A liners. Here too, suitability for drinking water hygiene must always be ensured. The use of repair clamps must be approved by the system manufacturer of the liner.

12 Notes on economic efficiency and useful life

For pressure hose liners in the drinking water sector, experience of at least 10 years for glass fibre liners, 15 years for glass fibre-reinforced needled felt liners and over 20 years for fabric hoses is available at the time of publication of this information sheet. The materials used have also been in use in hose lining technology for decades - their chemical and mechanical characteristics are well known.

Pressure hose liners can be expected to have a technical useful life of 50 years, provided that the requirements formulated here for materials, technology, execution of installation and quality monitoring are met.

EXKLUSIV

However, pressure hose liners are subject to special operating conditions that must be taken into account when designing the systems (e.g. number of switching cycles of the poly(ethylene naphthate), pressure changes), as well as the condition or fatigue strength of the existing pipeline (especially for class B and C). Due to the complexity of the pressure cured-in-place pipes/existing pipe soil system and the special operating conditions, sewer rehabilitation of pressure pipes should be considered and evaluated on a case-by-case basis. The useful life of the renovated pipe can therefore be conservatively determined to be less than 50 years.

A pressure hose liner is a depreciable economic asset, as it is a sewer rehabilitation and not a repair. The basis for the respective depreciation period can be the above-mentioned aspects of the expected technical useful life. It is also possible to link the depreciation period to other assets, e.g. the remaining depreciation of the associated pumping station.

The regulations on the amortisation of sewer rehabilitation can vary greatly depending on the operator.

> **Note:** When timbering the hardened liner, e.g. when the pipe is abandoned or at the end of its service life, it can be thermally recycled. Information on this can be found in the manufacturer's safety data sheets.

13 Conforming systems

13.1 Differential Scanning Calorimetry (DSC)

Differential scanning calorimetry (DSC) is used for the examination; investigation of thermal effects. The glass transition temperature $_{Tg}$ and the residual exotherm ΔH of reactive plastics (thermosetting resin systems) can be determined via the curve of the determined heat flow Q against temperature. These can be directly correlated with the degree of hardness and are therefore used for quality control.

The test is carried out in accordance with DIN EN ISO 11357-2:2014-07 on test specimens taken from the outside of the liner, with masses ranging from 2 to 40 mg, a sampling rate of 20 K/min and under a continuous flow of nitrogen as purge gas. The sample is measured in two consecutive heating cycles.

The DSC test is particularly suitable for determining the degree of hardness.

13.2 Dynamic mechanical analysis (DMA)

The dynamic mechanical analysis (DMA) is used for the examination; investigation of thermo-mechanical characteristics. The curves of the temperature-dependent, oscillating contamination and the resulting response signal provide information about the visco-elastic properties (storage modulus E', loss modulus E'' and loss factor tanδ). These $_{allow}$ conclusions to be drawn about the glass transition temperatur $_{Tg}$.

The measurement is performed in three-point bending mode in accordance with DIN EN ISO 6721-5:1996-05 on rectangular specimens with a length-to-thickness ratio $_{La/d}$ > 16. The temperature rate is usually 2 K/min to ensure complete heating of the specimen. Other measurement parameters such as the oscillation frequency or load amplitude must also be defined for comparison purposes.

The DMA analysis is particularly suitable for determining the degree of hardness and the thermo-mechanical behaviour.

13.3 Electrical impedance spectroscopy (EIS)

Electrical impedance spectroscopy (EIS), also known as dielectric analysis, is a physical measurement method and is used for insitu hardness monitoring. The sensor placed on the outside of the liner is in direct contact with the resin and determines the ion mobility and polarisability of the molecules. These decrease due to progressive polymerisation or cross-linking and can be used as a measure of curing when compared with a reference master curve. It is also possible to determine glass transition temperaturs ($_{Tg}$ kinks) as indicators.

13.4 Three-point flexural test

In the flexural test, the mechanical parameters youngs modulus and flexural stress are determined in accordance with DIN EN ISO 178:2019-08. For the test, specimens representative of the pipe section are taken in the circumferential direction in accordance with DIN EN ISO 11296-4:2018-09 after the remedial action on site. A specimen must have a length of > 350 mm and a width in the circumferential direction of > 20 times the wall thickness in order to be able to take a sufficient number of standard-compliant specimens. The test also includes the determination of the total and composite wall thickness.

13.5 Apex pressure test

The apex pressure test is carried out in accordance with ISO 7685:2019 or DIN EN 1228:1996-08 and describes a procedure for determining the specific initial ring stiffness. A representative, complete pipe section with a length of > 300 mm is used as a test piece. The composite wall thickness is determined in accordance with DIN EN ISO 11296- 4:2018-09. The outer pure resin layer must not exceed 10 % of the composite thickness. In the case of thicker outer pure resin layers, it must be checked whether the sample is representative of the pipe.

13.6 24h- creep tendency

The 24-hour creep tendency test is carried out in accordance with DIN EN ISO 899-2:2015-06 on three-point bending specimens (see section 13.4) or on pipe sections in accordance with DIN EN 761:1994-08 (see section 13.5).

The load force is selected so that the deflection is in the linear-elastic range, i.e. the force to be applied should correspond to > 20 % of the quantile value of the flexural stress determined during the suitability test. To calculate the 24-hour creep bending, the modulus of elasticity after 3 minutes (on the pipe section) or 1 hour (on the three-point bending test specimen) is set in relation to the 24-hour modulus of elasticity at constant load.

As thermosetting resin systems are subject to post-crosslinking, creep tests should only be carried out after post-crosslinking has been completed. The tests can usually be carried out four weeks after installation. Detailed information can be found in the suitability certificate.

13.7 Residual monomer content

The residual monomer content allows a statement to be made about the curing of reactive resin moulding materials. The residual styrene content is determined by gas chromatography according to ISO 4901:2011-08; the acrylate monomer content can be determined according to

to these standards. Classification of the monomer used by the liner manufacturer is essential.
The time from off-cut to testing is critical and should be accurately documented. Refrigerated and sealed light and airtight storage is required. This avoids the possibility of post-crosslinking and influencing the result.

13.8 Spectral analysis

Spectral analysis is used to check whether the resin quality used corresponds to the resin quality offered. The method, which is based on ASTM D5576:2000, determines the qualitative composition of the reaction resin systems in comparison with the spectra stored in the suitability test.

13.9 Glass and filler content

The test is carried out in accordance with DIN EN ISO 1172:1998 using the calcination method. The verification of the ratio of organic matrix material to mineral filler and/or glass fibre content serves to prove that the composition of the end product corresponds to the manufacturer's specifications.

13.10 Leak test of the material sample

The leak test of the laminate is not compatible with the pressure test according to chapter 10.1 Comparable.

The test determines the impermeability of a test solution on a representative test piece at three test points under negative pressure. The test piece is only assessed as leak-proof if all three test points show no leaks.

13.11 Documentation of the results of the material test

The results of the material test must be stated in accordance with ***Table 7.*** The testing institute shall only provide assessments of the results where a clear request to this effect has been made.

***Table 7**: Presentation of the results of the material test*

Examination	Standard	Value	Unit	Result indication
Three-point bending	DIN EN 178; DIN EN 11296-4	Composite thickness $_{em}$	mm	1 decimal place
		Youngs modulus $_{Ef}$	N/mm^2	3 significant digits
		Flexural stress at first break $_{ofb}$	N/mm^2	3 significant digits
apex pressure test	ISO 7685; DIN EN 1228	Composite thickness em	mm	1 decimal place
		Ring stiffness S_0	N/m^2	integer
		Perimeter E-module	N/mm^2	3 significant digits
24 hCreep	DIN EN ISO 899-2; DIN EN 761	Composite thickness $_{em}$	mm	1 decimal place
		E-modulus $_{E1h}$	N/mm^2	3 significant digits
		E-modulus $_{E24h}$	N/mm^2	3 significant digits
		Creep tendency Kn_{24}	%	1 decimal place
Residual monomer content	ISO 4901	Sample weighing	g	3 decimal places
		Residual monomer content	%	1 decimal place
DSCAnalysis	ISO 11357	Glass transition temperature (TG$_1$,TG)$_2$	°C	1 decimal place
Dynamic mechanical analysis	ISO 6721	Complex modulus of elasticity E*	N/mm^2	3 significant digits
spectral analysis	i.A.a ASTM 5576; DIN 55673; DIN EN 1767	resin type	-	-
Determination of the filler and glass content	DIN EN ISO 1172	Resin content	%	1 decimal place
		Filler content	%	1 decimal place
		Glass content	%	1 decimal place
leak test	-	Tightness	Yes/no	-

13.12 Hygiene overview plan for the rehabilitation procedure

The requirements for the hygiene measures depend on the work step in the rehabilitation procedure, as work immediately before commissioning the pipe places higher hygiene demands than, for example, cleaning the pipe before sewer renovation. The requirements of DVGW W 291 apply. All tools, equipment and work clothing that come into contact with the drinking water systems after the sewer renovation or before the system is recommissioned in the meantime may only be used in drinking water systems (see chapter 7.3).

Table 8: Hygiene during the rehabilitation procedure

Work step		Hygiene measures
Optical inspection	**before interim recommissioning**	• Clean and disinfect all components • Protect equipment from contamination • Close pipe ends immediately after inspection
	before cleaning and sewer renovation	• No additional requirements
	after sewer renovation	• Clean and disinfect all components • Protect equipment from contamination • Close pipe ends immediately after inspection
Cleaning the pipe and removing obstructions	**before interim recommissioning**	• Clean and disinfect all components • Protect equipment from contamination • Only use water, drinking/potable water with HD or HDD • Do not leave water in the pipe • Close pipe ends immediately after cleaning
	before sewer renovation	• No additional requirements
	after sewer renovation	• Clean and disinfect all components • Protect equipment from contamination • Only use drinking water pigs • Only use water, drinking/potable water for flushing • Do not leave water in the pipe • Close pipe ends immediately after cleaning
Installation of the pressure hose liner		• Check all components for contamination • Store materials safely • No avoidable contact with surfaces facing the medium • Protect the inside of the liner from soiling • Remove possible contamination immediately • Seal pipe ends immediately after sewer renovation
Finalising work		• Protect the pipeline from contamination (e.g. cutting dust) • Store units (e.g. LEM) in a protected place • Only use clean units • No avoidable contact with the inside of units • Close the pipe ends immediately after completing the work

13.13 Additional instructions for carrying out High-pressure water cleaning

High-pressure water cleaning is carried out exclusively to prepare the existing pipeline prior to sewer renovation.
It is generally only used for metallic pipelines, as plastics (e.g. PVC, polyethylene) can be damaged when cleaning with pressures of > 250 bar. The following strong water pressures are used:

- < 800 bar Only for rough cleaning and removal of loose deposits (high pressure jetting or cleaning technology is often used here)
- > 800 - 1,200 bar Removal of grease, tar, bitumen, solid incrustations
- > 1,200 - 1,600 bar Removal of grease, tar, bitumen, solid incrustations, subsequently applied ZM lining
- > 1,600 - 2,500 bar additionally removal of factory-applied ZM lining

In addition to the strong water pressure at the pump, the available water delivery rate per minute, the length and dimensions of the cleaning hose used and the nozzle technology are important for successful cleaning. The recommended water delivery rate at the pump is at least 40 litres/minute in the above-mentioned pump pressure ranges. Depending on the system, the cleaning hose length is currently up to 500 m DN 12 (up to 1,800 bar) in one piece, extendable if necessary. As a rule, rotary nozzles are used with a nozzle distance to the pipe wall of approx. 2 to 6 cm (depending on the pipe dimensions).

Example: Pump pressure: approx. 1,500 bar at 40 litres/minute Cleaning hose length: 200 m
Pressure at the cleaning nozzle: approx. 1,300 - 1,350 bar (due to the drop in flow pressure over the hose length)

Cleaning lengths of up to approx. 100 m in the dimension range up to approx. DN 300 can generally be realised without a winch. From > DN 300, a winch is often used.

In principle, the dimension range from DN 80 - DN 1200 (possibly also up to DN 2500) can be cleaned using high-pressure or ultra-high-pressure water. From > DN 1200, however, it may be advisable to inspect the pipeline.

For pipes with a gradient of more than 10 %, a reduced feed speed must be expected if an auxiliary cable winch cannot be used. This must be taken into account in particular for pipes larger than DN 300.

14 Laws, standards and rules and regulations

14.1 Standards

DIN 1259 Glass

DIN 16946 Reactive resin moulding materials; cast resin moulding materials

DIN 18200 Proof of conformity for construction products - Factory production control, external surveillance and certification

DIN 18326 VOB Part C: General Technical Conditions of Contract for Construction Work (ATV), Renovation work on drainage sewers

DIN 18820 Laminates made of textile glass-reinforced unsaturated polyester andphenacrylate resins for load-bearing units (GF-UP, GF-PHA)

DIN 19523Requirements and test methods for determination of high-pressure jet resistance and flushing resistance of pipework components for drains and sewers.

DIN 30658 Means for sealing underground gas pipes at a later date Part 1: Foil hoses and fabric hoses for sealing gas pipes; safety requirements and tests

DIN 50100 Fatigue strength test - Performance and evaluation of cyclic tests with constant load amplitude for metallic material specimens and units

DIN CEN/TR 15729 Plastics piping systems - Glass fibre reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) - Report on the determination of mean abrasion after a specified number of passes

DIN EN 805 Water supply - Requirements for water supply systems and their units outside buildings

DIN EN 1092 Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories, PN designated Part 1: Steel flanges

DIN EN 10204 Metallic products - Types of inspection certificates DIN

EN 13121 Above-ground grp tanks and containers

DIN EN 14020 Reinforcing fibres - Specification for textile glass rovings Parts 1-3: Designation; Test methods and general requirements; Special requirements

DIN EN 15885 Classification and characteristics of techniques for the rehabilitation and repair of sewer pipes and sewers

DIN EN ISO 2078 Textile glass - Yarns - Designation

DIN EN ISO 11295 Classification and information for the planning and application of plastics piping systems for sewer rehabilitation and renewal

DIN EN ISO 11296 Plastics piping systems for the sewer rehabilitation of underground non-pressure drainage systems (non-pressure drainages) Part 1: General

	Part 4: Cured-in-place pipe lining
DIN EN ISO 11297	Plastics piping systems for the sewer rehabilitation of underground pressurised wastewater pipes Part 4: Cured-in-place pipe lining
DIN EN ISO 11298	Plastics piping systems for the sewer rehabilitation of underground water supply systems Part 4: Cured-in-place pipe lining
ISO 15306	Plastics piping systems- Pipes made of glass-reinforced thermosetting plastics - Determination of resistance to cyclic internal pressure

14.2 DVGW- Rules and regulations

DVGW GW 327	Lining of gas and water pipelines with fabric hoses to be glued in (worksheet)
DVGW GW	302Trenchless construction methods Part 1: Companies for the rehabilitation and new laying of pipelines - Requirements and tests Part 2: Rehabilitation of pipelines - Process engineering
DVGW W 330	Fabric hoses to be bonded for water pipes (test basis)
DVGW W 400	Technical rules for water distribution systems (worksheet)Part 2: Construction and testing
DVGW MANHOLE (SHAFT/CHAMBER) W 491	Qualification criteria for companies for the inspection and maintenance of water distribution systems

14.3 DWA- Rules and regulations

ATV-DVWK-A 127	Static calculation of sewer pipes and sewers DWA-A 143 Sewer renovation of drainage systems outside buildings Part 2: Static calculation for sewer renovation with lining and assembly methods Part 3: Curing on site cured-in-place pipes
DWA-M	144Additional technical contract conditions (ZTV) for the rehabilitation of drainage systems outside buildings Part 3: Sewer rehabilitation using the tube lining method (in-situ curing tube lining) for sewer pipes
DWA-M	149Condition assessment and evaluation of drainage systems outside buildings Part 5: Optical inspection

14.4 RSV- Rules and regulations

RSV M 1.1	Sewer rehabilitation of drainage sewers and pipes with cured-in-place pipe lining
RSV M 1.2	Sewer rehabilitation of pressurised wastewater pipes with pressure hose liners

14.5 GSTT- Rules and regulations

GSTT 20.2	Static calculation of pressure hose liners (n.a.)

15 Safety regulations

The existing laws regarding occupational safety, environmental protection and waste utilisation and disposal must be complied with. Essential safety regulations are listed below; this list is not exhaustive.

15.1 Accident prevention regulations

BGV A	1Principles of prevention

15.2 Employer's liability insurance association Rules

DGUV 103-003	Working in enclosed spaces of wastewater treatment plants
DGUV	112-190Use of respiratory protective devices
DGUV	112-198Use of personal protective equipment against falls from a height

15.3 Information from the employers' liability insurance association

DGUV 201-052	Pipeline construction work
DGUV 203-004	Use of electrical equipment with increased electricalhazard

15.4 Laws, ordinances, regulations on environmental protection

BBodSchG	Law on the protection of harmful soil changes and the sewer renovation of contaminated sites (Federal Soil Protection Act)
KrWG	Law on the Promotion of the Circular Economy and Ensuring the Environmentally Sound Management of Waste (Closed Substance Cycle Waste Management Act)
KTW-BWGL	Assessment basis for plastics and other organic materials in contact with water, drinking/potable water
GefStoffV	Ordinance on Protection against Hazardous Substances (Hazardous Substances Ordinance)
GGBefG	Law on the Transport of Dangerous Goods (Gefahrgutbeförderungsgesetz)
TA-Waste	Technical instructions for storage, chemical/physical, biological treatment, incineration and landfilling, General Administrative Regulation on the Waste Act
TRGS	519Technical rule for hazardous substances
Drinking Water Ordinance	Drinking Water Ordinance
WHG	Law on the organisation of the water balance (Water Resources Act)

16 List of abbreviations

ATV-DVWKAbwassertechnische Vereinigung e.V. - Englisch Association for Water Management and Cultural Engineering (renamed DWA in 2004)
CEN/TR Comité Européen de Normalisation/Technical Report (European Committee for Standardisation/Technical Rule)
DEA Dielectric analysis
DDK Differential scanning calorimetry (DSC)
DIN Englisch Institute for Standardisation (designation for a German standard) DIN EN Designation for a European standard
DIN EN ISO Designation for an ISO standard adopted as a European standard
DMA Dynamic Mechanical Analysis
DN Nominal diameter
DVGWDeutscher Verein des Gas- und Wasserfaches e.V. (German Technical and Scientific Association for Gas and Water)
DWADeutsche Vereinigung für Wasserwirtschaft, Wasser und Abfall e.V. E-CR Electric Corrosion Resistant (corrosion-resistant E-glass)
EPOXY RESIN Epoxy
GRPGlass fibre reinforced plastic
ISO International Organization for Standardisation
LEM Liner end sleeve
n.a. not published
OF Olefin
POLYETHYLENE Polyethylene
POLY(ETHYLENE TEREPHTHALATE) Polyethylene terephthalate
PN Nominal pressure
PP Polypropylene
PSAPersonal protective equipment
PU Polyurethane
TPU Thermoplastic polyurethane
UPUnsaturated polyester
UV Ultraviolet radiation
VINYL ESTER REIN vinyl ester
VOB/CVerdingungsordnung Bau, Part C

Formula symbol

as External diameter
di Internal diameter
e Wall thickness
ec composite thickness
etot Total wall thickness

17 List of illustrations

18 list of tables

19 Authors

The RSV working group 1.3 "Sewer rehabilitation of drinking water pipes with pressure hose liners" has the following members:

Chairwoman:

Leddig-Bahls, Susanne, Dr.	IQS Engineering AG

Employees:

Böhmig, Kathleen	Mauerspecht GmbH
Böhne, Wendelin	BKP Berolina
Burcek, Kai	MC-Bauchemie Müller GmbH & Co. KG
Grasnick, Gerd. Dr	Karl Weiss Technologies GmbH
Haacker, Andreas	Siebert + Knipschild GmbH
Herlitzius, Alexander	PSM Rohrsanierung GmbH
Hochstaffl, Robert	Reline Aptec GmbH
Hommel, Steffen	IRS mbH Sachsen
Kopietz, Mark, Dr.	SBKS GmbH & Co. KG
Meßmann, Sven	MC-Bauchemie Müller GmbH & Co KG
Münstermann, Timo	Saertex multiCom GmbH
Quernheim, Lars	Berolina
Sebastian, Jörg, Prof.	SBKS GmbH & Co.
Wahr, Jens	Diringer & Scheidel Rohrsanierung GmbH
Wittwer, Anika	IRS mbH Sachsen
Zinnecker, Jürgen	Aarsleff Rohrsanierung GmbH

Guests:

Bunn, Hannes	Hamburg Wasser
Dr Koch, Andreas	Hygiene Institute of the Ruhr Area
Möbs, Johannes	Hessenwasser GmbH & Co. KG Institute of
Pleschka, Damian	Hygiene of the Ruhr
Area Riechelmann, Janine	Hygiene Institute of the Ruhr Hamburg
Area Steinberg, Anne	Water
von Bernstorff, Daniel	SYSCribe GmbH

Please feel free to contact us if you have any questions! We look forward to hearing from you.

RSV e. V. - Office
Phone: +49 40 21074167
info@rsv-ev.de
www.rsv-ev.de