RSV factsheet 1.1

Sewer renovation with cured-in-place pipe lining

(November 2021)

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Preface

Cured-in-place piöe lining methods have successfully established themselves in the pipeline rehabilitation market over the past 50 years. Their flexibility and procedural diversity have made them the most successful and most frequently used trenchless rehabilitation method. The procedures have a wide range of applications in the field of sewer rehabilitation. The technology is already comprehensively defined in standards and regulations.

The existing worksheet is intended to provide supplements and comments to the existing rules and regulations. The normative basis is presented, requirements for materials, techniques and procedures are defined and the basics of planning, tendering, installation and testing are described. Emphasis is also placed on the rehabilitation system, consisting of the cured-in-place pipes and their connections in the manhole section or directly in the pipeline and the reconnection of connecting pipes.

Everyone is free to apply this factsheet. However, an obligation to apply it may arise from legal or administrative regulations, contracts or other legal grounds. We would be pleased if you could tell us about your experiences with the application of this factsheet.

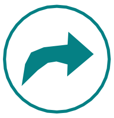
Hamburg,
November 2021

RSV - Rohrleitungssanierungsverband

The English language service is under construction. For more details see www.no-dig-germany.com .

Guide for special labels

In this factsheet, we refer to special contents at various points. These are graphically marked with symbols.

Symbol	Meaning
	**Information on the internet** You can find further information on the Internet at www.rsv-ev.de or on a corresponding website. In the PDF, the symbol is deposited with the link.
	**General content** This information is not specific to this factsheet, but also applies to other sewer renovation topics.
	**Need für regulation** The content published here points to regulatory gaps that should be addressed in future rulemaking.
	**Comment** These are comments on existing regulations. These may contain statements that deviate from them.
	**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 an RSV recommendation that deserves special attention from users.
	**Quote** At this point we quote or refer to other factsheets. Consultation is recommended for further questions.

1 Range of application

This factsheet applies to the renovation of predominantly underground, non-pressurised sewer pipes and pipelines in the public and non-public sector and specifies the requirements for plastic pipe systems that are manufactured from pipes curing on site using the CIPP method. For the area of connecting pipes, reference is made to the following factsheets in the respective current version:

- **RSV M 7.1** "Sewer renovation of underground connecting pipes and property drainage systems".
- **RSV M 7.2** "Top-hat profile technology for the integration of connecting pipes - repair / sewer rehabilitation"
- **RSV M 7.3** "Sewer renovation of gravity drainage systems inside buildings with reaction resin-based systems curing on site".
- **RSV M 5** "Repair of drainage pipes and sewers by means of robots".

The RSV factsheet 1.1 is based on DIN EN ISO 11296-4 "Plastic pipe systems for the sewer rehabilitation of buried non-pressure drainage networks (non-pressure drainages), Part 4: "Cured-in-place pipe lining". In the following diagram (***Figure 1***) according to DIN EN ISO 11296-1 (Part 1: General), the techniques contained in this factsheet are listed under the term sewer rehabilitation and the procedure group "curing on site pipe lining".

Cured-in-place pipe lining is, in the sense of the building regulations according to
The Prototype Building Regulation (MBO) for the States (Länder) of the Federal Republic of Germany is based on the regulations of § 16a of the Prototype Building Regulation (MBO) for a type of construction for whose application, particularly in the private sector, the granting of general technical approvals or approval in individual cases by the competent building supervisory authority is provided. The Model Administrative Regulation on Technical Building Regulations (MVV TB) is based on the regulations of the building codes; pipe lining is assigned to Part C.

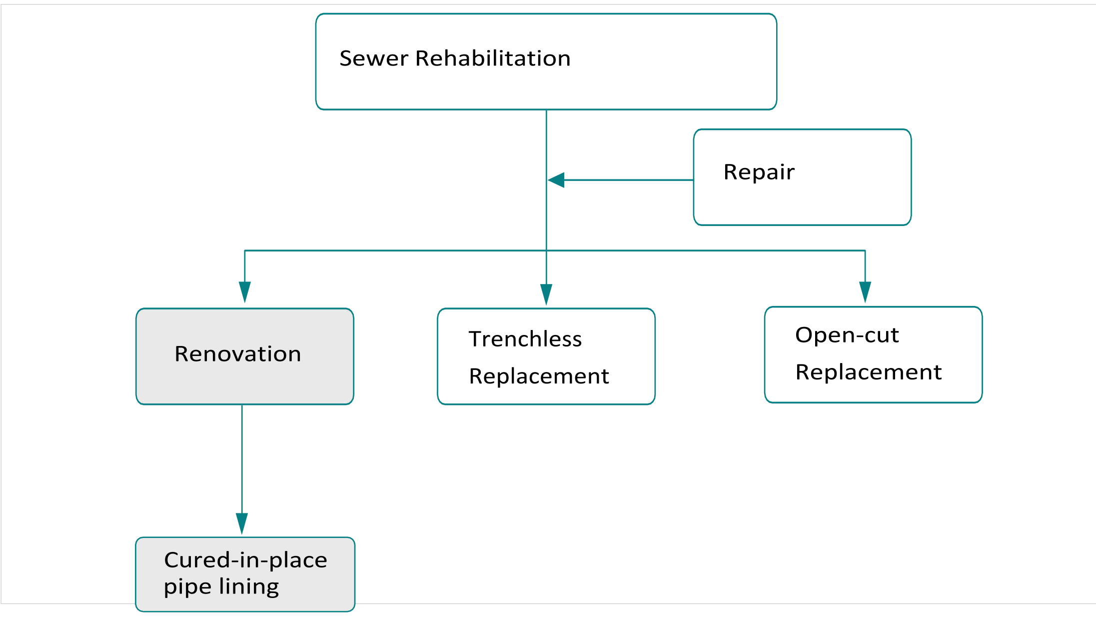


Figure 1*: Technology families based on DIN EN ISO 11295*

The use of procedures approved by the Deutsches Institut für Bautechnik (DIBt) is also recommended in the public sector.

If no national technical approval / general construction technique permit (abZ / aB; DIBt approval) is available, the corresponding individual verifications according to chapter 5.4 must be provided.

All existing pipe materials can be rehabilitated by means of cured-in-place pipe lining.
The sewer renovation of pipes made of asbestos cement requires special handling. More detailed information on the legal background can be found, among other things, in the RSV statement "Renovation of AZ pipes with cured-in-place pipes".

2 Definitions

The definitions of terms according to DIN EN 752, DIN EN ISO 11296-4 and DIN EN 15885 apply:

drain
Mostly underground pipe for discharge of wastewater and/or surface water from the point of origin to the sewer pipe;
In this factsheet, the industry-standard term connection; junction; contact is used.

sewer pipe
Mostly underground pipeline or other device for discharging wastewater and/or surface water from several sources.

foil
The following definitions apply based on DIN EN ISO 11296-4 (in DWA-A 143-3 extruded foils are referred to as coatings):

- **Permanent membrane:** Inner or outer liner designed to remain intact during insertion of the hose and curing of the resin system and to maintain its functions for the operational life of the hose liner.
- **Semi-permanent membrane:** Inner or outer liner designed to remain intact during insertion of the hose and curing of the resin system, but not expected to remain intact for the operational life of the hose liner.
- **Temporary membrane: inner liner** that only performs functions during installation and is removed during or after installation.

pipe section
Section of a sewer pipe between two manholes and / or special constructions

curing	The process of resin polymerisation that is triggered by heat or light or can be 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 substrate and / or reinforcement material
composite	combined of cured resin system, substrate and / or reinforcement, exclusively inner and / or outer foils (cf. laminate).
laminate	Cured composite made of carrier and/or reinforcement material and reactive resin; the wall structure of the cured-in-place pipes corresponds to the composite according to DIN EN ISO 11296-4.
light chain	Light sources in which several lamps (usually 8 to 12) are arranged in a row one behind the other. Application range usually DN 100 to DN 1200
light core	Light source in which several lamps (usually 4 to 6) are arranged radially around a centre. Several light cores can be arranged one behind the other (double core, triple core). Range of application usually from DN 600 to DN 2000.
useful life	The useful life is the period during which the rehabilitated sewers can be used for operational purposes. Residual useful life: Operational suitability that exceeds the estimated technical useful life.
preliner	Outer liner installed between the resin-impregnated hose and the existing pipeline; according to DIN EN ISO 11296-4: permanent or semi-permanent outer liner installed separately before insertion of the hose.
manhole	Structures with a removable cover fitted in a drain or sewer pipe to allow people to enter.
hose	Flexible hose made of carrier and/or reinforcement material, including all foils, impregnated with a reactive resin system (analogous to DWA-A 143-3; referred to as liner in DIN EN ISO 11296-4).
pipe lining	Fully installed and hardened hose; a sleeveless pipe, which is positive-locking to the existing sewer and can be connected to it (analogous to DWA-A 143-3; in DIN EN ISO 11296-4)
connection technology	**Form closure:** connection via the geometry of at least two units (e.g. liner in the pipe; in the horizontal direction, the form closure is established via sockets, contacts, position deviations, etc.). **Frictional locking:** Joints via the frictional forces of at least two units (e.g. cuff with compression seal in the pipe). **Material closure: joint between** two units via atomic or molecular forces (bonding, welding, soldering, vulcanising).

wear layer	Inner layer of the cured-in-place pipes, which is intended to compensate for the expected wear over the useful life as additional safety. The wear layer is to be defined by the system manufacturer and proven by means of appropriate suitability tests.
cured-in-place pipe lining	Lining with a flexible hose impregnated with a reactive resin. After curing, a pipe is formed. Based on DIN EN ISO 11296-1 / -4:2018-09
wall thickness	**Nominal wall thickness e_n:** Wall thickness of the cured-in-place pipes in the uncured state corresponding to the manufacturing dimension. **Design wall thickness:** required wall thickness of the composite, which is determined by static calculation, excluding any wear layer (corresponds to the composite thickness e_m according to DWA-A 143-3 or liner wall thickness t_L according to DWA-A 143-2). **Composite thickness (e_c):** Wall thickness of the combination of cured resin system, backing and/or reinforcement material, excluding all foils. **Total wall thickness (e_{tot}):** Thickness of the cured-in-place pipes consisting of the composite and all semi-permanent and / or per- manent foils. **Composite thickness (e_m):** The composite thickness results from the total wall thickness by subtracting the thicknesses of the inner liner, outer film, pure resin layers, wear layer and reinforcements as installation aids. (analogous to DWA-A 143-3; composite thickness is no longer used according to DIN EN ISO 11296-4 and corresponds to the new terminology of design wall thickness).

3 Pipe lining

Cured-in-place pipe lining is defined in various rules and regulations:

- of DIN EN ISO 11295 (DIN EN 15885),
- of DIN EN ISO 11296-4,
- in DWA Worksheets 143 Parts 1, 2, 3 and 21 as well as
- in DWA factsheet 144 Part 3.

DWA factsheet 144-3 presents additional technical contract conditions and divides the tube lining methods into material groups according to modulus of elasticity (E-modulus) and flexural strength. DWA Code of Practice 143-3 describes, among other things, the procedures for quality assurance on material samples. DWA Code of Practice 143-2 explains the static calculation of pipe lining systems.
The RSV factsheet 1.1 serves as a guide through the existing rules and regulations. It summarises the requirements for tube lining methods curing on site in one work, comments on them and supplements them with current requirements.

3.1 Materials

Cured-in-place pipes basically contain the following components:

- resin system
- support and / or reinforcement material
- Inner liner (permanent, semi-permanent or temporary)
- outer liner (permanent, semi-permanent)

The relationship between these components is shown in ***Figure 2.***
The inner and outer foils can be part of the end product (permanent) or installation aids (semi-permanent, temporary), depending on the procedure.

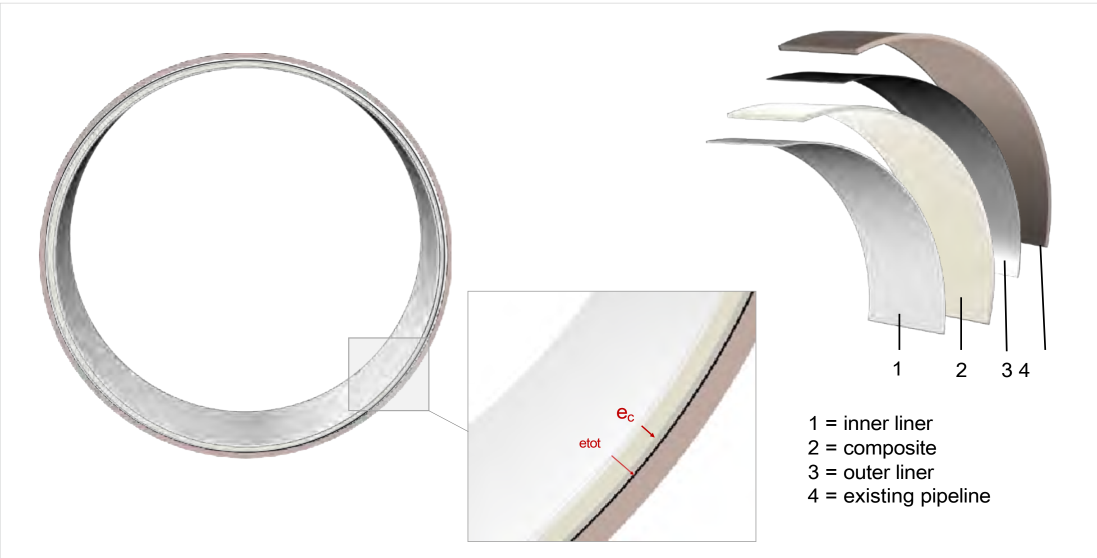


***Figure 2**: Typical wall construction of a pressure liner*

3.2 Technology overview, areas of application and - limits

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The systems available on the market can be differentiated as follows with regard to the liner materials used, areas of application and limits (***Table 1***):

Table 1*: Technical overview of cured-in-place pipes, areas of application and limitations*

	needled felt liner	glass fibre reinforced needled felt liner	glass fibre liner
DN range [mm]*	DN 100-DN 2200	DN 100-DN 1600	DN 150-DN 2000
Composite thickness [mm]*	3 to 50	3 to 40	3 to 30
resin type**	EP, UP, VE	EP, UP, VE	UP, VE
installation method	Inversion, combination indentation / inversion		Indentation (inversion)
pipe bend mobility	Heat curing (water / steam) Ambient temperature curing (for small DN)		UV curing, combined curing
Curvilinearity (depending on radius)*.	≤ 45° (larger bends with radii ≥ 5D possible with limitations)		≤ 15°

* The values given are possible scopes based on manufacturer's specifications.
** EP - epoxy resin, UP - unsaturated polyester resin, VE - vinyl ester resin

The possible pipe lengths depend on the project and system. The areas of application of the procedures must be checked in the course of planning (cf. chapter 6).

4 Connection techniques

For the connection of the liner, procedures shall be used that have proof of suitability. This proof of suitability is deemed to be provided, for example, by a general building approval (abZ) from the German Institute for Construction Technology (DIBt). All connections must be watertight; waterproof (free of dead space).

4.1 General

The effectiveness of the various connection techniques and materials depends on the materials to be joined. Connections to the cured-in-place pipes and to manhole or pipe materials are required.
With resin-based materials, a cohesively attached joint (bonding) is possible for the pipe materials concrete, stoneware, cast iron, fibre cement, GRP and PVC-U as well as for the cured-in-place pipes, depending on the system and with an appropriately defined adhesive surface and preparation of the adhesive base. An adhesive bond (force-fit) can be produced on the materials PP and polyethylene, but not a cohesively attached bond. A connection free of dead space is possible depending on the system.
The use of cement-bound mortar systems does not achieve a force-fit joint between the connection material and the liner. The seal effect - also against pressing water in the annular gap - is achieved by the form closure on the liner and, if necessary, the cohesively attached joint on the existing pipeline (with mineral materials). In all cases

of application, suitable substrate preparation must be ensured!

4.2 Connection in the manhole section

Any annular gap between the renovated pipe and the hose liner must be permanently protected against infiltration and exfiltration (sealing area). The connection can also be made as part of a manhole renovation (see RSV factsheet 6.2 "Manhole renovation").

The manhole connection is made using the following techniques and / or materials:

- swelling tape
- laminate by hand
- filling with reaction resin systems (resin filler)
- grouting with polyurethane (PU) or epoxy (EP) resins
- cuffs (elastomer/ stainless steel cuffs)

If necessary, wait for the shrinkage phase before cutting back the cured-in-place pipes in the manhole. The liner edge must be protected - in addition to the above-mentioned ortlaminates, resin fillers and cuffs, suitable mortar systems can also be used here.

> **Comment:** Cementitious mortar systems are suitable for levelling the edge of the liner, but not for sealing, as they cannot establish a sufficient bond with the liner.

4.3 Connection in the pipeline

When installing open-ended cured-in-place pipes, the liner must be connected in the pipeline free of dead space. This is usually done by using cuffs. Depending on the system and with appropriate preparation of the adhesive base, a cohesively attached joint (gluing) can also be made.

4.4 Connection of lateral pipes

4.4.1 Connections in trenchless construction

After curing of the cured-in-place pipes, the connecting pipes are opened from inside the pipe. The following connections are available for watertight; waterproof:

- grouting by means of robots
- use of lateral connection collars (tophat profiles)
- use of hand laminate in walkable areas

The type of connection of the connecting pipes depends on the respective construction site conditions and the tube lining method used.

4.4.1.1 Connection by grouting

In the case of connections by grouting, polyaddition resins (epoxy resins, silicate resins, etc.) or plastic-modified cement mortars are applied by means of a shuttering robot or a spigot grouting device so that these make a joint from the cured-in-place pipes to the connecting pipe (see RSV factsheet 5.

4.4.1.2 Connection with lateral connection collars (tophat profile)

The connection by means of lateral connection collars is defined in DIN EN ISO 11296-4 and explained in RSV factsheet 7.2 "Top-hat profile technology (connection collars)". Profiles made of polyester needle felt, glass fibres or similar corrosion-resistant materials are used.
The lateral connection collars (tophat profiles) must be cohesively attached to the liner and the existing connecting pipe free of dead space. The connection must be resistant to the usual high-pressure cleaning. Analogous to DIN EN ISO 11296-4, the tying-in techniques are to be classified according to the minimum length that extends into the connecting pipe (***Table 2***):

Table 2*: Minimum lengths for lateral connection collars (installation depths)*

Class	Minimum length in lateral connection pipe
A	1000 mm
B	400 mm, but at least 150 mm beyond the first joint in the existing lateral connection pipe
C	100 mm

The collar must extend at least 50 mm into the main pipe and create a cohesively attached joint. The specifications of DWA-A 143-7 must be observed.

4.4.2 Open construction connections

After installation of the cured-in-place pipe liner, the connections can be made by open construction through an excavation by means of connecting pieces (spigots). The procedure must ensure that the connection of existing connections and those to be connected later is technically faultless. Connecting pieces must be tightly connected to the cured-in-place pipes and the existing connecting pipe by means of positive-locking joints or cohesively attached bonding.

> The connecting pieces must seal on the inside of the cured-in-place pipes and not just over the borehole wall.

A 2-component sealant is pressed into the connecting pieces to compensate for small unevennesses (folds in pipe liner), to provide additional sealing and to protect or seal the cut edge of the cured-in-place pipes (see ***Fig. 3***).
If the provisional opening in the liner cannot be drilled over in a dimensionally accurate manner, it is possible to apply a junction to the cured-in-place pipes from the outside (***Fig. 4***) (cf. DIN EN 1610).

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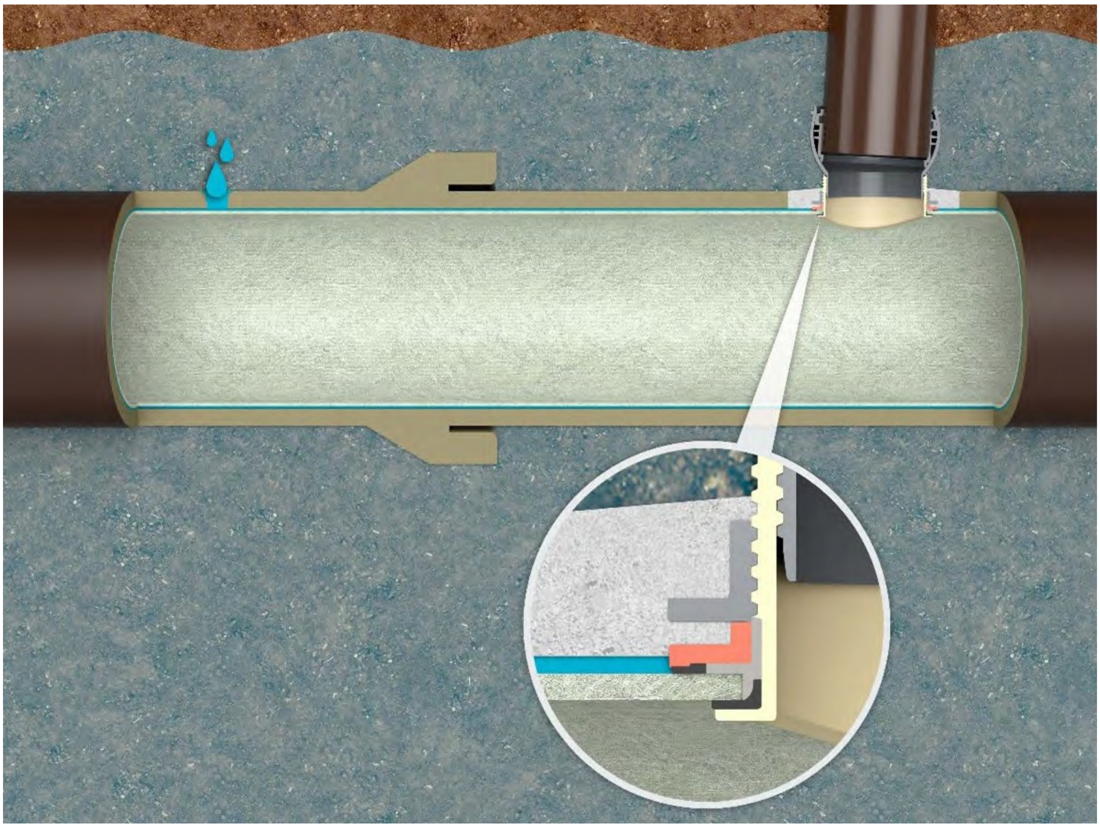


***Figure 3**: Example of a connecting piece for lateral pipes in open construction*

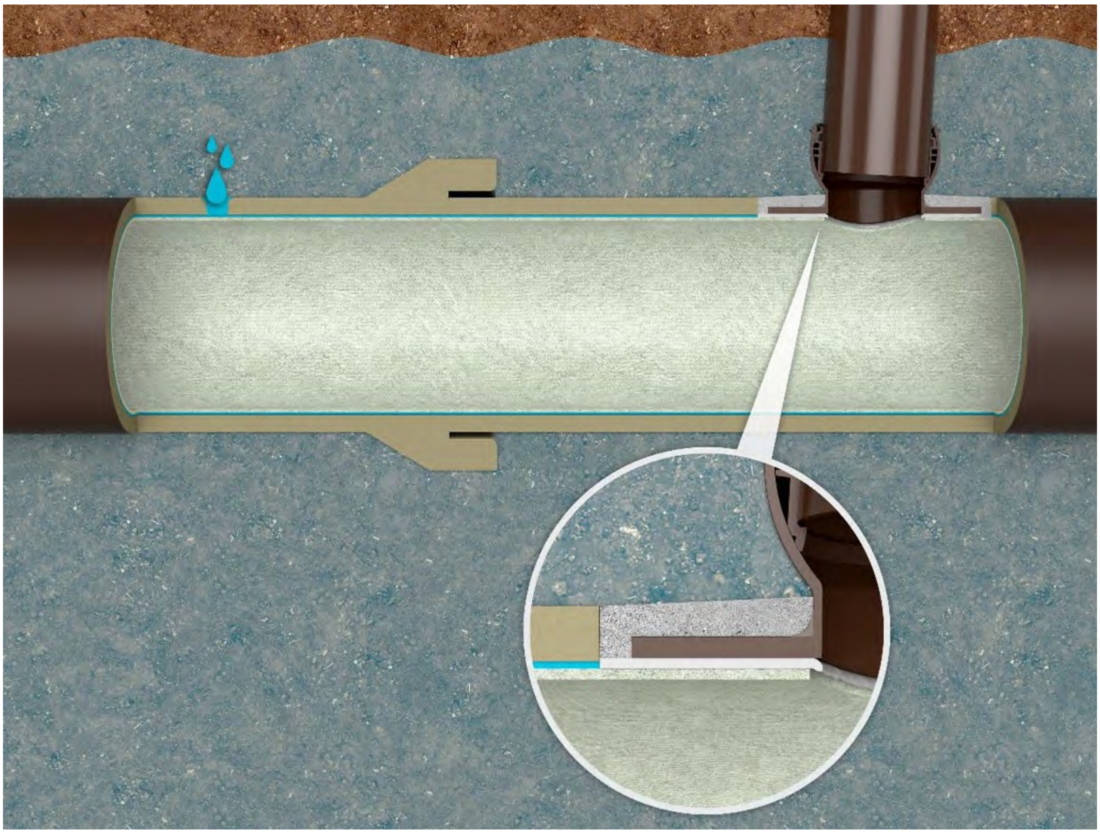


***Figure 4**: Example of a junction for lateral pipes in open construction*

The requirements of DWA-A 139 for tension-free connection of the private sewer lateral (ball joint or joint pieces) apply.

5 Requirements for pipe lining

A system of approval and quality testing procedures has been established for pipe lining, which sets strict requirements and continuously adapts them to the needs of the market in practice. The requirements for pipe lining, which are summarised in this chapter, offer a view of the main topics currently discussed in practice.

The pipe lining system must be quality-tested and coordinated from the used materials up to the installation technology and to the installation. All process steps must be controlled and documented to ensure the reproducibility of the end product. Within the scope of the suitability tests to be carried out, the procedure must prove its applicability for the sewer renovation and the pipline system, and the areas of application are defined.

5.1 Requirements for the materials

5.1.1 Hose / Hose carrier

Table 3 summarises the liner components. The material specifications from DIN EN ISO 11296-4 are not used, as not all materials specified there adequately meet the requirements for the durability of cured-in-place pipes.

Table 3*: Materials for components of the hose*

Hose component	Materials*
Resin type Filler type Hardener type	EP, UP, VE (without, chemically inert organic or chemically inert inorganic) Curing at ambient temperature, heat curing, uv light curing, combination of uv/heat curing
Substrate / Reinforcement	inert plasticiser-free polymer fibres e.g. poly(ethylene terephthalate), Corrosion-resistant glass fibres of the type "E-CR" according to 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 semi-permanent and permanent membranes, the material requirements are based on the necessary function, Foils must not negatively affect the operation of the pipe, Materials e.g. TPU, OF, PP, PE
In deviation from DIN EN ISO 11296-4:2018, glass fibres type "E" are excluded from use in this factsheet due to their low chemical resistance. The use of "C", "R" according to ISO 10467 and carbon fibres according to ISO 13002 are permissible if proof of suitability is provided.	

*Other materials can in principle be tested in accordance with this factsheet.

For all procedures, it must be ensured that the resin system is not impaired by the installation medium or by groundwater entering or water present in the existing pipeline. Inner and outer liners are used for this purpose. The outer liner can either be inserted into the pipeline before the liner is installed (preliner) or it is joined to the liner and inserted together with it. Sliding foils are also used in the insertion process. These can be outer liners with an additional sliding foil function or separate sliding foils. Abrasion-resistant materials must be used as sliding foils.

Recommodation: Especially in case of broken pieces, exposed reinforcement or other sharp-edged obstacles in the pipe bedding, which damage the liner during retraction and cannot be removed in advance, the application of separate sliding foils is necessary.

In groundwater-free zones, an outer liner can be dispensed with depending on the project requirements. A valid abZ with a corresponding note is required for this.

Note: The use without outer liner is permissible, for example, for open-end installations or for the production of connections to the existing pipeline that are free of dead space.

The liner must conform to the existing pipeline during the installation phase after inflation and must not form a planned gap. The limited annular gap to be considered in the structural analysis results from the thermal and chemical shrinkage of the resin system.

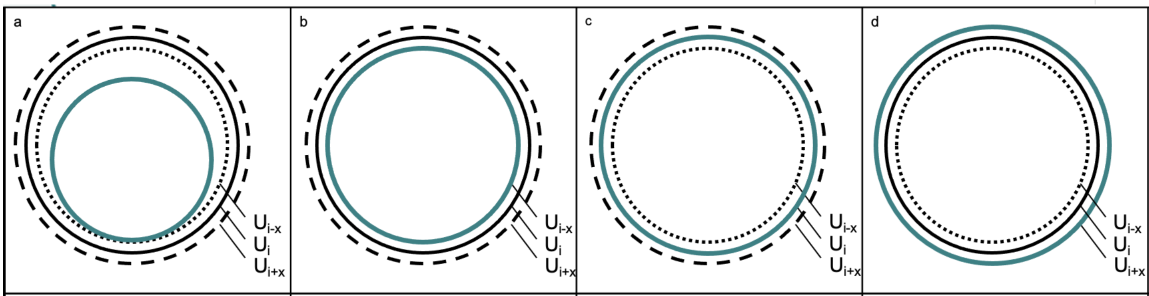
If cured-in-place pipes conform to the existing pipeline with positive-locking, it is guaranteed that

- the annular gap approach of the static calculation is not exceeded
- excess outer layers of pure resin are avoided
- manhole and connection attachments are not impaired
- the bedding of the liner in the existing pipeline is guaranteed.

The cured-in-place pipes are characterised by their expansion capacity and flexibility. To represent elongation, different elongation states are defined here (***Figure** 5*). During production, each hose is produced with an undersize and must expand to reach its characteristic values and to positively-locking to the existing pipeline (minimum expansion). The hose is produced for a certain nominal dimension of the inner circumference of the old pipe and reaches this with its nominal elongation. In addition, the hose can expand beyond the nominal expansion and compress against the existing pipe wall (maximum expansion). The expansion range between minimum expansion and maximum expansion is defined as the expansion capacity of the hose.

The elongation of the cured-in-place pipes beyond the nominal elongation leads to a reduction of the wall thickness.

The system-dependent expansion capacity of the carrier hose in the circumferential direction must be observed. Tolerance ranges (minimum and maximum elongation) are to be specified by the manufacturer.



Undersize	Minimum expansion	Nominal expansion	Maximum expansion
Corresponds to the production dimensions of the liner hose without expansion	Minimum necessary expansion from which the carrier/reinforcing material is stretched and compressed and the hose is form-fit to the old pipe	Expansion of the hose in relation to the internal circumference of the old pipe for ordering the hose	Maximum permitted expansion of the hose

a: In the condition produced in the factory (M condition in accordance with EN ISO 11296-1)

b, c, d: when installed (I condition in accordance with EN ISO 11296-1)

Legend:

- ······· U_{i-x} : Lower tolerance limit of the old pipe, internal circumference
- —— U_i : Nominal dimension of the old pipe, internal circumference
- - - - U_{i+x} : Upper tolerance limit of the old pipe, internal circumference
- —— liner hose

Information:

The elasticity of the liner hose describes its expansion between minimum expansion and maximum expansion. Expansion beyond the maximum expansion is possible but leads to impairments of the laminate quality.

***Figure 5**: Elongation states of cured-in-place pipes*

5.1.2 *Resin systems (unsaturated polyester, vinyl ester and epoxy resins)*

For cured-in-place pipes, resin types according to ***Table 4*** are preferred. In deviation from DWA-A 143-3:2014, the UP resins of group 2 according to DIN EN 13121-1 are excluded from use due to their lower chemical resistance.

For the selection of the different resin systems, the thermal, mechanical and (bio-)chemical contamination as well as the structural conditions must be taken into account. These are to be defined by the client. Moisture-sensitive resin systems must be protected by suitable measures (e.g. outer liners). A colouring or pigmentation to control the resin-curing mixture and / or

-Impregnation is permissible.

Table 4: *Preferred resin types [based on DWA-A 143-3: 2014]*

Waste water type	Preferably used resin types
Municipal waste water	UP resin • DIN 16946-2 min. type 1130 (thermal and mechanical requirements) • DIN 18820-1* Group 3 or according to DIN EN 13121-1 Group 4** EP resin • DIN 16946-2 type 1020, type 1021, type 1040 (thermal and mechanical requirements) or • Waste water resistant, hydrolysis resistant, temperature resistant epoxy resins with proof of suitability by an approved and independent testing institute. approved resins for highly aggressive waste water (see below)
Highly aggressive waste water e.g. industrial waste water (special waste water composition, specific waste water analysis necessary)	Vinyl ester pure • DIN 16946-2 min. type 1310 (thermal and mechanical requirements) • DIN 18820-1* Group 5 or according to DIN EN 13121-1 Group 7** or Group 8 EP resin • Proof of suitability for the specified waste water shall be provided by the bidder. • Resins that have been shown to be chemically resistant to attack from the specified waste water

* DIN 18820-1 withdrawn
** halogenated resin systems are excluded

5.2 Requirements for the plant technology

The plant technology for pipe lining includes:

- dosing and mixing technology of the resin systems
- impregnation technology
- installation technology
- hardening technique

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

5.2.1 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 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 are documented and stored.
The impregnation must ensure reliable wetting of the carrier and / or reinforcement material. The application of vacuum serves to deaerate the material.

5.2.2 Installation technology

The necessary equipment technology depends on the installation method of the hose liner system and the manufacturer's specifications. There are three procedures: the inversion process (carding), the insertion process and the combination of inversion and insertion methods.

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

- Pressure build-up according to manufacturer's specifications
- Gentle inversion, as continuous as possible
- Print control and documentation

The inversion speeds and pressures according to the manufacturer's specifications must be observed.
The requirements for the insertion process are:

- Electronic measurement of insertion forces
- Possibility of tractive force limitation

A record of the insertion forces is required if the winch allows insertion forces above the maximum permissible insertion forces according to the manufacturer's specifications.

5.2.3 *Hardening technique*

In pipe bend mobility, the following curing methods are possible: ambient temperature curing, heat curing, uv light curing, combined uv / heat curing.
Requirements for the hardening technique for heat curing:

- sufficient heating capacity
- sufficient circulation capacity
- automatic pressure monitoring and logging during curing (water column height for hot water curing; pressure manometer for steam curing)
- Temperature control and recording* on the flow and return as well as 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.
- Condensate drainage for steam curing

Requirements for uv light curing and combined curing:

- Suitable light source, illuminant and power approved by the liner manufacturer (see below for details), incl. logging with manufacturer's details.
- electronic* logging of the pass-through speed of the UV light source and the illuminant function
- Electronic* logging of the internal pressure
- Temperature control and recording* on the hose surface
- For combined curing and, depending on the system / project, for UV light curing: electronic* control of the temperature in the outer laminate (between hose and existing pipeline) at least at the starting and target points, if possible also at intermediate points.
- The lamps must not show any visible damage and must be free of any pollution or reflections (dark glass).

*Logging as a data set, not exclusively as a graph or diagram.

For the light source used (light core or light chain), the manufacturer must provide speed tables for each liner type with the following minimum curing data, depending on the dimension and wall thickness:

- clear designation of the light source
- Power specification for the lamps used
- Pass-through speeds
- Separate specifications for the start or stop phase (ignition intervals, pass-through speed)

For the sewer renovation of profiles that are not included in the speed tables, curing specifications specially adapted to the profile must be worked out together with the liner manufacturer.

Light sources and lamps that have not been verified by the liner manufacturer must not be used for curing cured-in-place pipes. Each lamp must be clearly identifiable, e.g. by means of a serial number. The time of commissioning must be documented.

Intensity measurement of the lamps must be carried out regularly in accordance with DWA-A 143-3 (first test after 400 operating hours at the latest, repeat test after 150 operating hours at the latest).

In deviation from the DWA specifications, the radiators must be checked for the first time after 200 operating hours - but at least once a year. This is shown by experience in remediation practice on the basis of regular control measurements.

It must be taken into account that the intensity of the lamps depends on the light sources and the power of the generator. If the light intensity is below 70 % of the reference, the lamps must be replaced. The test must be documented in accordance with DWA-A 143-3.

5.3 Requirements for the execution of installation

For each CIPP installation, a complete documentation of all relevant process steps must be made. These records must be kept so that, in the event of any defects, the cause can be determined and appropriate corrective measures can be taken. The retention periods for these documents must at least cover the period of the contractually agreed warranty period.

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

- Wall thickness of the delivered liner
  (Note: The supplied wall thickness of the impregnated cured-in-place pipes leads to the resulting composite thickness e_c or composite thickness e_m in the installed and cured product. In the case of UV curing, the specification of the delivered wall thickness must correlate with the specifications of the speed tables).
- Hose identification or production number
- Date of manufacture
- DN
- Length
- Weight
- pipe bend mobility
- If applicable, client, project, site and installation location / rehabilitation section
- Handling conditions, if applicable, such as: "Do not stack", "No direct sunlight or frost".

The hoses must be stored according to the specifications of the abZ or the manufacturer and checked for compliance with the delivery and storage conditions. In the case of hot and combination hardeners, compliance with the storage temperatures is checked by means of a thermal recorder. In the case of hose delivery in ice-cooled transport containers, the thermal recorders can be dispensed with. The liner must also be cooled with ice between layers to ensure safe transport. The current storage conditions (temperature) of the hose must be documented, especially at the start of installation.

In the case of UV or combined curing, the hose manufacturer must specify the maximum possible pass-through speed to the construction company, depending on the light source and the hose. This is done, if possible or necessary, depending on the project per delivery or as standard via table values. For heat curing, the required heating specifications must be specified depending on the laminate temperature (outside).

Upon arrival at the site, the hose shall be checked at least as follows:

- Checking the delivery documents
- Visual inspection of the hose
- Checking the flat dimension for conformity with the specified diameter

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

- CCTV recordings of the sewer pipe inspection or walk-through before and after the renovation measure
- if required: calibration record
- Installation and curing records including the following parameters:
  - Process-dependent documentation of the pressure, temperature and / or UV light parameters as well as the tensile forces occurring during the retraction of the hose.

- UV curing: documentation of the testing of the light sources and lamps according to chapter 5.2.3
- construction site daily reports
- If commissioned: Leak test report

With on-site impregnation additionally

- Dosing and mixing protocol, impregnation protocol

Ensure that the installation guidelines of the selected and tested hose lining method are followed exactly and controlled with in-house and third-party monitoring mechanisms.

5.4 Requirements for pipe lining

For cured-in-place pipe lining, an initial and suitability test must be available. This is covered by a valid national technical approval (abZ), e.g. from Deutsches Institut für Bautechnik (DIBt). The abZ is a prerequisite for the use of pipe lining on private property.

> For public areas, it is recommended to only use systems with a valid abZ.

In addition to the product requirements according to DIN EN ISO 11296-4, the abZ includes further suitability tests such as resistance to high-pressure rinsing, abrasion resistance, chemical resistance as well as an existing in-house and external monitoring under the responsibility of the system manufacturer. The in-house and external monitoring for the areas of production, suitability test and site testing are basically carried out in accordance with chapter 11.4.

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Within the scope of the suitability test, curing must be proven and system-related limit values must be defined. For epoxy resin laminates, this is done by defining glass transition temperaturs by means of DSC analysis (according to DWA-A 143-3).
In the case of UP and VE laminates, a residual monomer content is to be determined by means of gas chromatography (according to DWA-A 143-3).
The suitability test must define appropriate limit values for sufficient curing here, which can be tested on the end product (cf. chapter 8.3.2).

5.5 Qualification of the companies

Applicants for the construction, timbering, inspection or cleaning of sewers and pipelines must provide evidence of the required expertise, performance and reliability as well as quality monitoring - consisting of external and in-house monitoring. The requirements of the quality and testing regulations of an independent certification organisation (e.g. sewer construction quality protection association or equivalent) must be met.

Additionaly, the requirements specified by the client must be fulfilled (see DWA-A 143-3 section 7.4). The crew responsible for carrying out the remedial action must consist of skilled and instructed personnel. Training measures and instructions for the tube lining method used must be carried out and documented.

6 Planning

6.1 Basics

The cured-in-place pipe lining method is suitable for the majority of rehabilitation situations in public, commercial and private drainage pipes. In order to determine the extent to which the procedure can be used for the renovation of the existing pipeline, taking into account the operational, static and hydraulic requirements, a careful actual recording of the existing pipeline must be carried out. All planning documents must be made available to the planner by the client or network operator. In this context, reference is made to DIN EN 752. As far as the basic prerequisites and the requirements for planning are concerned, reference is made to DIN EN 14654-2 and the worksheets DWA-A 143-1, -2 and -21. In the following, we will take a closer look at some of the focal points.

6.2 Operational Requirements

In the course of planning, the temperatures and wastewater compositions to which the liner will be exposed over its expected operational life must be determined (cf. ISO 11296-4: 2018 section 8.5.1). In order to ensure that the cured-in-place pipes meet the performance requirements during their planned useful life, at least the following criteria shall be considered:

- The wastewater temperature does not exceed 35 °C permanently. Occasional short-term discharges of up to 50 °C can be considered uncritical.
- The composition of the waste water corresponds to that of municipal waste water.

In case of deviating requirements such as e.g.

- the waste water temperature permanently exceeds 35 °C,
- the wastewater composition does not correspond to that of a municipal wastewater, the cured-in-place pipes may be outside its proof of usability. In this case, only liner systems that can prove their suitability should be considered in the planning.

If there are other special operational conditions, these must be taken into account in the course of planning.

6.3 Inspection

The actual recording of the selected renovation section begins with an evaluation of the existing visual inspection. This must be checked with regard to completeness, quality and age. A current optical inspection, e.g. according to the specifications of the factsheet DWA-M 149-2 or M 149-5, is to be carried out if

- an insufficient optical quality does not allow a reliable damage assessment.
- an excessively high wastewater level (insufficient receiving water) does not allow sufficient assessment of the sole
- the inspections are incomplete
- the inspections are older than 3 years. In the case of certain damages (e.g. groundwater and soil ingress) or changed environmental conditions (e.g. construction activities in the vicinity), this period can also be shorter (damage development).

6.4 Measurement / Calibration

The planning is usually carried out on the basis of the existing documents. Depending on the project, a survey or continuous calibration of the pipeline may be necessary as part of the planning. This is carried out as follows:

- Circular profiles and egg-shaped profiles that cannot be walked on: For standardised circular egg-shaped profiles, the cross-section or circumferential dimension determined in the inspection manholes is sufficient. The measurement must be carried out in the pipe, as bindings and sockets falsify the values. Known manufacturing tolerances of the existing pipeline must also be included in the assessment. If the planner cannot adequately assess the profile dimensions (e.g. severe internal corrosion, in-situ concrete canals), a continuous calibration of the pipe section is recommended.
- Walkable egg-shaped profiles: If the profiles are masonry, calibration by means of 3D measurement is recommended due to the profile fluctuations to be expected. Alternatively, circumferential measurements can be taken at a reasonable distance,
  e. g. every 5 to 10 m. For other materials, the use of calibration should be considered, e.g. if there are noticeable irregularities.

The planner must take into account that, depending on the material, the existing pipelines may have different manufacturing tolerances than are permissible according to current standards. In the case of pipes manufactured on site (masonry, in-situ concrete), larger tolerances must also be assumed. In the case of masonry, random counting of masonry layers over the pipe zone can provide information on dimensional tolerances.

Pipe liner systems have different expansion capacities (cf. chapter 5.1.1). The planner must check whether these cover the existing pipeline tolerances. If necessary, other technical solutions must be used to bridge larger dimensional deviations. For example, a reinforcement hose can prevent the overexpansion of a hose in oversized areas; resulting annulus must be statically considered or filled.

> **Note:** If the control measurement of the nominal diameter and the inner circumference of the sewers is not carried out properly and if calibration is not carried out despite variations in the existing pipeline, folds in the pipe liner or an enlarged annular gap may occur if the selected liner type cannot cover this via its elongation (cf. chapter 5.1.1).

6.5 Assessment of the bedding situation

According to DWA-A 143-2, the existing pipeline condition must be determined for the static calculation of a cured-in-place pipes. For this purpose, the lateral bedding of the existing pipeline and the groundwater level must be determined (cf. chapter 6.5.2).
In the case of old pipe condition III, additional information is required for the structural analysis, as the old pipe-floor system is classified as no longer sustainable in the long term.

6.5.1 Notes from the locality

With regard to the assessment of the bedding situation of the existing pipeline (cf. chapter 6.5.2), attention should be paid to the following points with regard to the location:

- Road settlements along the pipeline route
- Local settlements (comparison with individual damages from the visual inspection)
- Excavations by other pipeline supports that may have permanently disturbed the bedding system
- Indications of construction measures of other kinds (building basements, special civil engineering, etc.) that could have permanently disturbed the bedding system

6.5.2 soil investigation

The necessity and scope of the required soil investigations are determined on the basis of existing investigations from other measures in joint with the visual inspection as well as the local situation. In DWA-A 143-2 (e.g. chapter 4.2.1) it is defined that for the old pipe condition II the old pipe-soil system is assumed to be solely load-bearing if there is a verified functional lateral bedding. For the verification of the lateral bedding, ramming core probing and/or long-term observations are explicitly mentioned. If there are no indications of disturbance of the bedding from the long-term observation, this means that no soil investigation is required for old pipe condition I and II. Sufficiently good bedding can be assumed on the basis of such a long-term observation if

- the groundwater level is below the pipe bedding and no other influences are known that would indicate a lack of bedding (e.g. lateral excavation, visible deflection of the existing pipeline) or

- the groundwater level inverts above the pipe bedding, but there is no or only slight gw entry without soil ingress and without deformation of the profile.

In these cases, it is sufficient to determine the design water level.

In the case of sewers with a high potential for consequential damage in the event of failure, it is recommended, even with positive long-term observation, to carry out comprehensive foundation soil investigations in order to be able to assess the existing pipe soil system sufficiently precisely with the aid of a geotechnical report, if necessary, and to be able to prove it statically.

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If the existing observations suggest a disturbance of the bedding or if such a disturbance cannot be excluded, soil investigations are necessary to assess the actual bedding situation. ***Table 5*** gives an overview of possible procedures.

Table 5*: Procedure for assessing the bedding situation*

damage pattern	Bedding assessment	Measure
Gw entry flowing / visible, without soil ingress	No negative influence on bedding expected	To confirm the bedding, if necessary, spot-check (every 1-2 pipe sections) small pile-driving core probing (KRB) and dynamic probing with light pile-driving probe (DPL) or heavy pile-driving probe (DPH).
GW incrustations without gw entry	No negative influence on bedding expected	as above In addition, evaluate current outcrops (not older than 10 years) in order to be able to estimate changes in the GW status.
Gw entry with soil ingress visible	Negative influence on bedding likely	KRB in the pipeline zone and DPL or DPH, preferably over the entire pipe zone (approx. every 25 m to 50 m according to DIN EN 1997-2).
Transverse cracks in existing pipeline with offset *	Cause of damage presumably due to poor bedding or single-cell influence in the area of damage	KRB and DPL or DPH at least at the damage in the pipeline zone, preferably over the entire pipe zone (approx. every 25 m to 50 m).
Continuous longitudinal cracks / four-joint cracks *	Cause of damage probably due to poor pipe bedding	KRB and DPL or DPH in the pipeline zone in the damage area and over the entire pipe run (approx. every 2 m to 50 m).
Deformation / Ovalisation *	Overloading of the pipe, presumably associated with poor bedding	KRB and DPL or DPH at least in the area of the deformation and over the entire pipe zone (approx. every 25 m to 50 m).

* If long-term observations are available that confirm a consolidated system, the subsoil analyses can be dispensed with if necessary. The cause of the damage may, for example, already lie in poor execution of installation, so that the damage due to settlement occurred directly, but deterioration over time is not to be expected.

Decisive for assessing the bedding are the values of the DPL or DPH. These are only informative in joint with the existing soil types, which is why the small pile driving is additionally necessary to determine the soil layers.

The results of the soil investigation are to be evaluated with regard to the sufficient bedding or the stability of the existing pipeline.

Some assessment tools are given below:

- Damage visible in visual inspection, but sufficient soil characteristics: If the dynamic probing shows good bearing densities, visible damage may originate from the construction phase or be caused by individual events (e.g. settlement in the course of a neighbouring site). However, the existing pipe soil system is fully load-bearing. Sewer rehabilitation is feasible.
- No deformations and insufficient soil properties: If no deformations can be detected despite insufficient soil properties, it cannot be assumed that the pipe is overloaded at the present time. Due to the insufficient soil properties, the load-bearing capacity of the existing pipe soil system must be statically verified and the existing pipe condition classified.
- Deformations (e.g. ovalisation in the case of the circular profile, lowered crest in the case of the egg) and insufficient soil properties: If deformations of the existing profile can be detected in the visual inspection and this correlates with poor soil properties, it can be assumed that the pipe is overloaded. The renovation capability must be questioned and the load-bearing capacity of the existing pipeline floor system must be statically verified.

6.6 Determination of a old pipe condition

The old pipe condition is to be determined from the determined data. Essential criteria here are:

- Transverse and longitudinal cracks
- shard formation
- socket gap
- Local imperfections
- Ovalisation
- Leaks
- For masonry: degree of damage to the joints (wash-out), shifts in the stone structure
- soil ingress
- Bedding of the existing pipeline
- Design water level (determined from the groundwater level plus an allowance for the GW rise after sewer rehabilitation. Pronounced irregularities in the profile cross-section may require further surcharges for higher safety).

If necessary, a mathematical verification of the existing pipeline must be carried out. This determines the extent to which the profile of the existing pipe is statically stressed in its current state (stability assessment).

6.7 Static Calculation

The determination of a required design wall thickness for the calculation of the offer is the task of the planning. This can be taken from DWA-M 144-3 in the standard case (standard profiles, old pipe condition II, standard load cases) using the material groups.

The mechanical parameters of the individual cured-in-place pipes can be found in the abZ. If required, a static calculation must be carried out in accordance with DWA-A 143-2.

> **Note:** The static calculation can be carried out with bar models or by the finite element method (FEM). The FEM simulation takes into account the actual geometry of the existing pipeline and can map the specific boundary conditions and the bedding situation in detail. This means that lower liner wall thicknesses may be possible, especially for existing pipe condition III and IIIa.

For existing pipe state IIIa according to DWA-A 143-2, the static calculation is based on ATV-DVWK-A 127 (earth-bedded liner).

If deviations in the annular gap are to be expected beyond the minimum rates specified in DWA-A 143-2, this must be taken into account in the structural dimensioning due to the lower bedding effect (bedding in the existing pipe soil system). Depending on the static requirements, the annulus may have to be filled. A loose-fitting liner must be positionally secured so that no impermissible forces (e.g. due to buoyancy) can act on connections, junctions.

It should also be noted that overexpanded laminates, which do not fit the existing pipeline, cannot reliably achieve their mechanical parameters from the suitability test. In this case, measures to prevent overexpansion, such as the possibility of using a reinforcement hose, must be taken into account in the planning.

Consideration of forced deformations
Forced deformations occur when subsequent deformations are imposed on the cured-in-place pipes (in addition to the pre-deformation of the existing pipeline), e.g. due to low overlaps (< 1.5 m) caused by the action of traffic loads.
Possible forced loading of the liner must always be taken into account for existing pipe state (ARZ) III in accordance with the recommendations of DWA-A 143-2.
In the case of ARZ II, this is generally not necessary, as forced deformations are only possible with low overlaps (< 1.5 m) and in the presence of live loads. To evaluate this influence, comprehensive comparative calculations were carried out on the basis of the material groups and standard status tables documented in DWA-M 144-3. The results show that if the liner wall thicknesses and material characteristics of DWA-M 144-3 (MKG 1 to 26) are adhered to, a forced deformation of 3% (relative diameter change) can always be absorbed with sufficient certainty.

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6.8 Tender

As a general rule, the VOB / C and in particular DIN 18326 Chapter 0 "Notes for the inflation of the performance specification" must be observed.

When tendering for pipe liner methods, the geometry of the sewers to be rehabilitated must be described. If necessary, liner manufacturer-related research should be carried out in order to assess the suitability of the systems for the project-specific conditions.

In addition to the characteristics (nominal diameter, length, pipe material, connections, etc.), the following points in particular must be taken into account:

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- **DIN 18326 0.1.2:** Number, type, position, dimensions, materials and connection angles of existing connections; junction; contact
  - Connections (repair procedure):
    Details of the intended connection techniques for connections (cf. chapter 4.4) are to be provided in the DA and these are to be recorded as LV items.
- **DIN 18326 0.1.4:** Position deviations and dimensional changes within the existing sewer support / DIN 18326 0.2.6: Specifications for calibrations and optical inspection
  - Change of the inner pipe diameter:
    If there is a defined change in diameter, the liner is generally made up accordingly by the manufacturer (e.g. installation of a cone). In small diameter ranges, flexible liner materials can be selected that allow for dimensional changes according to the manufacturer's specifications. The required diameter change must be specified in the tender (in the construction description and in the specifications).
  - Variances of the internal pipe diameter (e.g. due to internal corrosion, in the case of pipes produced in-situ such as in-situ concrete, masonry, in the case of large existing pipeline tolerances), dimensions of the existing pipes, in particular profile shapes and fittings:
    To deal with material-dependent fluctuations in the internal diameter of the existing pipeline, the information in chapter 5.1.1 on elongation of liners should be taken into account. The planning should check whether diameter fluctuations can be compensated by the flexibility of the hose. It must be assessed whether the installation can be carried out using the expansion capacity of the hoses or whether a corresponding fabrication (see above) is required. A corresponding reference to the fluctuations, if possible with indication of the absolute fluctuation range (min / max), is to be included in the tender (DA and tender).
  - Changes of direction:
    Changes of direction in the existing pipeline, such as bends or chutes, must be indicated in the DA and their location should be shown in the construction drawing. Note: Changes in direction result in compression or stretching of the hose.
- **DIN 18326 0.1.6:** Number, type, dimensions and condition of damaged areas on the drainage channel and its surroundings / DIN 18326 0.2.5: Scope of preparatory work in the existing pipeline, in particular number, type, location and dimensions of obstacles to be removed as well as repair areas.

- Pipe offsets, position deviations (local imperfections):
  It must be checked whether these are covered by the selected load-bearing capacity verification and allow the sewer renovation to be carried out. A description in the BB is helpful. If necessary, a separate item should be provided for milling the offsets.
- Root ingrowths, incrustations (milling):
  Details of the existing obstacles in the DA are to be provided and the removal recorded as LV items.
- Groundwater infiltrations:
  In the case of strong, pressing groundwater infiltrations, these should be sealed in advance with suitable short liners, grouting or injections. Positions for this are to be provided in the LV. In egg-shaped profiles that cannot be walked on, sealing can be carried out.
  Slight gw entry (dripping to flowing) does not have to be sealed separately; in this case, the extent of the gw entry is to be shown in the SC and it is to be pointed out that the hose is to be additionally secured against gw depending on the process (e.g. by an additional, possibly reinforced outer liner). This additional protection must be specified in the corresponding items in the specifications.
- Drainage obstacles:
  The extent of the existing obstacles is to be described in the DA and their removal is to be recorded as LV items.
- Deformations (ovalisation):
  Deformations shall be named in the DA in terms of location and expression.
- Underbends:
  The shape and position of the underbends must be indicated (BB and LV).
- Damage patterns:
  The damage patterns shall be described in the DA.

■ **DIN 18326 0.2.12:** Wastewater diversions or wastewater bypasses for sewers and connecting pipes with the relevant flow rates. Special features e.g. lifting stations, shut-offs. Discharges of wastewater in closed pipes, if necessary via special structures, e.g. pipe bridges, pipe crossings.

- discharge diversion:
  The DA shall define dry weather and stormwater runoff and indicate how and for what quantities discharge diversion is to be carried out.

■ **DIN 18326 0.2.19:** Preparatory work on existing manholes and structures, construction of extraction pits, reconstruction of manhole structures.

- Excavations for local damage repair or renewal of connecting pipes:
  Excavations for maintaining the receiving water as well as any excavations required for liner installation are to be determined during the planning stage, shown in the AP and taken into account in LV items.

■ **DIN 18299 0.1.10:** Hydrological values of groundwater [...]

- groundwater:
  The tender must specify the design water level above the pipe bedding to determine the design wall thickness of the cured-in-place pipes (BB and LV). In addition to the design water level, the actual groundwater level should be specified.

7 rehabilitation procedure

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Information on the rehabilitation procedure and the installation of CIPP lining procedure can be found in section 6 of DWA factsheet 144-3. This factsheet briefly describes the main points and provides additional information where necessary.

7.1 Construction site sequence planning

The essential points for the preparation of the renovation measure are:

- Start-up meeting with the client
- Checking the data supplied from the planning by recording the pipe to be renovated. All necessary data such as length, geometry, changes in direction, damage pattern and obstacles are recorded.
- Determination of the wall thickness to be ordered
- Ordering of hoses: The internal diameter of the existing pipeline and its variations, the length of pipe to be renovated, the statically required wall thickness of the hose and the design must be submitted to the manufacturer sufficiently in advance of the installation so that the fabrication can be carried out in good time.
- Ordering of further required materials (aids, moulded parts, cuffs etc.) on the basis of the measured values.
- Review of the layout and size of the proposed excavations
- Preparation of a construction schedule and coordination with the client
- Creation of a discharge diversion concept
- Obtaining the necessary permits
- Distribute citizen information
- Verification of sufficient building clearance
- Possible precautions for temperature control of the materials depending on the expected ambient conditions

Note: If data deviating from the planning is found, the client must be informed immediately and, if necessary, the renovation concept must be adjusted.

7.2 Preparatory work

Before starting the work, the following preliminary work must be carried out on the basis of this information:

7.2.1 Establish accessibility

When using CIPP lining methods, the liner is usually installed via manhole structures. Any excavations that may be required must be constructed in accordance with the applicable rules and regulations.
The space required for the installation of cured-in-place pipes depends on the different installation techniques. In general, cured-in-place pipes can be installed in non-accessible dimensions (< DN 800)

without structural changes to the manhole structure. For larger dimensions, it may be necessary for procedural or local reasons to create an excavation at the installation or start shaft or to remove the manhole cone.
In addition, depending on the process technology, it may be necessary to create a straight flume in the manhole structure.

7.2.2 *Obstacles / Obstacle-free*

Obstacles that prevent continuous pipe cleaning, can lead to damage when the cured-in-place pipes are inverted or retracted, or impair subsequent operational safety, must be identified by means of a suitable visual inspection or walk-through and, if necessary, removed by robot or manually.
The type and location of the obstacles must be documented in an inspection or inspection log.
Obstacles are, for example:

- Diameter reductions, diameter expansions
- Incrustations
- Cross section reducing deposits
- protruding house connections, seals, shards, crossing pipes
- Ingress of roots
- Installations that protrude into the pipe cross-section, e.g. sliding frames, ladders, brackets

7.2.3 *Discharge diversion (maintaining the receiving water)*

Before starting the work, the sewage control must be ensured. Appropriate measures must be taken to prevent sewage from the sewer system above the rehabilitation section from entering the pipe section to be rehabilitated and to prevent backwater from the system below. Receiving water can be ensured by diversion or overpumping. The backwater of the wastewater is permissible with a pre-flooding concept approved by the client.
Discharge diversion is not mandatory for every connecting pipe. The discharge diversion from connecting pipes in the case of higher wastewater volumes and longer rehabilitation times must be installed in accordance with the planning specifications.

7.2.4 *Cleaning*

The cleaning procedures should be chosen in such a way that any impairment of the damaged sewer or pipe is avoided. In practice, high-pressure water and hydromechanical pipe cleaning procedures have proven effective in removing incrustations, loose deposits, etc.

7.2.5 *CCTV inspection*

The cleaning result and the other preparatory work carried out must be checked and documented by means of a visual inspection or walk-through.
Should it have been necessary to remove obstacles during the preparatory phase, the results of this work - if not yet carried out - are also to be documented.

7.2.6 *Pre-sealing*

Groundwater penetration must be prevented in accordance with the CIPP system manufacturer's installation specifications. The resin system can generally be protected from infiltrating groundwater by using outer liners. In case of strongly infiltrating groundwater, pre-sealing, e.g. by means of injection, may be necessary.

7.2.7 *Control measurement / Calibration*

The client's specifications regarding the nominal diameter and the circumference of the old sewer are to be checked by the contractor. This is done at least by control measurements in the manholes. Depending on the local boundary conditions, calibration on the basis of the pipe section may be necessary, cf. chapter 6.4. The circumference values of the existing pipeline determined from the control measurement or calibration are decisive for the production of the cured-in-place pipes.

7.2.8 *Calibrating the connections*

The lateral pipes are to be measured and documented according to station and position. The same device that is used for subsequent opening is to be used here. If possible, the same personnel should measure and open the connections.

7.3 Installation of the cured-in-place pipes

The requirements for the system technology and execution of installation can be found in chapters 5.2 and 5.3. The basic outlets of a cured-in-place pipes installation are described below.

7.3.1 *Impregnation of the liner*

The dosing and mixing of the resin components as well as the impregnation of the liner with the resin system takes place in the factory or on site.

7.3.2 *Installation procedure*

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

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

Water or air can be used as the inversion or installation medium. The installation must be carried out in a manner that is gentle on the material and in accordance with the manufacturer's procedure. If hoses are lifted to the installation site by crane, the hose must not be constricted in such a way as to damage the liner.

> For the installation of large or heavy liners (from approx. DN 800), the use of conveyor belts or conveyor aids is recommended.

7.3.2.1 Inversion

In the inversion method, the liner is rolled in under pressure, taking into account the respective construction conditions and installation regulations (cf*. Fig. 6 a, b*).

In the inversion methods, the pressure required for the crimping must be maintained, taking into account the respective installation conditions and installation regulations, so that any inward bulging that may be caused by groundwater pressure or the pressure of the waste water in the connections is avoided and the liner can be crimped.

7.3.2.2 Retraction

In the retraction method, the hose is retracted into the pipe by means of a rope connection and winch and then inflated with compressed air (*cf. Fig. 6 c, d*). When using the retraction methods, the permissible pulling force must not be exceeded, taking into account the respective installation conditions and installation regulations. The winches used must comply with the specifications in chapter 5.2.2. Damage to the outer liners of the cured-in-place pipes must be avoided at all costs, e.g. by using separate sliding foils or sliding foils integrated on the liner.

7.3.2.3 Combination of retraction and inversion

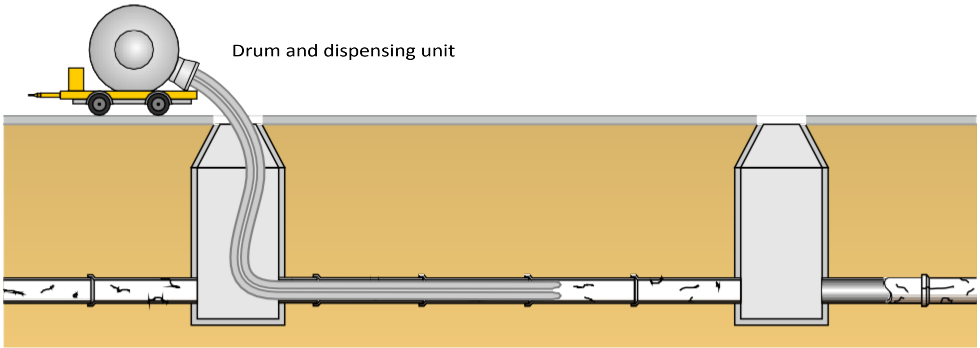
In the combined procedure, first a hose is retracted into the pipe to be rehabilitated and then a second hose is inverted into the retracted one. The individual work steps are carried out according to the above descriptions.

7.3.3 curing

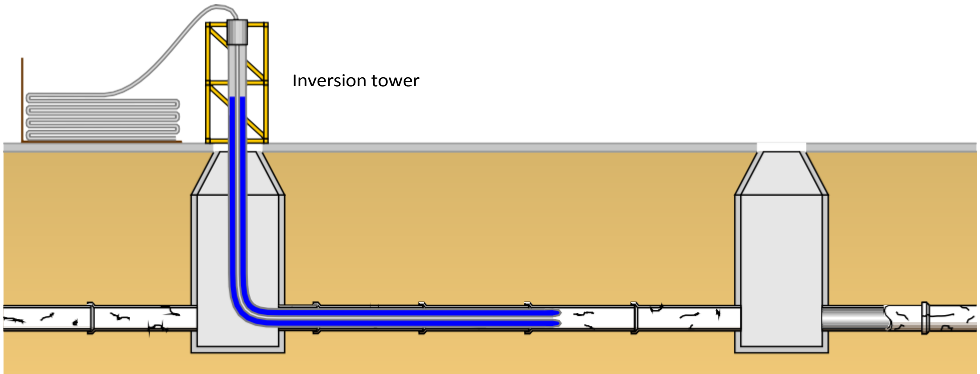
The curing takes place either through

- Heat curing,
- Uv light curing or
- Combined curing (uv light curing and heat curing).

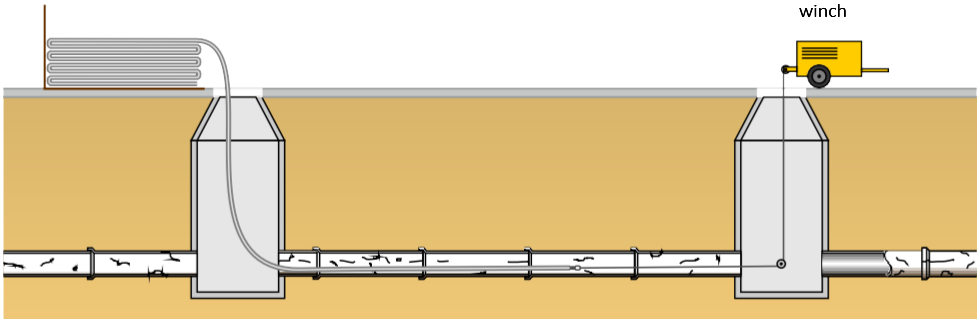
In principle, epoxy resin systems curing under ambient temperature. However, the reaction must be controlled and accelerated by adding heat.
During the entire curing phase, the process parameters must be documented and must comply with the specifications in the process description. The requirements for curing can be found in chapter 5.2.3.
In resin systems with significant shrinkage (UP, vinyl ester rein), relief cuts may be necessary for synthetic fibre liners. These must be sealed permanently and watertight after the shrinkage has subsided.



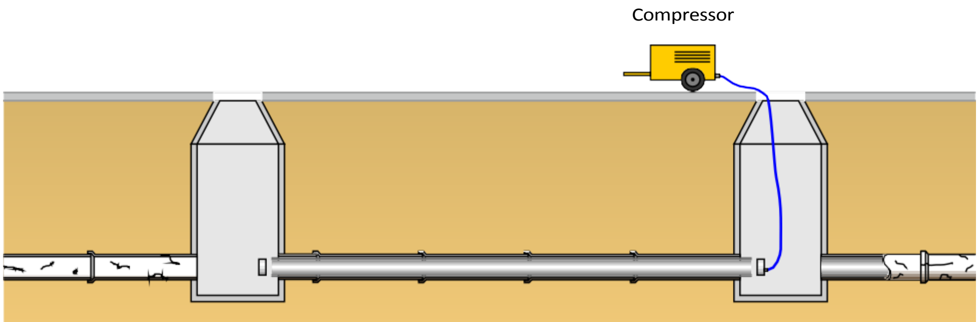
a) Inversion by means of compressed air



b) Inversion by means of water



c) Retraction by means of winch



d) Inflation of the retracted cured-in-place pipes by means of compressed air

Figure 6*: Schematic representation of the installation methods*

7.4 Rework

After completion of the rehabilitation work, the liner in the manhole section is to be cut off and the connecting pipes are to be opened completely. The connection is made in accordance with the requirements of the process description (see chapter 4).

> **Note:** Depending on the project, it is possible that the connections will be carried out as part of subsequent connection and manhole renovation projects.

8 Quality inspection of the end product

8.1 Leak test

The rehabilitated sewer must be leak-proof in accordance with DIN EN 752. The leak test must be carried out according to the state of the art and is carried out either with air or water. As a minimum, the cured-in-place pipes must be checked after curing and before opening the connections; junction; contact.

The leak test is carried out in accordance with the specifications of DIN EN 1610 or DWA-A 139. The test using negative air pressure is approved in accordance with DWA-A 139 and is preferable, particularly for large pipe diameters, for reasons of occupational safety. The test conditions for negative air pressure are contained in DWA-A 139: 2009 and are to be applied for the negative pressure test (***Table 6***). The specifications only apply to test objects that are completely above the groundwater level.

Table 6*: Conditions for the leak test with negative air pressure [based on DWA-A 139:2009].*

Test method (all pipe materials)		p_0	max. Δp	Testing time in minutes [min] – Pipe diameter DN [mm]											
		in kPa		800	900	1000	1100	1200	1300	1400	1500	1500	1600	1700	1800
Negative pressure	LE_U	-10	1,1	12,0	13,5	15,0	16,5	18,0	19,5	21,0	22,5	22,5	24,0	25,5	27,0
	LF_U	-20	1,1	8,0	9,0	10,0	11,0	12,0	13,0	14,0	15,0	15,0	16,0	17,0	18,0

P_0 is related to atmospheric pressure column 1 kPa = 10 mbar = 0.1 m water
LE_U - test method negative pressure, replacement for test method LC according to DIN EN 1610
LF_U = test method negative pressure, replacement for test method LD according to DIN EN 1610

Calculation of test times (t) for other nominal diameters (DN):
Procedure LE_U: t=0.015 - DN [min]. *Procedure LF_U: t=0.01 - DN [min]* *Round to nearest half minute*

In addition, the pure laminate impermeability (without inner and / or outer liner, if these are not permanent membranes) must be demonstrated on a construction site sample.
Both exams must be passed independently of each other.

8.2 CCTV Inspection

After completion of all work on the cured-in-place pipes, a CCTV inspection is carried out. The type and scope of the documentation are to be specified by the client. The inspection of accessible sewers and manholes can be carried out by direct visual inspection. The result is to be documented in writing and by photos.
A characteristic of cured-in-place pipes is that they conform positively-locking to the existing old pipe. The annular gap can be visually checked by cutting back the cured-in-place pipes in the manhole section. If there are larger annular gaps than assumed in the liner statics, these must be measured and taken into account statically (see chapter 6.7).
Due to the condition of the old pipeline or special boundary conditions, wrinkles may occasionally occur. Special boundary conditions include e.g.

- limited access possibilities
- Bends in the pipe run
- Pipe offsets
- Variations of the old pipe diameter

The rules and regulations for cured-in-place pipe lining DIN EN ISO 11296-4, DWA-A 143-3 and DWA-M 144-3 define different limits for the formation of folds and surface irregularities. Wrinkles or surface irregularities that lie within these limit values do not represent a defect. They do not lead to any restrictions with regard to the operational suitability, stability or tightness of the renovated system. In the case of wrinkling or surface irregularities that are greater than the permissible limit values, a case-by-case assessment must be carried out. Annex 11.4 provides information on this.

The definitions of the rules and regulations are listed and commented on below.

DIN EN ISO 11296-4, chap. 8.2

- **in straight lines**
  Surface irregularities ≤ 2 % of the nominal diameter of the existing pipeline or 6 mm. The larger value shall apply.

- **in bends**
  No concrete information

Egg-shaped profiles are not considered separately. For line runs with bends, it is pointed out that folds will generally occur.

DWA-A 143-3, Chap. 4.2.4

- **in straight sections and arches with radius > 10 x DN**
  Folds ≤ 2 % of the nominal diameter or, in the case of egg-shaped profiles, of the smaller diameter or 6 mm. The larger value shall apply.

- **in bends with a radius of 5 x DN ≤ $_{Rbend}$ ≤ 10 x DN**

  Circular profiles: Folds ≤ 3 % ofthe nominal diameter or 20 mm. The larger value applies.
  Egg-shaped profiles: Folds ≤ 3% of the hydraulic equivalent circle or 20 mm. The smaller value applies up to DN 600 (hydraulic equivalent circuit) and the larger value applies > DN 600 (hydraulic equivalent circuit).

- **in bends with a radius R $_{bend}$ < 5 x DN**

  The boundaries shall be defined separately.

The permissible limit values for egg-shaped profiles in straight sections are determined in relation to the smaller diameter (vertex circle). This leads to a better evaluation of the circular profiles compared to egg-shaped profiles with a similar equivalent circle diameter. The hydraulic equivalent circle designates the equivalent diameter based on the egg-shaped profile circumference. The final condition for egg-shaped profiles with diameters ≤ DN 600 (hydraulic equivalent circle) in sections with bends ("The smaller value applies.") leads to disproportionately better evaluations of the circular profiles compared to egg-shaped profiles with similar equivalent circle diameters.

DWA-M 144-3, chapter 7.1.3

- **in straight sections and arches with radius > 10 x DN**

  Folds ≤ 2 % of the nominal diameter or, in the case of egg-shaped profiles, of the smaller diameter or 6 mm. The larger value shall apply.

- **in bends with a radius of 5 x DN ≤ R_{bend} ≤ 10 x DN**

  Circular profiles: Folds ≤ 3 % of the nominal diameter or 20 mm. The smaller value applies.
  Egg-shaped profiles: Folds ≤ 3 % of the hydraulic equivalent circle or 20 mm. The smaller value applies.

The permissible limit values for egg-shaped profiles in straight sections are determined in relation to the smaller diameter (vertex circle). This leads to a better evaluation of the circular profiles compared to egg-shaped profiles with a similar equivalent circle diameter. The hydraulic equivalent circle designates the equivalent diameter based on the egg-shaped profile circumference. The final condition for sections with bends ("The smaller value applies.") is not practical. It leads to the fact that from a diameter or replacement diameter of DN 1000 the permissible pleat heights are limited to max. 20 mm. In dimensions > DN 1000, higher limit values are therefore permissible in straight sections than in sections with bends.

Recommendation RSV 1.1

The different formulations and weightings of the rules and regulations sometimes lead to widely differing limit values.

It is recommended to use the specifications of DIN EN ISO 11296-4. For egg and special profiles, the substitute circle diameter must be used.

The flexibility and bendability of the cured-in-place pipes represent a significant process advantage of this technology. The formation of folds in bends depends on many factors, such as pipe geometry, shape of the bend, liner wall thickness, etc. Therefore, it is not possible to predict the shape, position and development of the folds in bends.

8.3 Material testing at Test pieces

8.3.1 Off-cut of material samples

In order to assess the degree of hardness achieved and the cured-in-place pipes characteristics obtained, a corresponding test piece is taken from the cured-in-place pipes of each curing process in the presence of the client or a person appointed by him. The minimum sample size according to DWA-A 143-3 is:

- 20 x wall thickness in circumferential direction
- 35 cm lengthwise

If a creep inclination test is ordered, the total length must be at least 40 cm. A division of the sample is possible. Minimum size of the individual segments: 50 mm width and 20 x wall thickness in circumferential direction. For apex pressure tests, a circular ring section of at least 40 cm length must be taken.

The sampling point is to be determined in advance with the client. In the case of non-accessible sewers, the sample is usually taken from the manhole section (by using a suitable, sewer-simulating support).

If sufficient support in the sampling area is not ensured, for example due to insufficient space, this will result in unrepresentative samples.

An intermediate manhole is most suitable for sampling as it is free of installation, inflation and / or curing equipment. Sampling from the start or target shaft can be representative to a limited extent.

In the case of larger dimensions, deviating channel geometries (e.g. egg-shaped profiles) or if it is not possible to take a representative sample from the pipe section, the sample can be taken from the manhole. This also applies to any second sampling that may be necessary. The sampling points in the pipe section must be sealed permanently, water-tight and in liner wall thickness.

The client and the contractor must also agree on the following:

- Time and place of sampling
- if applicable, on the closure of the sampling point

Samples from UV-cured cured-in-place pipes must be labelled immediately after removal and packed in opaque packaging to prevent post-curing.
The material sample is labelled as follows:

- Site designation
- Date of sample collection
- Shaft number
- Holding number
- Signature of the Principal's Representative and the Contractor's Representative

The sample taken shall be deemed representative for the respective installation section, provided that the contractor does not communicate any reservations. After joint labelling, the sample is taken into custody by the client until it is handed over to an accredited testing institute. The sample submission form is filled in jointly by the client and the installation company on site after the sample has been off-cut (cf. chapter 11.3). The tests to be carried out are to be marked with a cross and ordered. The correctness of the data shall be confirmed by the signature of both contracting parties after joint inspection. The original sample submission form remains with the client. The company carrying out the installation shall receive a copy. Another copy of the original is sent to the testing institute with the sample.

8.3.2 *Testing of a representative sample*

The tests listed in Annex 11.5, item 3 must be carried out on the sample. A flow chart for the standard test can be found in Annex 11.2. Information on how to carry out the material test can be found in Code of Practice DWA-A 143-3. The results of the material test are to be compared with the system-specific characteristic values according to abZ.

> **Note:** The characteristic values listed in the abZ are quantile values. The characteristic values determined in the suitability test are reduced to take into account manufacturing tolerances. For products manufactured on site (construction site conditions), a quantile factor of 0.8 is recommended in accordance with DIN 18820. This is used in many existing abZ.

> **Regulatory gap:** DWA-M 144-3 provides guidelines for the evaluation of test results. The factsheet requires additional tests to be carried out in the event of deviations in the short-term E-modulus and flexural stress that lie outside a range of -10 % to +20 % compared to the characteristic values determined in the suitability test. This requirement is in contradiction to the abZ. The characteristic values specified in the abZ are minimum values. If the characteristic values from the abZ are not met, this must be evaluated on a case-by-case basis. Exceeding the minimum values from the abZ by approx. +50 % is typical depending on the system. Additional tests are not required.

Contrary to the specifications of DWA-A 143-3, but in accordance with DIN EN ISO 11296-4, the grinding off of excess resin on the back of the test pipes is permissible. A mathematical deduction of excess resin thicknesses is not permissible, as this would lead to an overestimation of the material characteristics of the sample. If the mechanical properties of the material fall below the values specified in the suitability test, the curing can be checked. For epoxy resin laminates, this is done by determining the glass transition temperatur by means of DSC analysis (according to DWA-A 143-3). For UP and vinyl ester rein resin laminates, a residual monomer content is determined by gas chromatography (according to DWA-A 143-3). The glass transition temperatures for epoxy resins are part of the abZ. The residual monomer content is currently not part of the abZ.

Regulatory gap: DWA-M 144-3: 2012 specifies a limit value of 4 % residual styrene content in relation to the total laminate. The limit value specification of the DWA factsheet is not secured with regard to the suitability tests within the scope of the abZ and must be re-evaluated. The limit value is too high and the hose processes curing on site do indeed have lower residual styrene contents in modern remediation practice. A new definition of the limit value for sewer renovation with cured-in-place pipes is currently being discussed in practice and is being worked on by the RSV.

Information for testing laboratories: If excessive residual styrene content is suspected (odour, consistency in the outer laminate), the laboratory must inform its client and, if necessary, recommend testing of the residual styrene content. If undercuring of epoxy resin laminates is suspected, the laboratory must inform the client and, if necessary, recommend a DSC analysis in accordance with DWA-A 143-3.

The 24h creep tendency can be used to evaluate the long-term behaviour of the laminate. If the determined creep tendency is less than or equal to the value specified in the suitability certificate (or in the abZ), the reduction factor A1 can be used to calculate the long-term characteristic values for a structural recalculation using the determined material characteristic values (actual values).

Regulatory gap: The mentioned formula for the 24h creep tendency in DWA-A 143-3: 2014 for determining the bearing force is only applicable if the deflection is in the linear-elastic range. The support force must be selected so high that it corresponds to at least 20 % of the quantile value of the flexural stress determined in the suitability test.

8.4 Monitoring of the used testing equipment

All test equipment used for documented proof of the quality of the renovated pipe must be regularly checked with calibration standards or certified reference measuring instruments. This includes in particular devices for pressure, temperature and force measurement.
The performance (type and scope) and result of the inspections must be documented, as well as the due date of the next monitoring.
For this purpose, it is necessary that the measuring devices are marked with device or inventory numbers. Only inspected measuring instruments may be used. The

measuring

number shall be noted on the respective protocols or the devices shall be marked. The aforementioned provisions shall apply mutatis mutandis to measuring instruments that are permanently integrated in work equipment and can only be tested in conjunction with it.

9 Operation of the renovated pipe

Approved cured-in-place pipes have proven their resistance to high-pressure flushing (according to DIN 19523) and mechanical abrasion (according to DIN EN 295-3). These verifications are carried out under simulation of 50 years of operation.
The special requirements in the operation of sewers rehabilitated by means of cured-in-place pipe lining must be taken into account in the operation and maintenance plan according to DIN EN 752. In particular, the specific conditions for hose liners must be observed during the cleaning and visual inspection of rehabilitated pipes. For this, good documentation of the inventory and corresponding identification in the cadastre is essential.
The personnel must be instructed in the handling of cured-in-place pipes.

9.1 Cleaning of the renovated pipe

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Only high-pressure cleaning or combined high-pressure cleaning or surge flushing should be used for cleaning cured-in-place pipes (see DIN EN 14654-1). Due to the low hydraulic roughness of the cured-in-place pipes, low jet flushing stream power densities are sufficient for cleaning.

The RSV factsheet 12.1 "Cleaning of renovated pipelines - transmission of DIN 19523 into practice" provides concrete information on high-pressure cleaning and gives examples of flushing pressures when using common jetting nozzles.

For high-pressure cleaning, select the nozzle and the rinsing parameters,

- that the efficiency for removing the deposits (clearing material) is increased to a maximum,
- that the risk of damage to the rehabilitated pipe is reduced to a minimum, and
- as appropriate for the nature of the deposits to be removed.

It should be cleaned with as little pressure as possible.
The use of mechanical cleaning devices such as chain cutters, mechanical root cutters, scrapers, etc. in pipes rehabilitated by means of pipe lining should be avoided. Such devices can considerably reduce the useful life of cured-in-place pipes (destruction of the protective pure resin layer or the inner liner). Extensive damage to the cured-in-place pipes is also possible.

9.2 Use of robot and camera systems

When using robots and camera systems for optical inspection, subsequent connection of connecting pipes or for repairs, it must be ensured that the equipment used does not cause any damage to the liner. The vehicles must be equipped with drive wheels that do not damage the liner surface. The use of pointed or very rough wheel surfaces (e.g. granulate coatings) to improve the friction of the wheels is not permitted.

10 Economic efficiency and useful life

With regard to economic efficiency considerations, especially in comparison with other types of renovation, the consideration of the useful life of the system is a relevant influencing factor. The useful life approach is included in technical considerations (technical useful life), cost comparison calculations and depreciation-relevant considerations. Different useful lives can be used for these areas of consideration.

10.1 useful life

For cured-in-place pipes in the wastewater sector, there is experience of approx. 35 years with glass fibre liners and almost 50 years with needled felt liners. Provided that the requirements for material, technology, execution of installation and quality control are met during installation, technical useful lives of at least 50 years can be assumed. The reason for this is, first of all, the suitability certificates established in the relevant national technical approvals / general construction technique permits (abZ / aB; DIBt approval), which are designed for this time horizon with regard to the relevant reduction factors.
Analyses of needled felt liners installed more than 40 years ago have shown hardly any signs of ageing and the material characteristics are almost the same as their initial values. The positive experiences indicate that the 50-year technical useful life, with the long-term view taken as a basis in the DWA-A 143-2 design basis, is rather a conservative approach. This results, among other things, from the fact that the permanently existing load cases assumed in the stability calculation (essentially GW pressure) often do not act permanently on the liners.

> The experience available today indicates that cured-in-place pipes can be expected to have a technical useful life of more than 50 years - provided that the existing pipeline is properly manufactured on site.

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10.2 Cost comparison calculation

A cost comparison calculation is carried out to evaluate several renovation options among each other. If sewer rehabilitation by means of pipe lining is technically possible, a cost comparison calculation is not necessary in the standard case as the cost advantage of pipe lining dominates. In the case of rehabilitation planning of walkable sewer pipes on longer stretches and / or special planning requirements in terms of statics, hydraulics or other factors, an examination of alternatives and variants in the course of requirements planning can make economic sense.

The economic efficiency analysis is carried out using a dynamic cost comparison calculation (KVR guidelines, DWA 2012) based on the principle of present cost values. The dynamic cost comparison calculation takes into account possible different useful lives of the previously selected technical design options and materials and thus goes far beyond the simple comparison of different direct costs. In the economic evaluation, the selected or expected useful life is of decisive importance. The period under consideration depends on the interest of the cost unit (depreciation, useful life).

In the cost comparison calculation, the procedure is examined with regard to the expected project cost cash value (PCV).

PKB = IK+RIK-∑DFAKE (ZS,ND)

The essential technical terms for the calculation formula are:

Discount factor single payment (DFAKE)	Also called the discount factor, which is determined by multiplying the present value of a cost variable for a single payment at the end of the nth year after the reference date. The factor is assigned to a Table taken from the KVR guideline.
Investment costs (IC)	The IC are the costs required for the one-off realisation of the measure during the period under consideration.
Reinvestment costs (RIK)	The RIK are the costs necessary to repeat the realisation of the same or dependent measures in the period under consideration.
Operating costs (BK)	Operating costs are costs resulting from the measure for ongoing operation and maintenance.
Useful life (ND)	The useful life is the period of time during which the measure fulfils its purpose or after which the measure has to be repeated or a further replacement measure has to be carried out. The technical useful life for pipe lining is set at 50 years.
Interest rate (ZS)	The interest rate is used to calculate the annual real or imputed interest on the asset value - equivalent to IC.
Project cost cash value (PKB)	With the project cost cash value, all payments are discounted to a reference point in time within the framework of the dynamic cost comparison calculation and thus enables an evaluation of different payment dates.

Notes on the calculation

EXKLUSIV

Residual values can arise in the calculation if the examination; investigation period is not a multiple of the technical useful lives of the renovation variants to be examined. The period to be considered does not generally exceed 120 years. Residual values are not offset in order to ensure the required equality of benefits.

As a rule, inflation is not included in the calculation. The operating costs are not taken into account, as the operating costs for sewer rehabilitation and renewal are usually not assessed differently. Even if the useful life of the connection; junction; contact is shorter, this is not relevant, as the useful life of the renovation is used for depreciation. Indirect costs, as advantages of trenchless procedures such as the lower traffic and neighbourhood disturbance as well as construction time, are to be assessed separately.

For a verification of the calculation results, a sensitivity analysis with variation of the interest rate (1 %, 3 % and 5 %) has to be carried out.

10.3 Budgetary classification (depreciation)

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Tube lining systems are procedures for the modernisation of existing sewers. These are regularly equivalent to a "fundamental renewal" within the meaning of the requirements of § 60 WHG. With proper planning and installation, the performance requirements of DIN EN 752 and the other relevant standards and regulations are taken into account on the basis of the "generally recognised rules of technology". These include, among other things, aspects of hydraulic performance, stability (in connection with the existing pipeline) and leak tightness requirements.

The tightness requirements for drains and sewers have increased significantly with the introduction of DIN EN 1610. This means that the modernisation issue (improvement, not restoration) already exists in principle.

In terms of budgetary law, these are - depending on the respective provisions of the municipal levy laws (KAG) of the individual federal states - widespread investments across all federal states. The renovation measures with tube lining methods can basically be regarded as "investment measures", for which an appropriate depreciation period is to be determined as a basis for the calculation of charges.

In accordance with the budgetary principles of the New Municipal Budgetary Law (NKHR), the internal determination of the depreciation period for these procedures should have a high correlation to the expected average technical useful life. The NKHR, which has now been introduced in almost all English municipalities, places a new and special emphasis on the value of measures carried out. It is no longer the lowest possible use of funds (cheap) that is decisive, but rather the best possible output (result) in terms of sustainability that is the budgetary core of public interest. In this respect, depreciation periods of 50 years seem fundamentally justified. The necessary quality requirements in the planning and execution of installation must be ensured.

In this respect, it is important to ensure proper planning in accordance with DWA-A 143-21 and implementation of measures in accordance with DWA-A 143-3 in joint with DWA-M 144-3 with consistent quality monitoring in all areas. This RSV factsheet 1.1 supplements the DWA rules and regulations with current requirements and findings and provides additional information and should be applied. In this way, the expected useful lives can be safely achieved.

10.4 Remaining useful life and Outlook

Previous findings from material tests and inspections of cured-in-place pipes that have been in service for many years indicate that the actual technical useful life exceeds the statically estimated technical useful life (generally 50 years). The period of time during which operational suitability of the liner can be expected beyond the intended technical useful life can be referred to as the remaining useful life.

It is expected that the original short-term characteristics of cured-in-place pipes will be maintained over the service life, provided that no chemical, thermal or mechanical damage to the liner has occurred.

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The assessment of the possible remaining useful life can be made primarily on the basis of a visual inspection. The technical useful life is considered to be completed when

- operational suitability no longer exists,
- there is visible damage such as leaks, cracks, laminate damage or
- Deflections are present that indicate deterioration of the existing pipe soil system.

In addition, a material sample can be taken to check whether the mechanical parameters still correspond to the product-specific characteristics.

The remaining useful life results in cost advantages for the network operator due to the longer useful life and postponed new investments. This has a positive influence on the fee structure.

Long-term investment planning can be carried out by estimating the expected service life of a liner. If required, a specific residual value analysis is possible. On the basis of a material sample taken (component section), the extent to which the material characteristics assumed in the original structural analysis have changed can be identified by means of material testing in the laboratory. The objective is to confirm that the mechanical parameters originally used in the structural analysis, including the reduction factors, are still valid and can be used for a further structural analysis.

The results of the deformation measurement and material testing can form the basis for a static recalculation and evaluation of the liner, if necessary, taking into account the possibly changed boundary conditions (actions, bedding conditions, pipe condition, etc.).

Further considerations on useful life and residual value analysis are currently being dealt with in detail within the framework of a DWA working group ("Useful life influencing factors in sewer rehabiliation"). Results are expected from 2022 onwards.

11 facilities

11.1 Installation protocol Example

1. details of the site

Site ID ____________ Date ____________ Project Manager ____________

Construction project ________________________

Site ID ________ Client ________________________

Plant manager _ Location ____________ Street ____________

2. details of the remediation route

Upper manhole ____________ lower manhole ____________ Number of pipe sections ___

Profile type *(circle, egg, etc.)* DN [mm] ____________ Length [m] ______

Old pipe material *(Stz, B, etc.)* Groundwater installation depth [m] ____________

Route *(straight, bends)* WeatherOutdoor temp . [°C]

3. preparatory work

HD cleaning ☐ *(date)* TV inspection *(date)* ☐ Obstacle clearance *(yes/no)*

Discharge diversion not necessary ☐ Backwater divert ☐

overpump Special features ________________________

4. cured-in-place pipes

System manufacturer ________________________ Liner ID ____________

____________ Liner ID ______ Wall thickness [mm] _ Resin type ____________

manufactured on ____________ shelf life until ____________ Material temp. [°C]

4.1 Impregnation of the cured-in-place pipes *(only for liners impregnated on-site)*

Impregnated length [m] ______ Impregnation responsible ______

	Designation	Batch ID	Made on	Shelf life until	Temp. is [°C]	Temp. set [°C]
Resin						

	Roller spacing [mm]	Mixing time [min]	Processing time [min]	Vacuum [bar]	Mixture ratio [wt.] Resin : Curing agent	Quantities [kg] Resin : Curing agent
should is					:	:

5a. Installation / curing *(heat curing, ambient temperature curing)*

Installation *(inversion, combined)* Installation medium *(water, air)*

Installation direction *(in, against)* Liner outer protection *(e.g. preliner)*

Curing *(hot water, steam, ambient temp.)* Start of installation *(date, time)*

	Installation pressure [bar]	Hardening pressure [bar]	Hardening phase [h]
should			

The pressure and temperature curves must be continuously documented at suitable intervals during the entire installation and curing phase (incl. cooling). This also includes recording the temperatures between the liner and existing pipeline in the manholes.

5b. Installation / curing *(light cure)*

Feed direction *(in, against)* Liner outer protection *(sliding foils, preliners, etc.)*

Light source type Start of installation *(date, time)*

	Hardening pressure [bar]	Pull-through speed [cm/min]
should		

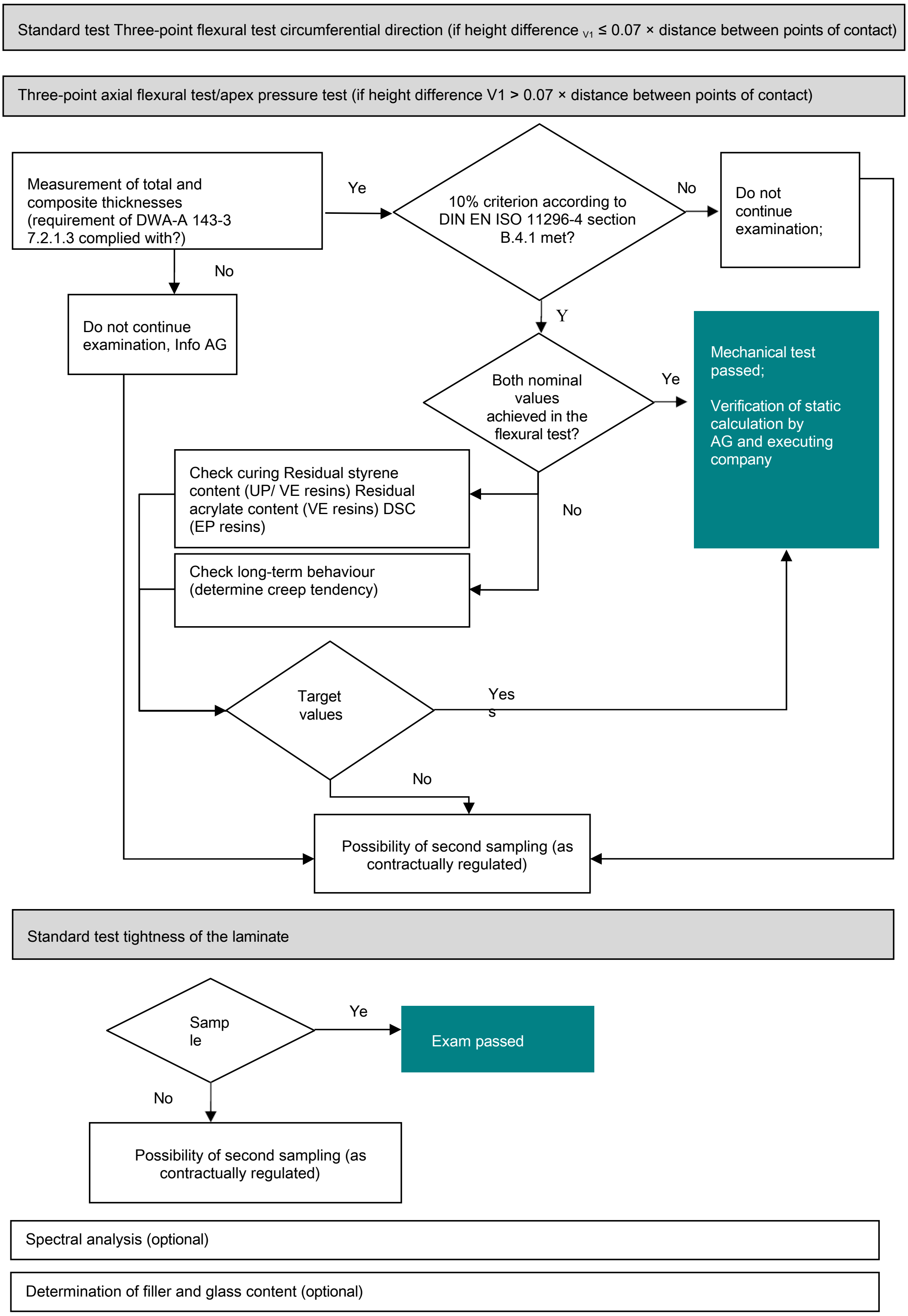
All relevant parameters such as pressure curve, curing speed, lamp condition and surface temperature of the liner must be continuously documented electronically at suitable intervals during the entire calibration and curing phase (incl. cooling).

6. sampling

Sample designation ____________ Sampling point *(end shaft, etc)*

Withdrawal position *(sole, crest, etc.)*

11.2 Flow chart for standard testing based on DWA-A 143-3



11.3 Sample submission form Example

Sample submission form material testing

Page 1 - Standard tests

Shipping to: ______________________________

☐ **Initial inspection** ☐ **Repeat test** for test report no.: ______________

Sampling	Date	Time	Installation date	Confirmation	Name	Signature
				executing Company		
				client		

Sample identification						
Materials Testing WG			DIBt approval no.			
client			Liner/ Material ID			
Building project			pipe section			
Executing company			Tube geometry*			
System manufacturer			DN [mm]*			
liner type*			Off-cut point	pipe section	End-manhole	ZW manhole
Sample designation*				☐	☐	☐
Materials	Carrier*	Resin	Off-cut position	crest	Fighter	sole
				☐	☐	☐
Coating is integrated part	☐ yes ☐ no	☐ inside ☐ outside	Comments			

Target values			
Youngs modulus E_f [MPa]		Circumferential modulus E_u [MPa]	
Flexural stress σ_{fB} [MPa]		Static erf. Wall thickness [mm]	

Test results (please tick the tests to be carried out)

Standard tests

☐ **Youngs modulus, flexural stress** according to DIN EN ISO 178/ DIN EN ISO 11296-4

Test date	Ef [MPa]	σfB [MPa]	em [mm]	ec [mm]	etot [mm]	Test direction
						○ axial ○ radial

☐ **Watertight; waterproof** according to DWA-A 143-3

Test date	Test time [min]	Test pressure [bar]	Test result
			○ ○

☐ **Circumferential E-modulus, initial ring stiffness** according to DIN EN 1228 (ISO 7685)

Test date	EU [MPa]	S0 [N/mm²]	em [mm]	ec [mm]	etot [mm]

☐ **Additional examinations commissioned (see page 2)**

Result evaluation / -sharing

Passing on the test results to: ☐ Client ☐ Executing company ☐ System

manufacturer Evaluation of the test results to be carried out by the testing institute? ☐ yes ☐ no

	fulfils	Not met
Youngs modulus E_f	○	○
Flexural stress σ_{fB}	○	○
Perimeter E module E_U	○	○
Wall thickness e_m	○	○

Comments

Signature Examiner/Laboratory Manager			

*Mandatory information for determining the target values

1 / 2

Sample submission form material testing

Page 2 - Additional examinations

Shipping to: ______________________________

☐ **Initial inspection** ☐ **Repeat test** for test report no.: ____________

Sample identification

Materials Testing WG		DIBt approval no.	
client		Liner/ Material ID	
Building project		pipe section	
Executing company		Tube geometry*	
System manufacturer		DN [mm]*	
liner type*		Off-cut point: pipe section ☐ / End-manhole ☐ / ZW manhole ☐	
Sample designation*			
Materials	Carrier*: / Resin:	off-cut-position: crest ☐ / Fighter ☐ / sole ☐	
Comments			

Setpoints

Glass transition temperatur T_{g1} [°C]		creep tendency [%]	
Glass transition temperatur T_{g2} [°C]		Residue on ignition [%]	
Residual monomer content [%]		Density ρ [g/cm³]	

Test results (please tick the tests to be carried out)

Additional

☐ **Thermal analysis (epoxy resins)** according to DIN EN ISO 11357-2/ half-step height method (DSC

Test date	Glass transition temperatures T_g [°C]			
	T_{g1}		T_{g2}	

☐ **Residual monomer content (UP / vinyl ester resins)** according to DIN

Test date	Weighing -in [mg]	Monomer type	Residual monomer content [mg/kg]	Residual monomer content [%]	Weighing in relation to Total	Weighing in relation to Pure resin
					○	○

☐ **24h creep tendency** based on DIN EN ISO 899-2

Test date	Kn24 [%]

☐ **24h creep tendency** i. A. to DIN EN 761 (ISO

Test date	Kn24 [%]

☐ **Calcination process** according to DIN EN ISO

Test date	Resin content [%]	Residue [%]	Glass proportion [%]	Surcharge [%]

☐ **Spectral analysis according** to ASTM D5576 (FT-IR)

Test date	Resin

☐ **Density** according to DIN EN

Test date	Density ρ [g/cm³]

Evaluation/ dissemination of results

Passing on the test results to: ☐ client ☐ executing firm ☐ System manufacturer

Evaluation of the test results to be carried out by the testing institute? ☐ y ☐

	fulfils	Not met
Glass transition temp. T_{g1}	○ ○	○ ○
Glass transition temp. T_{g2}	○ ○	○ ○
Residual monomer content	○ ○	○ ○
24h creep tendency		

Comments

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Signature of examiner/laboratory		Sample ID	

*Mandatory information for determining the target values

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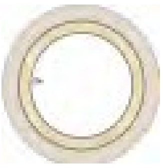
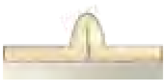
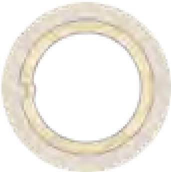
11.4 Wrinkle types, causes and assessment

Fold type	Scheme	Possible cause(s)	Evaluation
Axial fold (longitudinal fold), not filled		restricted access, change in cross-section, pipe offsets, fluctuations in old pipe diameter, groundwater penetration (invert fold), over-assembled hose, insufficient set-up pressure, insufficient curing	System statically weakened. Can lead to curing deficits with purely UV-curing systems (thickness, unfavourable UV irradiation angle). No curing deficits to be expected with heat curing systems (except for invert folds).
	 Invert fold		
Axial fold (longitudinal fold), filled	 Filled fold with separation	Restricted access, change in cross-section, pipe offsets, fluctuations in existing pipeline diameter, over-assembled hose	System statically weakened (separation e.g. by an outer liner acts like an unfilled fold). Can lead to curing deficits with purely UV-curing systems (thickness, unfavourable UV irradiation angle). No curing deficits to be expected with heat curing systems.
	 Filled folds without Ply separation		No effect on the static load-bearing capacity. Does not occur with UV-curing systems. No curing deficits to be expected with heat curing systems.
	 Surface fold	restricted access, elongation of the inner layer during installation	No effect on the static load-bearing capacity. Does not occur with UV-curing systems. No curing deficits to be expected with heat curing systems.
	 Inner folds in the laminate	restricted access, pipe offsets, change of direction (bends)	No effect on the static load-bearing capacity. Can lead to curing deficits in UV-curing systems (thickness). No curing deficits to be expected with heat curing systems.
Fold in circumferential direction (cross fold)	 not filled	Restricted access, change of cross-section, pipe offsets, change of direction (bends), compression of the hose during installation.	No effect on the static load-bearing capacity. Possibly effects on the high pressure flushing resistance. No curing deficits are to be expected with UV-curing systems, depending on the degree. No curing deficits to be expected with heat curing systems.
	 filled		

Concealed folds		Compression of the hose during installation (pressure drop).	System statically weakened. The assumptions made in the static calculation no longer apply (e.g. annular gap). Can lead to curing deficits in UV-curing systems (thickness, unfavourable UV irradiation angle). Can lead to curing deficits in heat curing systems.
Shape fold		Insufficient cleaning, insufficient reprofiling of the existing pipeline	system may be statically weakened. Check the assumptions made in the static calculation for the imperfections,
Overexpansion, increased ring gap, non conforming liner (Counterpart to the wrinkling)		Cross-section change, underfabricated hose	System statically weakened (lack of compression of the material, annular gap). No hardening deficits to be expected. Note: This is hardly recognisable in the visual inspection. This can be indicated by very smooth liners without any image of the existing pipeline and the inlets.

11.5 Overview of the tests for in-house and external monitoring

	No.	Subject of the examination	Proof of the properties	Testing according to specification	Standards and guidelines	Extent and frequency of: Self-monitorin	External moni
Production	1.	Materials	Factory certification		DIN EN 10204		At least 2 times per year acc. DIN 18200
	1.1	Reaction resin masses Reactants	Delivery data Storage stability Curing behaviour	Viscosity Density Gelling time Refractive index	DIN EN ISO 3219 or DIN EN ISO 2555 DIN 51757 or DIN EN ISO 2811-1 DIN 16946-1 or DIN EN ISO 10364 ISO 5661	each delivery	
	1.2	Synthetic fibre - substrate	Designation / Type	Thickness Weight per unit area Tensile strength elongation	DIN EN 29073-3 DIN EN ISO 9864 DIN EN ISO 9863-1	each delivery	
	1.3	Textile glass fibre reinforcement	Designation / Type	Glass area weight Glass distribution	DIN 61850 DIN EN 14020-2 i.A. DIN EN ISO 9864 i.A. DIN EN ISO 9863-1	each delivery	
	1.4	Aggregates	Substance type / designation	Grain size Bulk density Water content	DIN ISO 3310-1	each delivery	
suitability test	2	Prefabricated liner hoses	Suitability test				At least 2 times per year acc. DIN 18200 (randomly)
	2.1	Liner hoses unhardened ready for installation	Resin consumption wall structure	Impregnation weight Reaction behaviour	DIN 16946-1	Initial test (1x) and subsequently each manufacture	
	2.2	Liner hoses cured pipe	Suitability certificate mechanical and chemical characteristics	Peak pressure test (short term / long term)	DIN EN 761 DIN EN 1228 ISO 7685 ISO 7684 ISO 10468	Initial test (1x) System-dependent depending on wall structure and dimension	
				Ring bending tensile strength Ring stiffness Circumferential modulus of elasticity	DIN EN 761 DIN EN 1228 ISO 7685 ISO 7684 ISO 10468		
				longitudinal tensile stress	DIN EN ISO 527-2 DIN EN 1393		
				Internal pressure test (short term / long term)	ISO 8521 ISO 7509 / ISO 10928 (only for pressure lines)		
				chemical suitability	DIN EN ISO 175 DIN EN 1120		
				Suitability against HD flushing devices	DIN 19523		
				Watertight; waterproof	DIN EN 1610		
				Glass / filler content	DIN EN ISO 1172		
				Density of the cured-in-place pipes	DIN EN ISO 1183		
				Flexural strength Youngs modulus as 5 % quantile value	DIN EN ISO 11296-4 DIN EN ISO 178 DIN EN 1228		

			Tensile strength Elongation at break	DIN EN ISO 527-4		
			Creep tendency as a function of sample age	DIN EN 761 DIN EN ISO 899-2		

	3	Site samples	Moulding material properties				
			Mechanical parameters measured against the pipe bend (in circumferential direction)	Flexural strength Youngs modulus Wall thickness	DIN EN ISO 11296-4 DIN EN ISO 178 DIN EN 1228	each curing measure	2 times per year, alternatively external quality assurance Operation: every Construction measure by AG
				Laminate leak test	Negative pressure test with water		
				24h E-module creep tendency	DIN EN ISO 899-2 DIN EN 761	as required / in individual cases	
				Annular gap measurement liner / existing pipeline		Every accessible channel	
				Residual monomer content	ISO 4901 in accordance with DIN 53394	as required / in individual cases	

12 Standards and Rules and regulations

12.1 standards

DIN 16946	Reactive resin moulding materials; casting resin moulding materials
DIN 18820	Laminates of textile-glass reinforced unsaturated polyester and phenacrylate resins for load-bearing units (GF-UP, GF-PHA)
DIN 19523	Requirements and test methods for determination of the high-pressure jet resistance and flushing resistance of pipe components for drains and sewers.
DIN 53394	Testing of plastics; determination of monomeric styrene in reactive resin moulding materials based on unsaturated polyester resins
DIN 53765	Testing of plastics and elastomers; thermal analysis; differential scanning calorimetry (DDC)
DIN 55673	Paints and varnishes and their raw materials - Near infrared spectrometric analysis - General working principles
DIN 61853-1	Textile glass; textile glass mats for plastic reinforcement
DIN CEN / TR 15729	Plastics piping systems - Glass fibre reinforced duro- Plastic materials (GRP) based on unsaturated polyester resin (UP) - Report on the determination of the mean abrasion after a fixed number of runs
DIN EN 752	Drainage systems outside buildings
DIN EN 761	Plastics piping systems - Pipes made of glass fibre reinforced thermosetting resin systems (GRP) - Determination of the creep factor in the dry state
DIN EN 1228	Plastics piping systems - Pipes made of glass fibre reinforced thermosetting resin systems (GRP) - Determination of the specific initial ring stiffness
DIN EN 1610	Installation and testing of drains and sewers DIN EN 1767 Products and systems for protection and repair of concrete structures - Test methods - Infrared analysis
DIN EN 1997	Eurocode 7: Design, calculation and dimensioning in geotechnics Part 2: Exploration and examination of the foundation soil
DIN EN 12127	Textiles - Textile fabrics - Determination of mass per unit area using small samples
DIN EN 13121	Above-ground GRP tanks and containers
DIN EN 13380	General requirements for units for sewer rehabilitation and repair outside buildings
DIN EN 14364	Plastics piping systems for drains and sewers -Ducts with or without pressure - Glass fibre reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) - Specifications for pipes, fittings and joints

DIN EN 14654	Management and monitoring of operational measures in drains and sewers Part 2: Sewer renovation
DIN EN 15885	Classification and characteristics of techniques for the renovation, repair and renewal of sewer pipes and sewers -pipes
DIN EN ISO 178	Plastics - Determination of flexural properties DIN
EN ISO 899	Plastics - Determination of creep behaviour
DIN EN ISO 1172	Textile glass reinforced plastics - Prepregs, moulding compounds and laminates - Determination of textile glass and mineral filler content; calcination method
DIN EN ISO 1183	Plastics - Procedure for the determination of the density of non-foamed plastics
DIN EN ISO 9001	Quality management systems - Requirements
DIN EN ISO 11296	Plastics piping systems for the sewer rehabilitation of buried non-pressure drainage networks (non-pressure drainages) Part 1: General Part 4: Cured-in-place pipe lining on site Amendment 1: Update of definitions, requirements for markings and procedures for the alternative indication of flexural test results (ISO 11296-4:2018 / AMD 1:2020); English and German version EN ISO 11296-4:2018 / prA1:2020.
VOB / C ATV DIN 18299	VOB Construction Tendering and Contract Regulations Part C: General technical contract conditions for construction works (ATV) - General regulations for construction works of any kind
VOB / C ATV DIN 18326	VOB Contracting Regulations for Construction Work Part C: General technical terms of contract for construction works (ATV) - Renovation works on drainage sewers

12.2 DWA- rules and regulations

ATV-A 139	Installation and testing of drains and sewers
DWA-A 143	Remediation of drainage systems outside buildings Part 1: Planning and monitoring of remedial actions Part 2: Structural analysis for the sewer renovation and -ducts with lining and assembly methods Part 3: Cured-in-place pipes curing on site Part 7: Repair of drains and sewers using short liners, tees and tophat profiles (lateral connection collars) Part 21: Structural Rehabilitation Planning
DWA-M 144	Additional technical terms of contract (ZTV) for the sewer renovation of drainage systems outside buildings Part 3: Sewer rehabilitation with tube lining method (cured-in-place pipe lining) for sewer pipes

DWA-M 149 Condition survey and assessment of drainage systems outside buildings Part 2: Coding system for optical inspection Part 5: Optical inspection

12.3 RSV- Rules and regulations

RSV M 5	Repair from drainage pipes and sewers by robotic methods
RSV M 6.2	Rehabilitation of manholes and structures in drainage systems - repair / renovation
RSV M 7.1	Sewer rehabilitation of non-pressurised pipes / connecting pipes with cured-in-place pipe lining
RSV M 7.2	Top-hat profile technology for connecting pipes - repair / sewer rehabilitation
RSV M 7.3	Sewer renovation of gravity drainage systems inside buildings with curing on site reaction resin-based systems

13 Safety regulations and laws

The existing laws with regard to occupational safety, environmental protection and waste recycling and disposal must be complied with. Essential safety regulations are listed below; this list is not to be understood as exhaustive.

13.1 Accident prevention regulations

UVV - BGV A 1 Principles of Prevention in the version of 01 January 2004 UVV - BGV C 5 Waste water systems conforming to the version of 01 January 1997

13.2 Berufsgenossenschaftliche Rules

DGUV 103-003 Work in enclosed spaces of waste water systems
DGUV 112-190 Use of respiratory protective equipment
DGUV 112-198 Use of personal protective equipment against falls from a height DGUV 201-052 Pipeline construction work

13.3 Berufsgenossenschaftliche Information

BGI 594	Use of electrical equipment in the event of increased electrical hazards of March 2006

13.4 Laws, ordinances, regulations on environmental protection

AbfBestV	Waste Destruction Ordinance
AbfG	Waste Act
AbfRestÜberwV	Waste and Residual Materials Monitoring Ordinance
AVK-TV Manual	Working Group Reinforced Plastics-Technical Association e.V.
BBodSchG	Law for the Protection of Harmful Soil Changes and for the Sewer Renovation of Contaminated Sites (Federal Soil Protection Act)
GefStoffV	Ordinance on Hazardous Substances
GGVS	Dangerous Goods Ordinance Road
RestBestV	Ordinance on the Determination of
Residual Substances	
TA-Abfall	Second General Administrative Regulation on the Waste Act Part 1: Technical Instructions for the Storage, Chemical / Physical and Biological Treatment, Incineration and Disposal of Wastes Requiring Special Supervision
WHG	Law on the Order of Water Resources (Water Resources Act)

14 List of abbreviations

abZ General national technical approval aB
General construction technique
permit
ATV-DVW Abwassertechnische Vereinigung e.V. - German 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)
DDK Differential scanning calorimetry (DSC) DIN Deutsches Institut für Normung (English 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
DPH Dynamic probing with heavy pile-driving
probe DPL Dynamic probing with light pile-driving
probe
DWA German Association for Water, Water and Waste e.V. E-CR
Electric Corrosion Resistant (E-glass)
EP Epoxy
GRP Glass fibre reinforced plastic
ISO International Organization for Standardization
KAG Municipal Charges Act
KRB Small pile driving
NKHR New municipal budget and accounting system OF
Olefin
POLYETHYLENE Polyethylene
POLY(ETHYLENE TEREPHTHALATE) Polyethylene terephthalate
PN Nominal pressure
PP Polypropylene
PPE Personal protective equipment
TPU Thermoplastic polyurethane
UP Unsaturated polyester
UV Ultraviolet radiation
VINYL ESTER PURE Vinylester
VOB / C Contracting Rules for
Construction, Part C WHG Federal Water Act

Formula symbol

d_a External diameter
d_i Internal diameter
e Wall thickness
e_c Composite thickness
e_m Composite thickness
e_n Nominal wall thickness
e_{tot} Total wall thickness
t_L Liner wall thickness (design wall thickness)

15 List of figures

16 list of tables

17 Author List

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