IKT - Institute for Underground Infrastructure,
Gelsenkirchen
Germany
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IKT-Comparative Product Test

Rehabilitation methods for wastewater pressure pipes
- Class A liners –

Gelsenkirchen, November 2022

IKT-Comparative Product Test Report:

This English language report summarises the results of the IKT-Comparative Product Test "Rehabilitation methods for wastewater pressure pipes – Class A liners", which was undertaken as a part of the research project "Comparative studies on the rehabilitation of wastewater pressure pipes“ (AZ: 54.05.03-002-F+E/2017.0001).

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1 Background

1.1 Need for the investigation

When damage to wastewater pressure pipes is detected, immediate action is usually required. Trenchless rehabilitation techniques are in the forefront of available options for repairing such damage, as these are expected to cause relatively minor inconvenience at ground level. In many cases, the economic and environmental advantages of trenchless rehabilitation methods outweigh those of replacement using open trench methods. However, in connection with trenchless rehabilitation techniques, wastewater network operators often mention the issue of the difficult situations experienced with wastewater pressure pipes. These include: a lack of, or low number of, access points; coping with bends; the presence of aeration and deaeration valves; lack of information on the exact pipe location; the presence of high and low points in the pipe run; and, in some cases small nominal diameters. Although the first rehabilitation techniques for wastewater pressure pipes are now available on the market, this area still has a considerable need for investigation:

- There is a lack of neutral and independent information on the general suitability of systems for installation into wastewater pressure pipes, the scope of application and the application limits of the individual processes and products, e.g., regarding ability to address specific damage scenarios occurring in such pipes.
- At present, there is relatively little industry experience with rehabilitation methods for wastewater pressure pipes, especially with regard to the procedures for selecting and undertaking rehabilitation. These include: the selection of rehabilitation techniques tailored to the specific application, the implementation of quality assurance measures and the need for over pumping or tankering during installation.
- The current standards and regulations concerning the rehabilitation of wastewater pressure pipes are incomplete. On the one hand, the requirements for the rehabilitation of wastewater pipelines tend only to be specified for the area of gravity pipelines [1]. On the other hand, the terminology and requirements from regulations for the maintenance of water supply pressure pipes cannot be transferred to wastewater pressure pipes without further investigation.

This report summarises the results of the IKT-Comparative Product Test "Rehabilitation methods for wastewater pressure pipes – Class A liners", which was implemented as part of the wider research project "Comparative studies on the rehabilitation of wastewater pressure pipes“.

1.2 Concept of an IKT-Comparative Product Test

The aim of an IKT-Comparative Product Test is to provide wastewater network operators with reliable and independent information on the properties of products and procedures on the market. Statements in process descriptions and manufacturers' marketing information about the performance and quality of their products are subjected to independent and neutral evaluation and testing through an IKT-Comparative Product Test.

The central aspect of this is determining performance under long-term operating conditions. Therefore, testing of their conformity against technical regulations and standards is not a major part of the evaluation, but rather examination of performance against stresses that actually occur during operation, to which the products will be exposed in practice for decades.

The warranty period for sewerage technology products is currently a maximum of five years (in Germany). This is a very short period of time compared to the usual target service lives of 15 - 50 years or more. Damage that only occurs after the five-year warranty period has expired is particularly disadvantageous to clients. Recourse to the manufacturer is only possible in the rarest of cases and is also associated with protracted legal disputes. This results in a considerable financial risk for network operators, which can be reduced by an IKT-Comparative Product Test.

The investigations undertaken in an IKT-Comparative Product Test focus on the installed quality of the products and procedures and its reduction over time during operation. This is undertaken with reference to the fact that the act of installing a product or process in the field can already cause a considerable reduction in quality compared to the “100%” tested factory or laboratory quality. Reasons for this can be unfavourable conditions in the sewer at the time of installation as well as special difficulties in the interaction of process technology and rehabilitation materials. Depending on the process, further reduction in quality is to be expected to a greater or lesser extent during operation Figure 1.

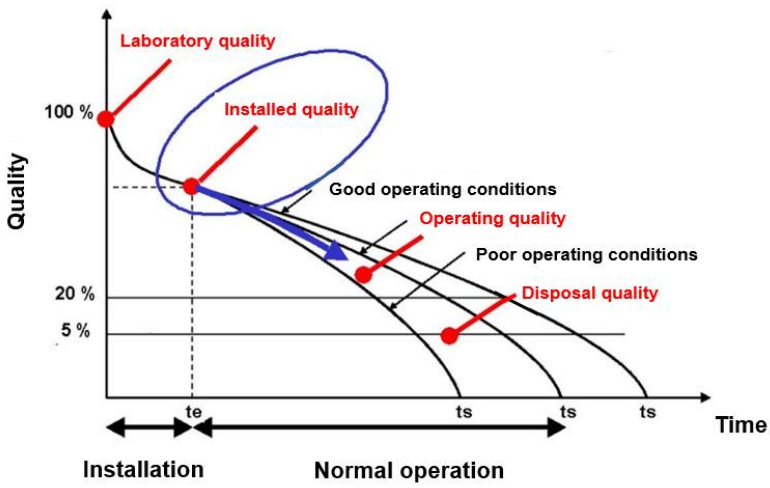


Figure 1. The focus of investigation (blue) of IKT-Comparative Product Tests within a schematic of the performance of an installed product over time.

1.3 Network operators’ participation in the evaluation

An IKT-Comparative Product Test is always accompanied by a Steering Committee made up of a group of wastewater network operators. This Steering Committee decides, through regular meetings, on the key aspects of the project:

- the selection of products or procedures to be evaluated
- the construction or maintenance task to be assessed in the testing of the products or processes

- the relevant performance targets and quality requirements
- the scope and focus of the evaluation programme
- the exchange of information with the product or process manufacturers
- the evaluation and publication of the results

The following wastewater network operators were involved in this IKT-Comparative Product Test on "Rehabilitation methods for wastewater pressure pipes – Class A liners" and formed the Steering Committee:

- Stadt Bottrop
- Emschergenossenschaft
- hanseWasser Bremen GmbH
- Technische Werke Burscheid AöR
- Stadt Iserlohn
- Stadt Voerde
- Stadtentwässerungsbetriebe Köln AöR
- Wupperverband

The actual testing and the documentation of the results were carried out by IKT, as a neutral, independent institute. Within the scope of the testing, IKT was responsible in particular for the engineering development and implementation of the test set-ups and the test programme. Decisions in these regards were made in direct consultation with the Steering Committee.

2 Rehabilitation process overview

In order to improve the performance of a wastewater pressure pipe, the pipe can be rehabilitated. Rehabilitation refers to measures to restore or improve existing pipelines. Rehabilitation techniques include repair, renovation and replacement [2].

A **repair procedure** is used to rehabilitate localised damage, restoring that section of the pipe to its nominal condition [2]. Another possibility for rehabilitation is **renovation**, in which procedures are carried out to improve the current functionality of an existing pipeline. This can be implemented with full or partial inclusion of the original host pipe. Renovation procedures include:

- Lining with continuous pipes
- Lining with discrete pipes
- Lining with close fit pipes
- Lining with cured in place pipes
- Lining with adhesive backed hoses
- Lining with sprayed polymer material
- Lining with inserted hoses
- Lining with cement mortar

If the use of repair and renovation procedures is uneconomical, then a **replacement** can be used to rehabilitate. In this case a new pipeline is installed, either produced in the previous line of the pipe or a different line layout. In this process, the new pipeline system takes over the function of the original pipeline [2].

In the IKT-Comparative Product Test on "Rehabilitation methods for wastewater pressure pipes – Class A liners", only renovation methods were considered, with the focus on the following renovation methods [2]:

- **Close-fit pipe lining:** In this process, the cross-section of a length of PE or PVC-U pipe is reduced before it is drawn into the host pipe. This reduction of the pipe cross-section is achieved by mechanical or thermo-mechanical means and can be carried out in the manufacturing plant or at the installation site. After the section of pipe has been drawn in, it is reformed back by heat and/or pressure and thus fits tightly against the host pipe [2].
- **In-situ lining with cured in place pipes:** For this method, a flexible hose is used as a carrier material which is impregnated with a reaction resin (unsaturated polyester resin, epoxy resin or vinyl ester resin). The installation is undertaken by inverting the hose by means of pressure or by pulling in the hose and then curing it in both cases. By curing the reaction resin with the help of heat, ultraviolet radiation (UV) or the ambient temperature, a load-bearing pipe is created within the host pipe [2].

  Furthermore, on-site curing hose-lining procedures with bonded fabric hoses are available. This method consists of two components, a hose liner and a fabric hose (pressure hose). Two installation variants are available: In the first case, a prefabricated, resin-impregnated hose liner with an already integrated fabric hose is installed. In the second case, two installation phases are used: a hose liner is impregnated with resin, pulled into the host pipe (if necessary, also with a preliner), and then the pressure hose is inverted into the not yet cured hose liner and glued to it. After the resin has been cured, this creates a load-bearing pipe.

Lining methods are divided in EN ISO 11295 [2] into different static classes from A to D (Figure 2).

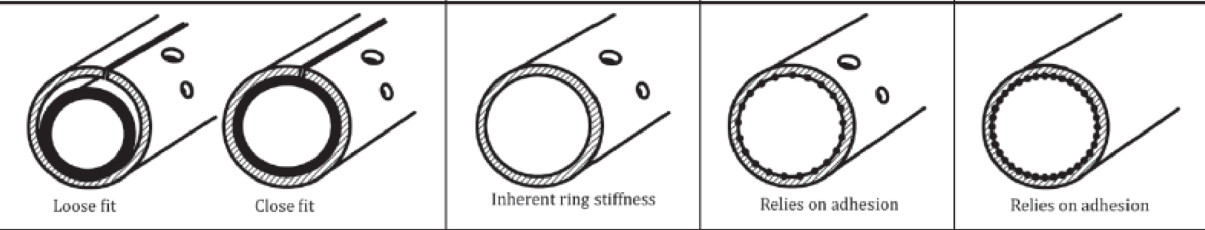
<table>
<tr><th colspan="2">Class A</th><th colspan="2">Class B</th><th>Class C</th><th>Class D</th></tr>
<tr><td colspan="6">
</td></tr>
<tr><td colspan="2">Independent</td><td colspan="4">Interactive</td></tr>
<tr><td colspan="2">Fully structural</td><td colspan="3">Semi-structural</td><td>Non-structural</td></tr>
<tr><td>Lining with continuous pipes</td><td colspan="4">—</td><td rowspan="6">This document is not applicable</td></tr>
<tr><td>Lining with discrete pipes</td><td colspan="4">—</td></tr>
<tr><td rowspan="3">—</td><td colspan="2">Lining with close-fit pipes</td><td colspan="2">—</td></tr>
<tr><td colspan="4">Lining with cured-in-place pipes</td></tr>
<tr><td colspan="2">—</td><td colspan="2">Lining with adhesive-backed hoses</td></tr>
<tr><td>—</td><td>—</td><td colspan="2">Lining with sprayed polymeric materials</td><td>—</td></tr>
</table>

Figure 2. Static classification of lining technologies, from EN ISO 11295 [2].

The differences between the four static classifications are defined in

Liner characteristics	Class A	Class B	Class C	Class D
Can survive internally or externally induced (burst, bending or shear) failure of host pipe	+	—	—	—
Long-term pressure rating ≥ maximum allowable operating pressure (PFA)	+	—	—	—
Inherent ring stiffness[a]	+	+	—[b]	—[b]
Long-term hole and gap spanning at PFA	+	+[c]	+	—
Provides internal barrier layer[d]	+	+	+	+

\+ applies

— does not apply

[a] The minimum requirement is for the liner to be self-supporting when pipe is depressurized.

[b] The liner relies on adhesion to the host pipe to be self-supporting when depressurized.

[c] The liner becomes sufficiently close-fit for radial transfer of internal pressure stress to the host pipe, either during installation or within a short period from initial application of operating pressure.

[d] The liner serves as barrier to the corrosion, abrasion and/or tuberculation/scaling of the host pipe and to the contamination of the pipe contents by the host pipe; it also generally reduces surface roughness for improved flow capacity.

Figure 3. A “Class A” liner is independent of the host pipe and is on its own is capable of withstanding loading from both inside and outside without failure. Class A liners are fully capable of withstanding static loads. The liner does not adhere to the host pipe, but is connected to the host pipe at either end. Class A liners have their own ring stiff-ness, so that the liner is self-supporting in case of a pressure drop within the pipe.

Class B or C liners are considered interactive liners, these rely on some radial support from the host pipe when loads occur to prevent failure [2]. Class D liners only provide internal corrosion protection.

Only Class A liners have been considered in this Project for the rehabilitation of wastewater pressure pipes.

Liner characteristics	Class A	Class B	Class C	Class D
Can survive internally or externally induced (burst, bending or shear) failure of host pipe	+	—	—	—
Long-term pressure rating ≥ maximum allowable operating pressure (PFA)	+	—	—	—
Inherent ring stiffness[a]	+	+	—[b]	—[b]
Long-term hole and gap spanning at PFA	+	+[c]	+	—
Provides internal barrier layer[d]	+	+	+	+

\+ applies

— does not apply

[a] The minimum requirement is for the liner to be self-supporting when pipe is depressurized.

[b] The liner relies on adhesion to the host pipe to be self-supporting when depressurized.

[c] The liner becomes sufficiently close-fit for radial transfer of internal pressure stress to the host pipe, either during installation or within a short period from initial application of operating pressure.

[d] The liner serves as barrier to the corrosion, abrasion and/or tuberculation/scaling of the host pipe and to the contamination of the pipe contents by the host pipe; it also generally reduces surface roughness for improved flow capacity.

Figure 3. Static classification characteristics of liners, from EN ISO 11295 [2].

3 Rehabilitation task

3.1 Damage scenarios

Within the framework of this IKT-Comparative Product Test the rehabilitation of damaged wastewater pressure pipes had to take place under the same boundary conditions for each product that was evaluated. These include, in particular, the geometric designs of the damage scenarios to be renovated, the pipe materials to be encountered and the external loads to be applied. The selection of damage scenarios for the subsequent renovation task is of particular importance for the implementation of comparative product and process tests.

The **damage scenarios** used in this project were defined by the participating network operators (Steering Committee) during working sessions. Due to the extreme diversity of damage encountered in practice, one of the main objectives was to define “representative” damage scenarios for the test set-up. In doing so, the following criteria were taken into account:

- The damage scenario must be capable of being rehabilitated using the available renovation methods.
- The appearance of the damage must sufficiently reflect the situations found in practice.
- The damage scenario must be reproducible in terms of testing in order to offer all participating manufacturers the same starting conditions.

Based on these evaluation criteria, damage scenarios were identified and defined, using the experience of the participating network operators. When defining the damage scenarios, only damage scenarios that can be rehabilitated with trenchless renovation methods were selected. Accordingly, damage scenarios that represented extreme situations were not taken into account. As a rule, such damage is usually repaired as quickly as possible using the open trench method.

Steel was chosen as the rigid pipe material for the test pipe sections (Section 3.2), since, with the exception of the damage scenarios "ovalisation" and "brittle fracture", all the other damage scenarios considered that occurred in flexible pipe also occur in rigid pipes. For this IKT-Comparative Product Test, "ovalisation" was created in the steel pipe (from 1m flanged sections), so the ability of the technologies to line through a deformed pipe could be considered. Regarding a "brittle fracture" to a flexible pipe, this was considered to be an extreme damage situation that cannot usually be renovated and so this scenario was not included. The complete failure of the host pipe subsequent to renovation was examined using the damage scenario "longitudinal crack", in which the complete loss of host pipe support was simulated by removing the host pipe from one section during a phase of the testing.

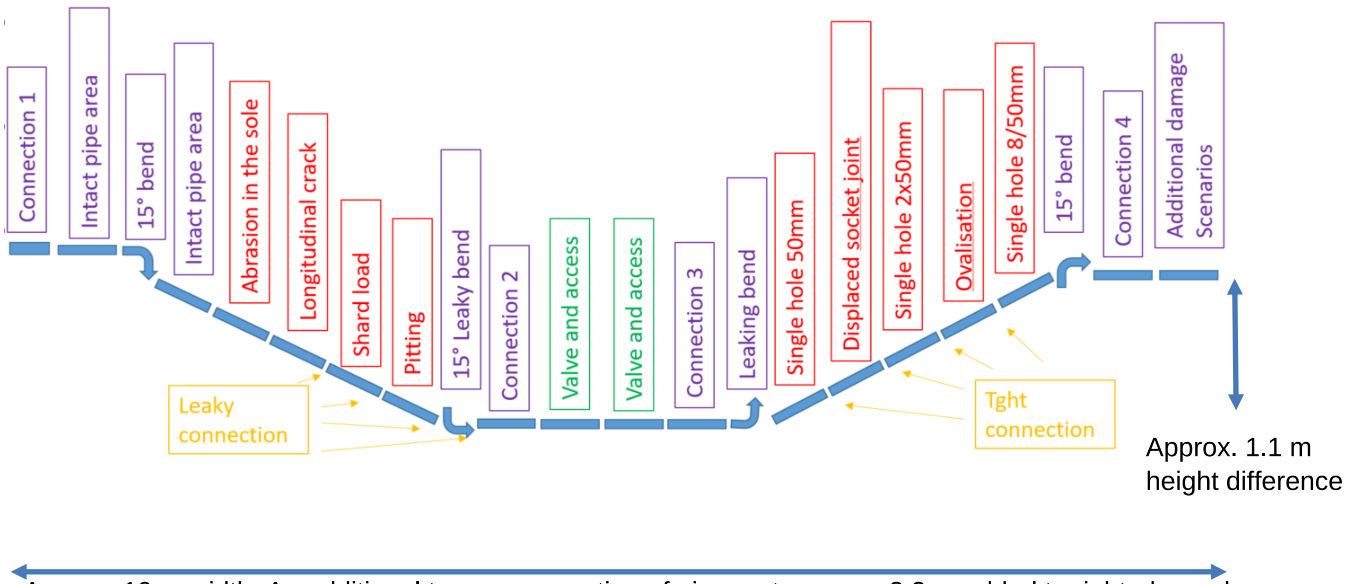
Damage scenarios in host pipes can continue develop further after rehabilitation. For example, the corrosion of the host pipe in a rehabilitated pipeline can continue to progress and take on a greater extent of damage. Therefore, for several of the selected damage scenarios (Table 1), a further deterioration of pipe condition was simulated in the course of the loading and testing programme - testing phase "operating conditions after renovation" (Section 3.3).

To check the reproducibility of the damage scenarios, preliminary tests were carried out to ensure that the same starting conditions could be created for all manufacturers for the testing. In a further step, a **mock test setup on a scale of 1:1**, using PVC pipe, was set up and presented to the Steering Committee. This was used on the one hand, to check its conformity with practice; and on the other for the members of the Steering Committee to make changes directly on the mock-up, in particular to improve its practical relevance (Figure 4).

Figure 4. Selection of damage scenarios by the Steering Committee members (top left and right) and the mock test setup in PVC pipe (bottom).

In addition, the mock test setup (renovation task) was shown to the manufacturers of rehabilitation technologies selected by the Steering Committee. This industry consultation served in particular to record any fundamental concerns they had about the proposed test setup and to identify the potential applications and limitations of their different renovation systems. After consultation with the Steering Committee concerning manufacturers feedback, it was also possible to implement further changes to the test setup, if necessary. After completion of this coordination process, the final test setup and thus the renovation task for the comparative testing were finalised.

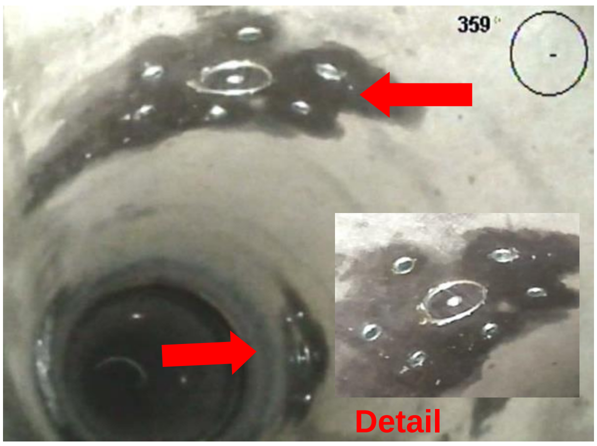
An overview of the completed test pipe lines and the positions of the selected damage scenarios is provided in Figure 5 and the eleven damage scenarios that were selected are explained in Table 1.



Approx. 19 m width. An additional temporary section of pipe up to a max. 3.3 m added to right, depending on number of additional damage scenarios to be lined

Figure 5 General sketch of the test pipe showing the positions of the damage scenarios (each in a separate 1m flanged steel pipe section or a bend) and approx. dimensions of the rig.

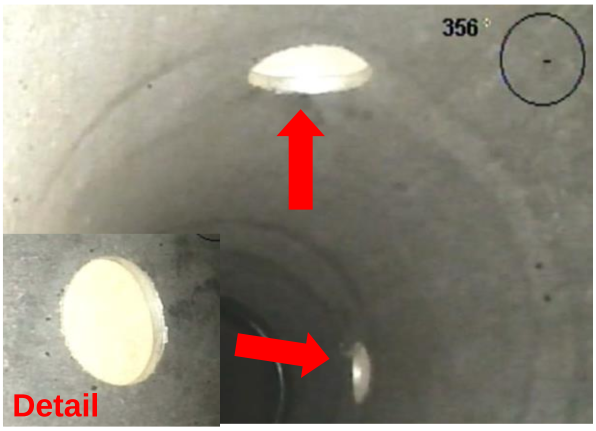
Table 1. Damage scenarios selected for inclusion in the evaluation.

Damage scenarios 1-11	
1. Leaky connection 4x leaking flange connections. For each leaking flange connection, a 5 mm section of the gasket was removed at three points on its circumference (4, 8, 12 o'clock positions).	
2. Pitting Two groups of holes, spaced 30 cm apart. Single open holes were present during installation of the liner: • 1x ø 8 mm (position at crown) • 1x ø 8 mm (position at 3 o'clock in the spring line) To simulate further deterioration in host pipe condition post installation, the ø 8 mm holes were widened to ø 30 mm and another six holes ø 10 mm were opened around each.	

3. Single hole 48 mm

Two single holes, spaced 30 cm apart:

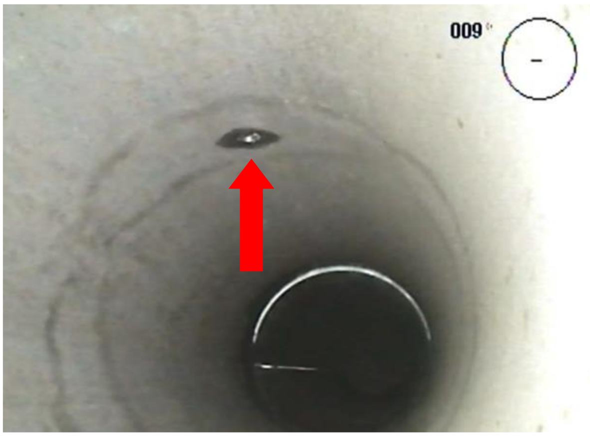
- 1x ø 48 mm (position at crown)
- 1x ø 48 mm (in 3 o'clock position in the spring line)



4. Shard load

During the installation of the liner, a geometrically intact pipe was simulated (flush inner pipe wall).

To simulate further deterioration in host pipe condition post installation the peak pressure of a broken shard of the host pipe was simulated by insertion of a weighted punch through a hole in the crown (F = 300 N, shard punch = ø shank 6 mm/ ø tip 2 mm) [3].



5. Longitudinal cracks

During installation of a liner, a geometrically intact pipe was simulated, which although having cracks in both spring lines 3 o’clock and 9 o’clock), was tightly secured.

To simulate complete loss of the host pipe post installation, with a complete loss of the host pipe resistance, the two halves of the pipe were removed.

6. 15° Leaky bend (2x)

During liner installation, a geometrically intact pipe was simulated (flush inner pipe wall).

To simulate further deterioration in host pipe condition post installation, a hole (ø 8 mm) was opened on the outside of two of the bends (here in the centre of the picture).

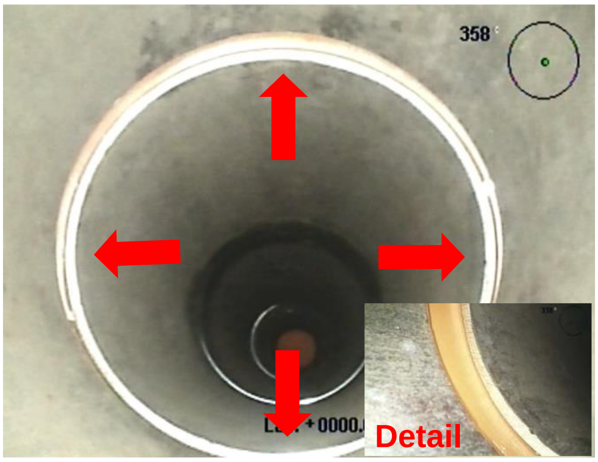
7. Abrasion in the invert

A recess along the invert in which 6x individual holes, each with ø 10 mm, are evenly distributed.
Dimensions of the damage to the invert:

- Width = 30 mm
- Depth = 5.1 mm

8. Axially displaced socket joint

Simulation of a socket joint with 31 mm longitudinal offset (circumferential).

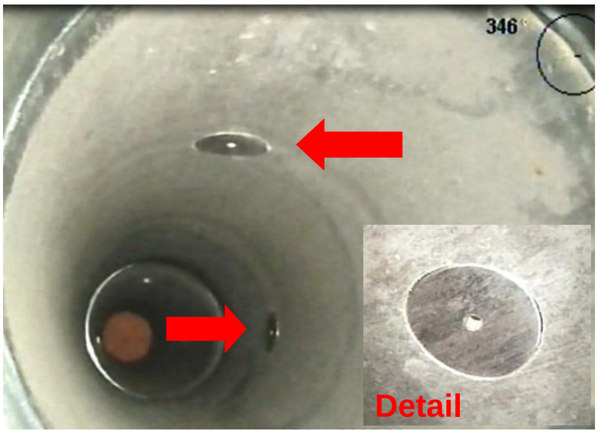


9. Single hole 8/48 mm

Two single holes, spaced 30 cm apart:

- 1x ø 8 mm (position at the crown at 12 o'clock)
- 1x ø 8 mm (position in the spring line at 3 o'clock)

To simulate further deterioration of the host pipe post installation, the two existing holes were enlarged to ø 48 mm.

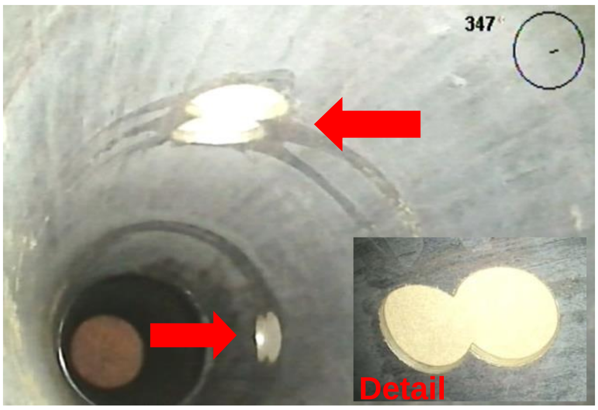


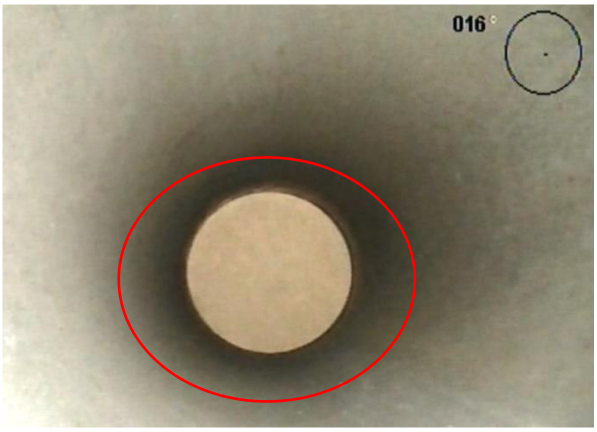
10. Double hole 2x 48 mm*

Two single holes, spaced 30 cm apart:

- 2x ø 48 mm, overlapping L = 90 mm (position at crown)
- 2x ø 48 mm, overlapping L = 90 mm (3 o'clock position in the spring line)

The loading caused by the two points in the overlap is referred to later in this report as 'Metal tip' loading.



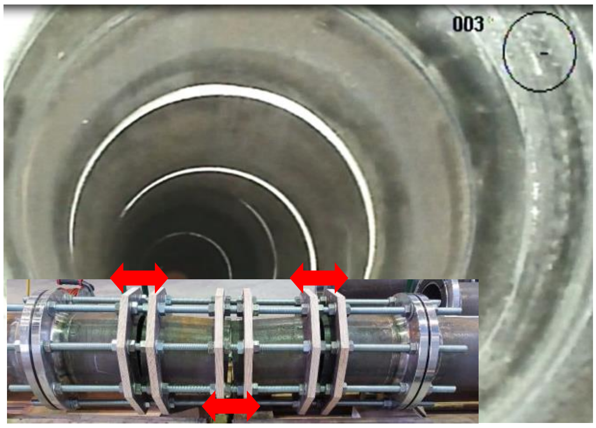
11. Ovalisation by 6%	

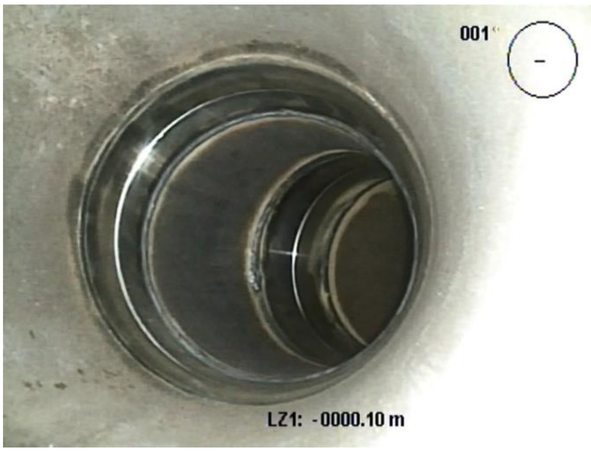
* If concerns were raised by the lining system manufacturer regarding whether this damage scenario could be renovated, this damage scenario was replaced by an undamaged pipe section.

The experimental set-up into which these damage scenarios were placed and its operation regarding the loading and testing programme are explained in the next section.

In addition, the system manufacturers had the opportunity to rehabilitate three further damage scenarios on a voluntary basis. For these, the results did not contribute to the overall comparative evaluation, but they were undertaken to inform both the manufacturers and the wastewater network operators of liner performance in these situations. These were created on an additional section of the test pipe line that was attached to the rig during liner installation. It was then removed for visual evaluation of the damage scenarios and was not subjected to any further operational loads during the project. The three damage scenarios were "angled transverse cracks", "incrustation" and "maximum rehabilitable bend" (Table 2). If the system manufacturer did not wish to rehabilitate these damage scenarios, the damaged section of pipe was replaced with undamaged pipe sections during installation.

Table 2. Selected damage scenarios, that manufacturers could choose to rehabilitate on a voluntary basis in order to explore their effect on the installed liner. These were not subsequently subjected to operational loads.

Damage scenarios I-III, renovated on a voluntary basis	
I. Angled transverse cracks 3 transverse cracks, each 25 cm apart. The middle transverse crack opens in the invert (31 mm) and thus causes an angulation in the pipe. The two outer transverse cracks open accordingly at the apex (15.5 mm).	

II. Incrustation Cross-section reduction by 6 % (12 mm) over 30 cm length. Deposit with rough surface adhered firmly to the pipe wall. Preliminary work by installer to remove the incrustation was not permitted.	
III. Maximum bend that can be renovated Renovation of a horizontal bend (15° to 90° depending on the information given in the manufacturer's self-disclosure).	

3.2 Development of the test rig

The damage scenarios explained above (Section 3.1) needed to be installed into a **test rig,** which would both allow the installation of trenchless renovation systems and generate the operational loading with parameters typical of pumping stations. For the development of the test rigs, in DN 200 nominal diameter, a mock-up of the test setup was initially created from PVC pipes (Figure 4), following intensive preliminary planning and coordination with all project participants. This made it possible to visualise the renovation task and was of great help for the detailed planning.

An essential evaluation criterion already identified in the planning phase of the project was the layout of bends that were to be included. These were defined according to decisions of the Steering Committee, in such a way that these did not lead to the exclusion of individual products. However, it was also required that the products would be able to demonstrate the maximum angle of bend they could be installed through.

On this basis, discussions were held with manufacturers in order to compare application possibilities and limits and to address any concerns. The results were presented to the Steering Committee, discussed and then the test set-up with steel pipes in the form of a pressure pipe was finalised.

The IKT large-scale test facility was utilised for the construction and operation of the tests. This offered comprehensive possibilities for pipe routing, accessibility, observation, groundwater simulation, etc. Furthermore, it was of great importance in the context of this project to be able to fully inspect the rehabilitated pipelines in order to be able to detect even minor leaks and to carry out planned changes in the condition of individual damage scenarios. For this reason, the pipes to be renovated were deliberately not covered with soil. All these considerations meant that the large-scale test facility could only accommodate a maximum of four test pipelines, running in parallel, at one time. Thus, as it had been determined that up to eight products should be evaluated (6 for this IKT-Comparative Product Test and 2 additional systems for research purposes, see Section 3.3), this had to be undertaken in two sequential test rig setups, each with four test lines.

IKT's large-scale test facility is a solid steel trough with internal dimensions of 6 m × 6 m × 18 m (w × h × l). In addition, two working platforms were installed for this test, one at each end of the large-scale test facility (Figure 6 - test hall side in foreground: l=6 m × w=6 m; and hall far wall side in the background: l=2 m × w=6 m). Figure 6 shows the above-ground test setup from the front platform, as it was prepared for operation.

Figure 6. View of testing set-up in the IKT large-scale test facility from the front work platform showing the four installed pipes and blue pressure vessels.

In each of the two sequential **test rig set-ups**, four test pipes were constructed above the walkable surface of the experimental area. These were paired, with each pair connected at either end via T-pieces (with gate valves) to a single return line and pump (Figure 7). The blue arrows in Figure 7 show the direction of flow within the pipes. Only one renovated pipe in each pair was in operation at any one time, the other was closed off at the front and back ends via gate valves. The total length of each pipeline circuit was approx. 46 m.

Thus, with two such set-ups in the IKT large-scale test facility, two test pipelines and the two **pumps** could be operated in parallel (see also Figure 6). It was not possible to operate more pumps in parallel because of the available power supply.

The frequency converters for the control and regulation of the pumps were installed outside the large-scale test facility to avoid any contact with water.

The **riser pipes** (Figure 7) each contained an **electromagnetic flowmeter**, which was used to display and control the flow rate. A **pressure sensor** for determining the internal pressure in the pipe system was also installed in each riser. The required pressures in the closed pipeline circuit were applied via **membrane equalisation vessels** ('blue pressure vessels' in Figure 6) in each pipe run, when they were above the filling pressure of approx. 3.2 bar from the drinking water network used to fill the test rigs. The design of the test section as a closed system made it quite easy to apply the required pressure, to reliably control it and, in particular, to immediately detect any pressure losses or leaks.

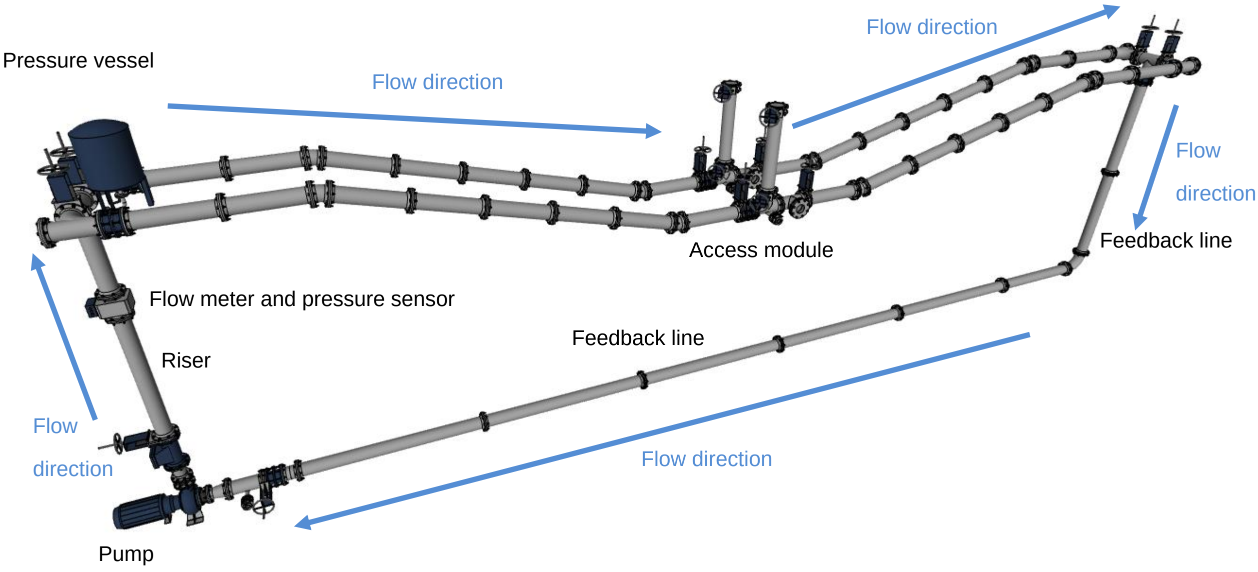


Figure 7. Experimental set up for a pair of test pipes operated separately using a single return line and pump. Blue arrows show the flow direction.

Figure 8. View of the two pumping stations, showing for the nearer pump its support platform, riser pipe with gate valve (leading upwards) and suction pipe coming from the right, also with a gate valve.

The **course of the pipelines** laid above ground was modelled on a siphon, so the pipes could run down into the test pit and up out of the other side which enabled sections to be submerged when the pit was flooded as part of the testing. Their length was approx. 19 m and they were mainly assembled from one-metre-long flanged pipes of nominal width DN 200. These were made of black steel, with an outer diameter of 219.1 mm and a wall thickness of 6.3 mm. The inner diameter was 206.5 mm and thus represented the dimensional limit for the maximum outer diameter of the renovation systems to be installed. The nominal pressure of the undamaged steel pipes was PN 10, which should also be maintained by the installed renovation systems.

In addition, the pipeline route contained four vertical 15° bends. The low point in the middle of each siphon contained an operating device (access module) equipped with gates, which provided accessibility, e.g., for inspections and addition of abrasive material as part of the testing. Each test pipe contained a compensation pipe section as well as two fitting/expansion pieces to compensate for dimensional tolerances. These were particularly necessary when the access module had to be removed to facilitate installation of the renovation system.

Rubber sealing rings made of EPDM were used to seal the flange connections of the steel pipe sections. These had the hole pattern of the flange bolting, making it possible to secure the position of the seal as required. This was particularly useful in creating the damage scenario "leaking pipe connection" (locations shown in Figure 5).

To secure the position of the four parallel pipelines, six HEA 200 cross beams were welded to the longitudinal sides of the large-scale test facility (Figure 10). The steel test pipes were fixed to them by means of clamps.

The two return lines (suction lines) ran almost horizontally at the bottom of the IKT large-scale test facility and were covered with sand up to a height of approx. 4 m. In order to exclude leaks in these pipes, leak tests were carried out during their construction. The height of the sand backfill was oriented to the course of the pipes laid above ground and remained about one metre below them. This ensured that all pipes could be walked alongside and inspected.

Prior to the construction of the pipelines with damage scenarios, one undamaged steel pipeline was first laid for each pair of lines in order to be able to record the initial performance of the two pumps (Figure 9).

Figure 9. Setup for initial evaluation of the hydraulic performance of undamaged steel pipe, before liner installation (test zero measurement). For pump 1 the continuous undamaged pipe run is on the left side of the test rig and pump 2 on the right side.

Figure 9 shows the steel pipes laid longitudinally along the sides of the large-scale test facility, which were used to record the performance characteristics of both pumps (performance evaluation test - before refurbishment). For this purpose, the speed band of each pump was increased in hundredths steps from 100 - 1400 revolutions per minute and the flow rate, power consumption and frequency were recorded for each speed step. After liner installation, these performance evaluation tests were then repeated several times during the course of the test programme, in order to be able to record any changes, e.g., due to the reduction in cross-section associated with renovation.

After completion of these tests, the pipe sections were set up with the damage scenarios ready for installation of renovation systems. For this purpose, the four-pipeline layout already explained was constructed, but each line was supplemented at the front with two one-metre-long steel pipes, which were also lined (Figure 10, left). These were removed (cut off) after completion of installation of the respective renovation system and served to provide liner samples for laboratory tests (Table 6). After removing these sampling pipes, the installers were able to connect the renovation system onto the pipe loop and thus close the pipeline circuit ready for the operational testing phase.

Figure 10. Set-up for installation of a liner into the test rig. Left foreground, point of entry for liner – the test pipeline has been extended by two additional one-metre-long steel pipes (subsequently removed) for the purpose of obtaining liner samples for laboratory testing. Centre photo showing where the central access module (see Figure 7) has been removed so lining can be run through to the far section of the test pipe. Right photo shows a second extension of the test pipeline at the far end (susequently removed) with additional damage scenarios including the angled offset joint damage scenario and the maximum bend that could be rehabilitated, as suggested by the manufacturer (right).

The access module located in the low point of the siphon was temporarily removed for the installation of most of the renovation systems, as the gates and openings in it had to be functional for subsequent operation of the testing and inspection of the renovated pipeline (Figure 10, centre). The respective lining system or close fit pipe was installed through the first section of test pipes and across the gap where the access module had been removed into the second test pipe section. Where the lining system spanned this gap that section was cut out. End seals were fitted either side (connections 2 and 3 in Figure 5) before the access module was refitted between them.

At the far end point of the test pipe, an extra pipe section of up to 3.3m was temporarily added during the liner installation. This contained the additional (voluntary) damage scenarios (I to III in Table 2) including one example of the maximum bend that the manufacturer recommended the product could be installed through (Figure 10, right). These essentially served to check further aspects of the installation capability of the renovation systems. These special damage scenarios were not part of the subsequent loading and testing programme applied in the rig. Their purpose was to provide information regarding the visual appearance of the installed liners through the additional damage scenarios and bends. The aim was to understand what might happen in the event that such situations arise in the course of a renovation and have to be lined through, e.g., for reasons of time and cost. After installation, this additional pipe section was removed and the renovation system was connected to the existing steel pipes so that the pipe circuit was closed again for subsequent operation.

After installation of the renovation systems, the loading and testing programme was started. This is shown in detail in Section 3.4.

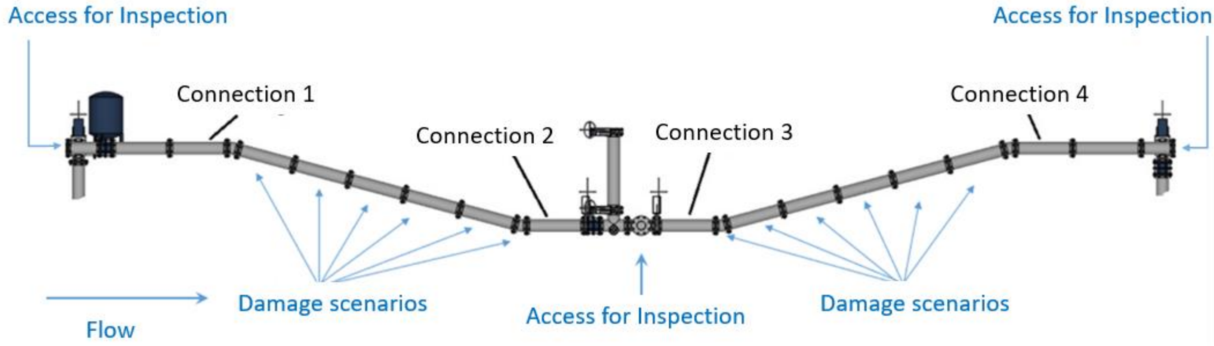


Figure 11. Above-ground test pipeline layout with the location of damage scenarios, access points and connections(end seals). Following installation of a liner the rig contained two sections of liner, each with an end seal at either end: Section 1 between Connections 1 and 2, and Section 2 between Connections 3 and 4. The access module between Connections 2 and 3 was not lined.

3.3 Market review and selection of rehabilitation products for testing

An essential goal of IKT-Comparative Product Tests is to provide wastewater network operators with solid and reliable information about the strengths and weaknesses, as well as the scope of application and limitations, of relevant products offered on the market. Accordingly, the procedure for selecting renovation companies was closely coordinated with the Steering Committee.

For this IKT-Comparative Product Test a total of six test setups (Section 3.1) for Class A liner systems were used in the IKT large-scale test facility. In addition to the Class A renovation systems participating in this product test, two further systems were selected for evaluation for research purposes by the Steering Committee members. Both systems explicitly do not belong to Class A and their results are not presented in this report. These were a cement mortar lining from Berkel (dry mortar Sulfadur, commonly used as corrosion protection, not a structural liner, so corresponding to Class D) and an inserted tube from Amex Sanivar AG (SaniTube), which is not assigned to any class according to DIN EN ISO 11295. The allocation of the renovation lots for the six products this IKT-Comparative Product Test is detailed below.

As a necessary condition for participation in the IKT-Comparative Product Test, the renovation systems were defined as needing to belong to Class A as defined EN ISO 11295, to be capable of installation into pipe with a DN 200 diameter and be able to take a bend of at least 15°.

For the award of the renovation lots, a market review of systems available in the German market was undertaken, which yielded 10 manufacturers offering a total of 12 Class A systems (1 manufacturer with 3 systems) for the renovation of wastewater pressure pipes.

The Steering Committee members decided that all the available renovation manufacturers, whose products were in scope, would be approached regarding their participation in this IKT-Comparative Product Test.

Accordingly, all manufacturers were invited to visit the 1:1 scale mock-up test setup at IKT. Subsequently, the manufacturers were asked to submit bids, based on a call for tenders from IKT, for the renovation task. If a manufacturer did not carry out renovation themselves, they were asked to appoint an installation company to carry out the work.

The feedback from contacting the individual manufacturers is summarised below. Documents with relevant comments from the manufacturers can be found in Annexes I - VII.

Four manufacturers of cured in place liners submitted a bid (NordiTube Technologies SE with Nordiflow W PE and Nordiflow W PP, Esders Pipeline Service, Karl Weiss Technologies GmbH, and Amex Sanivar AG).

Two close fit system manufacturers, Wavin GmbH and egeplast international GmbH submitted bids, but both raised concerns about the damage scenario with the overlapping "double overlapping hole 2 x 48 mm" with the sharp points (Annex I and II-A). As a result, the Steering Committee decided that this damage scenario could be replaced by an undamaged pipe section if concerns about it were raised by a manufacturer.

Three manufacturers (NordiTube Technologies SE with r.tec Close-Fit Liner, RELINE APTEC GmbH and Saertex multiCom GmbH) did not fulfil the necessary conditions required by the Steering Committee for participation, these are discussed in more detail below:

NordiTube Technologies SE with r.tec Close-Fit Liner
According to the manufacturer, the renovation system could not be used in the test because the 15° bends on the rig were too close together (Annex III). The necessary condition for participation in the IKT product test could therefore not be fulfilled (renovation of the 15° bends in the rig).

RELINE APTEC GmbH
According to the manufacturer, bends up to a maximum of 5° can be renovated with the renovation system (Annex IV). The necessary condition for participation in the IKT product test could therefore not be fulfilled (renovation of 15° bends).

Saertex multiCom GmbH
According to the manufacturer, the renovation system can only be used from a nominal width of DN 250 and is designed for use in straight sections of pipe (Annex V). The

necessary condition for participation in the IKT product test could therefore not be fulfilled (renovation of nominal width DN 200 and renovation of 15° bends).

Two manufacturers (Pipe-Aqua-Tec GmbH & Co.KG and REHAU AG + Co) cancelled their participation in the IKT-Comparative Product Test. Their reasons are discussed detailed below.

Table 3. Market overview of rehabilitation systems for Class A wastewater pressure pipes.

System	Manufacturer
Cured in place pipe liners	
AlphalinerPN	RELINE APTEC GmbH
BlueLine	Pipe-Aqua-Tec GmbH & Co.KG
Esders HPS Liner	Esders Pipeline Service GmbH
Nordiflow W PE	NordiTube Technologies SE
Nordiflow W PP	NordiTube Technologies SE
Saertex liner pressure	Saertex multiCom GmbH
SaniPipe	Amex Sanivar Ltd
Starline Structure-S	KARL WEISS Technologies GmbH
Close-fit lining	
Compact Pipe	Wavin GmbH
egeLiner	egeplast international GmbH
r.tec Close-Fit Liner	NordiTube Technologies SE
U-Liner	REHAU AG + Co.

Pipe-Aqua-Tec GmbH Co.KG
Pipe-Aqua-Tec GmbH & Co.KG submitted a bid for participation in the IKT-Comparative Product Test on 15 January 2022. On 19 April 2022, the manufacturer informed IKT that it would not participate in the test due to the damage scenario "double overlapping hole" (Annex VI-A). Consequently, on behalf of the Steering Committee, IKT informed the manufacturer on 29 June 2021 that the damage scenario "double overlapping hole" would be replaced by a pipe section without damage scenario (Annex VI-B). The manufacturer then cancelled participation in the IKT-Comparative Product Test on 26 July 2021 for capacity reasons (Annex VI A-C).

REHAU AG +Co.
The manufacturer cancelled its participation in the IKT product test due to space constraints in the IKT test hall (Annex VI).

A total of seven bids were submitted, that met the necessary conditions required by the Steering Committee. In order to maintain manufacturer diversity, the Steering Committee members selected only one product from NordiTube Technologies SE (Nordiflow W PE). For organisational reasons, the manufacturer egeplast international GmbH could only supply pipes with gas marking, but conformity of this to its wastewater pipe was confirmed (Appendix II-B).

The six installations for the IKT-Comparative Product Test that were awarded to manufacturers by the Steering Committee are shown in Table 4.

Table 4. Overview of the six Class A renovation systems participating in this IKT-Comparative Product Test.

System	Renovation system	Manufacturer	Installation company
Cured in place pipe	Nordiflow W PE	NordiTube Technologies SE	Esders Pipeline Service GmbH
	Starline Structure-S	Karl Weiss Technologies GmbH	Karl Weiss Technologies GmbH
	SaniPipe	Amex Sanivar Ltd	Amex Sanivar Ltd
	Esders HPS Liner	Esders Pipeline Service GmbH	Esders Pipeline Service GmbH
Close-Fit-Lining	Compact Pipe	Wavin GmbH	Diringer & Scheidel Rohrsanierung GmbH & Co. KG
	egeLiner	egeplast international GmbH	Esders Pipeline Service GmbH

3.4 Loading and testing programme

In consultation with the Steering Committee, a loading and testing programme was decided for conducting the investigation of the performance of renovation systems in the IKT large-scale test facility, and for laboratory material tests on samples of the liners. This loading and testing programme is described below.

Investigations on the renovation systems

The investigations in the IKT large-scale test facility (Table 5) were divided into three operational phases (OPs):

- Operating conditions after renovation (OP 1)
- Operating conditions after damage deterioration (OP 2)
- Special operating conditions (OP 3)

In the operating phases "OP 1 after renovation" and "OP 2 after damage deterioration", loadings with different operating pressures were carried out, and for "OP 3 special operating conditions", in additional operational loads such as high-pressure cleaning were undertaken.

Table 5. Loading and testing programme of the three opertional phases.

Operating status	No.	Designation	Load parameters		Stress duration
Before the Renovation	0	Performance evaluation test "before renovation"	Recording the hydraulic capacity		/
OP 1 After renovation of the test pipes					
Operating conditions after renovation (OP 1)	1	Level check[1]	Level	0 l/s	0,5h
	2	Performance assessment test "after renovation[1] "	Recording the conveying capacity		4h
	3	Standard operating pressure "low delivery rate[1]"	approx. 2 bar	approx. 1 m/s, 30 l/s	24h
	4	Standard operating pressure "high delivery rate[1]"	approx. 2 bar	approx. 3 m/s, 90 l/s	24h
	5	Increased operating pressure "low delivery rate[1]"	approx. 6 bar	approx. 1 m/s, 30 l/s	24h
	6	Increased operating pressure "high delivery rate[1]"	approx. 6 bar	approx. 3 m/s, 90 l/s	24h
	7	Cyclic pressure[1]	approx. 2/4/6 bar	approx. 3 m/s, 90 l/s	24h
	8	Performance assessment test "following OP1[1]"	Recording the hydraulic capacity		4h
OP 2 Condition deterioration of the damage scenarios					
Operating conditions after damage deterioration (OP 2)	9	Performance assessment test "following damage scenario deterioration[1]"	Recording the conveying capacity		4h
	10	Standard operating pressure "low delivery rate[1]"	approx. 2 bar	approx. 1 m/s, 30 l/s	24h
	11	Standard operating pressure "high delivery rate[1]"	approx. 2 bar	approx. 3 m/s, 90 l/s	24h
	12	Increased operating pressure "low delivery rate[1]"	approx. 6 bar	approx. 1 m/s, 30 l/s	24h
	13	Increased operating pressure "high delivery rate[1]"	approx. 6 bar	approx. 3 m/s, 90 l/s	24h
	14	Cyclic pressure[1]	approx. 2/4/6 bar	approx. 3 m/s, 90 l/s	24h
	15	Performance assessment test "following OP 2[1]"	Recording the hydraulic capacity		4h
OP 3 Special operating conditions					
Special operating conditions (OP 3)	16	Static max. test pressure[1]	approx. 9 bar	0 l/s	24h
	17	High-pressure cleaning[1]	80 bar	-	1h
	18	Abrasive materials[1]	approx. 6 bar	approx. 3 m/s, 90 l/s	24h
	19	Performance evaluation test "after abrasion"[1]	Recording the hydraulic capacity		4h
	20	Air over-pressure and negative air pressure cycles[1]	approx. 0.2 bar / approx. - 0.2 bar	0 l/s	60 sec
	21	Flooding of the IKT large-scale test facility			
	22	Air overpressure test I with external water pressure[1]	approx. 0.4 bar - max. 1 mWs	0 l/s	1h
	23	Negative air pressure load with external water pressure[1]	approx. (- 0.8 bar) - max. 1 mWs	0 l/s	1h
	24	Air overpressure test II with external water pressure[1]	approx. 0.4 bar - max. 1 mWs	0 l/s	1h
	25	Performance assessment test following OP3[1]	Recording the hydraulic capacity		4h
	26	Leak test[1]	0.1 bar	Permissible pressure drop: 0.015 bar	120 sec

[1] A visual inspection was carried out after loading

In order to record changes in condition over time, each pipeline was emptied after each loading exercise and a visual inspection was carried out using camera technology. In addition, the pipes were visually inspected from the outside for any abnormalities whilst under load. The sequence of loads and inspections in the test programme is shown Table 5 and they are further explained below:

- **Hydraulic performance evaluation test (Items No. 0, 2, 8, 9, 15, 19 and 25 in the test programme)**
  Evaluation tests were undertaken to examine the hydraulic performance losses of the host pipe after installation of a liner, and any subsequent changes during the operating phases. For this purpose, one test was carried out before renovation (zero measurement) on undamaged host pipe and six tests were carried out at different times after renovation. For the performance evaluation tests, speed steps from 100 to 1400 rpm were applied and the pump frequency in Hertz, the amperage in amperes and the flow rate in l/s were recorded. The recorded delivery losses were then compared with each other.

- **Water level check (Item No. 1 in the test programme)**
  A water level test was carried out on the renovated pipes to check for leaks. This comprised filling renovated pipes with water to the top of the vertical pipe from the access module, not applying any additional pressure (the top of the access module pipe was left open) and observing for 30 minutes for any reduction of water level or obvious leakage from the renovated pipe.

- **Standard operating pressure (Items No. 3, 4, 10 and 11 in the test programme)**
  For the standard operating pressure, the renovated pipes were loaded twice with approx. 2 bar for 24 hours. During each period the pumps were run in cycles of 10 minutes in operation then five minutes off (96 cycles per 24 hours). For the first 24-hour period a "low flow rate" with a velocity of approx. 1 m/s and a flow rate of 30 l/s (Items Nos. 3 and 10) was used. For the second, a "high flow rate" with a velocity of approx. 3 m/s and a flow rate of 90 l/s (Items No. 4 and 11) was applied.

- **Higher operating pressure (Items No. 5, 6, 12 and 13 in the test programme)**
  For the increased operating pressures, the renovated pipes were loaded twice with approx. 6 bar for 24 hours, during which flow was again alternated: on for 10 min and off for 5 min (96 cycles per 24 hours). For the first 24-hour period a "low flow rate" with a velocity of approx. 1 m/s and a flow rate of 30 l/s (Items. No. 5 and 12) was used. For the second, a "high flow rate" with a velocity of approx. 3 m/s and a flow rate of 90 l/s (Items No. 6 and 13) was applied.

- **Cyclic operating pressure (Items No. 7 and 14 in the test programme)**
  For the cyclic operating pressure, pressure levels of 2, 4 and 6 bar were operated cyclically within 24 hours for 20 min at a time. In each case for the first 10 min, the pipe was operated with a flow velocity of 3 m/s and a flow rate of 90 l/s. Then, over the subsequent 10 min, the pressure needed for the next stage of the cycle was applied without pumping.

- **Maximum static pressure test (Item No. 9 in the test programme)**
  With this load, a 9 bar static water pressure was applied for 24 hours, without pump operation.

- **High-pressure cleaning (Item No. 7 in the test programme)**
  High-pressure cleaning was carried out at 80 bar at the cleaning nozzle and a water flow rate of approx. 249 l/min in five cycles with an omnidirectional nozzle (8 x 2.6 mm inserts, each with a 28.8° jet angle).

- **Abrasive materials (Item No. 18 in the test programme)**
  The pipe was filled with 5 kg of grit and operated for 24 hours at a pressure of 6 bar, a flow velocity of 3 m/s and a flow rate of 90 l/s. During the 24 hours, water was alternatively pumped at intervals of 10 min with a subsequent break of 5 min.

- **Positive and negative air pressure cycles (Item No. 20 in the test programme)**
  The pipes were alternately loaded with an air overpressure of approx. 0.2 bar and air under pressure of approx. -0.2 bar for 60 seconds each for 5 cycles.

- **Internal air pressure load (Items No. 22 and 24 in the test programme)**
  Approx. 0.4 bar air pressure was applied internally, together with an external water pressure of max. 1 mWs for one hour. During this loading, the pipes were visually inspected externally for rising air bubbles. For these tests and Item 23 the IKT large-scale test facility was flooded to a level near the top of the test rig (see Figure 12).

- **Negative air pressure load (Item No. 23 in the test programme)**
  The pipes were loaded with approx. -0.8 bar negative internal pressure and an external water pressure of max. 1 mWs for one hour.

- **Leak test (Item No. 26 in the test programme)**
  A leak test was carried out according to DIN EN 1610 with a test pressure of 0.1 bar air overpressure and a test time of 90 seconds. If the permissible pressure drop of 0.015 bar was not exceeded during the entire test time, the test is considered passed.

After completion of the loading and testing programme in the IKT large-scale test facility, the renovated test pipes were dismantled, divided into individual sections and further investigations were carried out on them. This included determining the reduction in cross-section caused by the renovation method by passing wooden balls with different diameters through the lined pipe. In addition, the wall thickness, the annular gap between the liner and host pipe and any folds in the liner were measured. The “shard load” damage scenario was continued outside the IKT large-scale test stand and the penetration depth of the load into the liner wall was measured after 188 loading days (for the evaluation criterion “robustness”).

Material tests on samples

In addition to the testing on the rig, static and cyclic material tests were carried out on test samples. These laboratory tests on liner samples are summarised in Table 6. The focus here was on the investigation of the mechanical characteristics and the chemical resistance of the liners.

Table 6. Material tests undertaken on samples of the liners taken after installation.

Material testing "after renovation"	Test series	Load	Examination
Wall thickness	1 test series (6 test specimens)	-	measure
Three-point bending test *DIN EN ISO 178 &* *DIN EN ISO 11296-4*	2 test series (3 test specimens), 1 test series of which is truncated	Point force	E-modulus & bending stress
Peak pressure test *DIN EN 1228*	1 test series (3 test specimens)	Point force	E-modulus & ring stiffness
APS watertightness test *Leak test according to APS test guideline*	2 test series (3 test specimens), of which 1 test series is truncated	Negative pressure	optical (tight/leaky)
Resistance to waste water* (chemical load)	2 test series (a 3 test specimens),	chemical	optical & weight change
APS watertightness test according to chemical stress* (resistance to waste water) *Leak test according to APS test guideline***	2 test series each (a 3 test specimens), 1 test series cut off in each case	Negative pressure	optical (tight/leaky)
Three-point bending test after chemical loading*. *DIN EN ISO 178 &* *DIN EN ISO 11296-4*	2 test series each (3 test specimens), 1 test series cut off in each case	Point force	E-modulus & bending stress
Tipping trough	1 test series (1 test specimen)	Abrasion	Material loss
APS watertightness test after tipping trough *Leak test according to APS test guideline*	2 test series (3 test specimens), of which 1 test series is truncated	Negative pressure	optical (tight/leaky)
Cyclic load (split disk test)	1 test series (3 test specimens)	Internal pressure	Force/optical
APS watertightness test after cyclic load (split disk test) *Leak test according to APS test guideline*	1 test series (a 3 test points)	Negative pressure	optical (tight/leaky)

* Exposure in each case to sulphuric acid, caustic soda and peroxide cleaner

**The APS watertightness test is used for assessing whether a liner sample has been fully wetted out or fully cured by determining whether water can pass through the wall of a liner. A negative pressure of 0.5 bar is applied to the external surface and a red dye coloured water to the inner. The test is undertaken for 30 minutes and the liner passes if no dye is drawn through.

In addition, further tests were carried out as appropriate on specific parts of the installed liner if abnormalities were detected during the loading and testing programme in the IKT large-scale test facility.

4 Evaluation scheme

4.1 Overview

The aim of the IKT-Comparative Product Tests is to evaluate products, processes and services offered on the market, to identify potential for improvement and at the same time to build up market pressure so that these potential improvements are applied by the product, process and service providers. The wastewater network operator as the customer specifies the quality requirements for the products, processes and services and how they are to be evaluated against these.

In the present IKT-Comparative Product Test, were subjected to a multi-part test of their systems.

The grading system used was based on the results of four key evaluation criteria:

- "watertightness",
- "stability",
- "operational performance", and
- "quality assurance"

and is assessed in each case with grades between "VERY GOOD (1.0)" and "inadequate (6.0)". These were each derived from consideration of performance in various sub-criteria.

Additional information was collected concerning their "robustness" (performance against “shard load”, “metal tip (double overlapping hole)”, “incrustation”, “angular deflection” and “maximum bend”), "wall construction", "wall thickness", "installation method", "curing method and time", "connection (type/ manufacturer)" and "total working time/ days on site".

Table 7 shows the evaluation scheme defined by the Steering Committee, the evaluation criteria and their weighting in the overall scoring and award of a grade.

From among the evaluation criteria (Table 7), the Steering Committee determined the evaluation criterion "stability - load-bearing capacity of the structure" to be a **knock-out criterion**. Accordingly, the Steering Committee made a decision on the basic usability of a system as a class A liner if there was a collapse or burst of the system during the evaluation.

If the Steering Committee evaluated a system as **"not usable as a class A liner"**, the overall grade "Inadequate (6.0)" was awarded regardless of how the liner scored against the other criteria.

The details of the evaluation scheme and grading are explained in Sections 4.2 to 4.5.

Table 7. Evaluation scheme (overview) with weighting (%) of scores.

Evaluation scheme		
Watertightness	**45%**	**Additional information (not scored)**
Exfiltration watertightness • Before damage scenario deterioration (OP1), 20% • After damage scenario deterioration (OP2), 30% • After OP 3 special operating conditions, 30% • Watertightness of test samples, 20%	80%	Robustness: performance with Shard load, Metal tip (double overlapping hole), Incrustation, Angular deflection, Max. bend
		Wall structure
		Wall thickness
Infiltration watertightness	20%	Installation procedure
Stability	**25%**	Curing method and time
Load-bearing capacity of the structure (knock-out criterion)	50%	Connection (type/ manufacturer)
Static proof	30%	Total working time/ days on site
Material and geometry	20%	
Operational performance	**15%**	
Overall visual impression • after renovation, 20% • after HD cleaning, 40% • after end of test programme, 40%	25%	
Hydraulic performance loss	25%	
Wrinkling/ Obstacles	25%	
Cross-section reduction	25%	
Quality assurance	**15%**	
Procedure manual	20%	
Training courses: Training courses offered by the manufacturer/ Training certificates of the renovator	20%	
Test certificates	20%	
Monitoring: in-house and external monitoring	20%	
Special conspicuous features	20%	

4.2 Watertightness

The **"watertightness"** of a system was evaluated on the basis of the results of both exfiltration permeability and infiltration permeability, which were weighted 80 % and 20 % respectively. Exfiltration watertightness was subdivided into the results of the tests undertaken in the IKT - large-scale test stand ("before damage deterioration (in OP 1)", 20 %, "after damage scenario deterioration (in OP 2)", 30 %, "after special operating conditions (OP 3)", 30 %), and following laboratory material tests on samples ("watertightness of test specimens", 20 %) (Section 3.4).

The evaluation criterion **"exfiltration watertightness"** was assessed by walking the length of pipe situated above ground after each load and visually inspecting them for abnormalities. Critique points were assigned for the grading depending on the sealing success for the conditions "before damage scenario deterioration (OP 1)", "after damage scenario deterioration (OP 2)" and "special operating conditions (OP 3)". As each of the test lines contained two separate sections of liner, each with end seals at either end (Figure 11), the respective critique points observed for liner sections 1 and 2 per were added together to determine a single grade according to the evaluation criteria set out in Table 8.

In Table 8, 0 critique points were awarded for liner sections 1 and 2 if there was no abnormality (colour code: "green" in results table). For the anomaly "moisture" (colour designation: "yellow" in results table), 1 critique point was awarded. “Moisture" is a conspicuous feature in which no continuous water leakage, less than three drops in five seconds, is recognisable. For the conspicuous exfiltration conditions "drops" (colour designation: "orange" in results table) and "flow/ water surge" (colour designation: "red" in results table) 4 and 5 critique points were awarded respectively. If the required target pressure could not be achieved due to leaks, 5 critique points were awarded (colour code: "purple" in results table). Systems were graded “VERY GOOD (1.0)" if all renovated damage scenarios showed no abnormalities (0 critique points). For five or more critique points, the grade 6.0 (inadequate) was awarded.

Table 8. Evaluation scheme for the evaluation criterion "Exfiltration watertightness - Investigations on the renovation system".

Critique points No conspicuous permeability - 0 (Green) Moisture - 1 (Yellow) Drop - 4 (Orange) Flow/ Water Surge - 5 (Red) Target pressure was not approached - 5 (purple)	**Grading**
0	1.0
1	2.0
2	3.0
3	4.0
4	5.0
≥ 5	6.0

For the grading of exfiltration watertightness with regard to the laboratory material tests on test pieces ("watertightness of test pieces", 20 %), the grade 1.0 was awarded if all APS watertightness tests were passed. Systems received a grade of 3.0 if one test piece out of a total of at least 33 test pieces failed the test across all test scenarios (installation, tipping trough, chemical loads, cyclical loads, points with anomalies). If further test pieces failed, but never more than one per test scenario, this resulted in a grade of 4.0. A grade of 5.0 was given if one test scenario was failed. If several test scenarios were not passed, grade 6.0 was awarded.

Table 9. Evaluation scheme for the evaluation criterion "exfiltration watertightness - watertightness of laboratory test samples”.

Evaluation "Watertightness” of test pieces	Grading
Passed all exams	1.0
Failed a maximum of one exam	3.0
Passed all test scenarios (e.g., 5 out of 6)	4.0
One test scenario failed	5.0
Several test scenarios not passed	6.0

In addition, tests were carried out on conspicuous features where anomalies were observed in the large-scale tests. Here, anomalies were treated like individual test scenarios.

The final score for exfiltration watertightness was composed of the following sub-criteria with the following weighting:

- before condition deterioration, 20%
- according to the condition deterioration, 30%
- Special operating conditions, 30%
- Watertightness of laboratory test samples, 20%

The evaluation criterion **"infiltration watertightness"** was evaluated by carrying out a visual inspection under external water pressure between the tests involving internal pressure loadings (Section 3.4). This optical inspection was carried out using camera technology. Critique points were then assigned for the grading depending on the sealing success. The respective critique points were added up for lined sections 1 and 2 and then an individual grade was determined according to Table 10. The final grade for infiltration watertightness was then calculated from the average of both individual grades for sections 1 and 2.

For these loads, according to the evaluation scheme in Table 10, 0 critique points were awarded for liner sections 1 and 2 if there was no abnormality (colour code: "green"). For the anomaly "moisture" (colour designation: "yellow"), 1 critique point was awarded. “Moisture" is a ‘conspicuous feature’ in which no continuous extraneous water ingress, less than three drops in five seconds, is recognisable. For the recognisable anomaly infiltration "drops" (colour designation: "orange" in results table) and "flow/ water surge" (colour designation: "red" in results table) 4 and 5 critique points were awarded, respectively.

Table 10. Evaluation scheme for the evaluation criterion "infiltration watertightness”.

Critique points No conspicuous permeability - 0 (Green) Moisture - 1 (Yellow) Drop - 4 (Orange) Flow/ Water Surge - 5 (Red)	**Grading**
0	1.0
1	2.0
2	3.0
3	4.0
4	5.0
≥ 5	6.0

In the 2.50 m long low point along the test pipe, only water surge was assessed in the invert (5-7 o'clock), since a comparative assessment of smaller anomalies (moisture, drops) was not clearly possible due to flowing, stagnant water in this area. Furthermore, only about 2/3 of the renovated pipe could be subjected to external water pressure, so that only this area could be considered for the evaluation (Figure 12).

Figure 12. Water level (GW) during infiltration tests.

The inspections of the renovation system were rated "VERY GOOD (1.0)" if both the renovated sections of pipe showed no abnormalities (0 critique points). From five critique points onwards, grade 6.0 (inadequate) was awarded.

In addition, the final score of the evaluation criterion "watertightness" was reduced (devalued) if rework due to leaks had to be carried out after completion of the initial installation (Table 11). Accordingly, there was no devaluation if a successful water level test was carried out after installation. In the case of a successful water level test only after the 1st rework or after the 2nd rework, devaluation of the grades was 1.0 or 2.0. A devaluation of 3.0 was incurred if "rework not successful (moisture)" was found. If no successful rework was achieved and dripping or flowing was visible, the evaluation criterion "watertightness" was graded 6.0, independent of the results achieved for the other watertightness criteria.

Table 11. Evaluation scheme for devaluation (reduction) of the score for the evaluation criterion "watertightness" for rework undertaken after installation.

Devaluation of the evaluation criterion "watertightness" for rework	Devaluation by
Successful water level test after renovation	0.0
Successful water level check after 1st rework	1.0
Successful water level check after 2nd rework	2.0
No successful rework, moisture	3.0
No successful rework, dripping or flowing	“Watertightness" grade 6.0

4.3 Stability

The "stability" of a liner was evaluated on the basis of the criteria "load-bearing capacity of the structure", "static proof" and "material and geometry", which were weighted 50 %, 30 % and 20 % respectively.

The evaluation criterion **"load-bearing capacity of the structure"** was evaluated over the entire test period. If no abnormalities were found, the grade 1.0 was awarded. If there was any abnormality in the form of deformation, wrinkling, holes or air pockets, the system received a grade of 2.0. If there were two or three abnormalities, the system received a grade of 3.0 or 4.0. A grade of 5.0 was given if potential risks of system failure (cracks, large deformations-wrinkles-flaws) were identified. In case of collapse or bursting, the grade 6.0 was awarded.

In addition, this criterion "stability - load-bearing capacity of the structure" was set as a knock-out criterion by the Steering Committee. Accordingly, if there was a collapse or burst of the system during the testing, the Steering Committee made a decision concerning the basic usability of the system as a class A liner. If the Steering Committee evaluated the system as "not usable as a class A liner", the overall grade "inadequate (6.0)" was assigned regardless of the results achieved for other criteria.

The evaluation scheme for the criterion "load-bearing capacity of the structure" is shown Table 12.

Table 12. Evaluation scheme for the evaluation criterion "load-bearing capacity of the structure".

Assessment "Load bearing capacity of the structure"	Grading
No abnormalities	1.0
1 conspicuous abnormality deformations, wrinkling, holes or air pockets	2.0
2 conspicuous abnormalities deformations, wrinkling, holes or air pockets	3.0
3 conspicuous abnormalities deformations, wrinkling, holes or air pockets	4.0
Possible risks of failure (cracks, large deformations-wrinkles-gaps)	5.0
Collapse/ Burst	6.0

The **"static proof"** provided with each product was checked with regard to its plausibility (against the renovation conditions set for the testing the systems) and was evaluated by an IKT expert to determine if there were deficiencies, for which critique points needed to be awarded.

Critique points were awarded in relation to the following performance considerations:

- Consideration of load cases (internal pressure and external pressure)
- Consideration of damage scenarios (ovalisation, socket offset, single hole)
- Plausibility of the calculation undertaken

A system was given grade 1.0 if there were no critique points (0 critique points). From four or five critique points, grades 5.0 or 6.0 were awarded.

Table 13 shows the evaluation scheme for the evaluation criterion "static proof".

Table 13. Evaluation scheme for the evaluation criterion "static proof".

Evaluation "static proof"	Grading
0 Critique points	1.0
1 Critique point	2.0
2 Critique points	3.0
3 Critique points	4.0
4 Critique points	5.0
≥ 5 Critique points	6.0

For the evaluation criterion **"material and geometry"**, an IKT assessor checked whether the material characteristics and geometry corresponded to the static assumptions for a system. The following points were checked and critiqued:

- Material parameters (tensile strength, bending strength, bending stiffness) according to the static assumptions.

- Geometry (wall thickness, annular gap, ovalisation) according to the static assumptions.

Table 14 shows the evaluation scheme for the criterion "material and geometry". A system was given a grade of 1.0 if there were no critique points (0 critique points). From four or five critique points, the grade 5.0 or 6.0 was awarded. If no static proof was available, the evaluation criterion was graded 6.0.

Table 14. Evaluation scheme for the criterion "material and geometry".

Assessment "Material and Geometry	Grading
0 Critique points	1.0
1 Critique point	2.0
2 Critique points	3.0
3 Critique points	4.0
4 Critique points	5.0
≥ 5 Critique points	6.0

4.4 Operational performance

“Operational performance" was assessed on the basis of the evaluation criteria "overall visual impression", "hydraulic performance loss", "wrinkling/obstructions" and "cross-section reduction", each of which was weighted at 25 %.

The evaluation criterion **"overall visual impression"** assessed whether the serviceability of the pipeline to convey wastewater had been restored, i.e., the impression of the extent to which the lined section of sewer was free of drainage obstacles as well as blockage hazards. The assessment was carried out by the network operators involved in the Steering Committee on the basis of photo documentation, for which they awarded grades (Table 15). A grade of "4" (sufficient) or better was considered a "pass". The evaluation results of the participating network operators were arithmetically averaged to an overall result for each system. The evaluation distinguishes between the liner states "after renovation", "after high-pressure cleaning" and "after the end of the test programme", with the evaluations being weighted 20% (after renovation), 40% (after high-pressure cleaning) and 40% (after the end of the test programme).

Table 15. Evaluation scheme for the criterion "overall visual impression”.

Evaluation "overall visual impression”	Grading
No abnormalities	1.0
Minor abnormalities	2.0
Medium abnormalities	3.0
Conspicuous abnormalities, but without restricting operation	4.0
Operational restriction	5.0
Operating failure	6.0

For the evaluation criterion **"hydraulic performance loss"**, one test was carried out before renovation (zero measurement) on a pipe with no damage scenarios present in the host pipe and six tests were carried out at different times after renovation. The recorded delivery losses were then compared with each other.

A system was rated "VERY GOOD (1.0)" if there was a hydraulic performance loss of less than 2.5 %. For a hydraulic performance loss of more than 25 %, a grade of 6.0 (unsatisfactory) was awarded. Values in between were graded accordingly (Table 16).

Table 16. Evaluation scheme for the criterion "hydraulic performance loss”.

Rating "Hydraulic performance loss”	Grading
< 2,5%	1.0
5% > x ≥ 2,5%	2.0
7,5% > x ≥ 5%	3.0
10% > x ≥ 7,5%	4.0
25% > x ≥ 10%	5.0
> 25%	6.0

"Wrinkling/obstacles"

The evaluation criterion **"wrinkling/obstacles"** was assessed for the two liner sections (50 %) and the four bends (50 %) by measuring the wrinkles and assessing possible obstacles in the pipe. Here, the four available bends were considered together as one complete assessment unit. A grade of 1.0 was awarded if the two liner sections or the 4 bends were either wrinkle-free or all wrinkles present were less than ≤ 6 mm in height. If there was at least one wrinkle greater than 6 mm, the system was awarded a grade of 5.0. If "exceptional hydraulic obstructions", e.g., protruding fragments, were detected, a grade of 6.0 was awarded. Table 17 The shows the evaluation scheme for the criterion "wrinkling/obstacles".

Table 17. Evaluation scheme for the evaluation criterion "wrinkling/obstacles – in liner sections and in bends".

Evaluation criterion "Wrinkling/ Obstacles" liner sections and bends	Grading
Wrinkle-free, all wrinkles ≤ 6 mm	1.0
> 6 mm	5.0
Exceptional hydraulic obstacle e.g., protruding fragments	6.0

"Cross-section reduction"

The evaluation criterion **"cross-section reduction"** was assessed by passing wooden balls with diameters of 150 mm to 185 mm through the renovated pipe. The wooden balls were pulled through the pipe with a maximum pulling force of 100 N using a winch (pulling speed: approx. 2 m/min). A separate evaluation was carried out for the sections (50 %), bends (25 %) and connections (25 %) on a liner.

The grade was determined from the diameter of the largest sphere that could fully traverse the lined pipe (Table 18).

Table 18. Evaluation of the evaluation criterion " cross-section reduction".

Evaluation criterion "cross-section reduction" - liner sections, bends, connections -	Grading
≥ 185 mm	1.0
≥ 180 mm	2.0
≥ 170 mm	3.0
≥ 160 mm	4.0
≥ 150 mm	5.0
< 150 mm	6.0

4.5 Quality assurance

The evaluation criterion **"quality assurance"** examined the extent to which the manufacturer monitors the quality of its system or demonstrates quality assurance measures.

Documentation was requested from the manufacturers and evaluated for the following evaluation criteria, each weighted at 20 %:

- **Installation manual (20 %)**

  A basic prerequisite for the application of a renovation system on an installation site is a meaningful description of the installation procedure for use by the installation team. The installation manual should be comprehensibly structured and clearly laid out, contain detailed information on the areas of application of the product and describe the handling of the system and the installation process in detail.

- **Training courses (20 %): Training certificate of the renovation staff (50 %), Training offered by the manufacturer (50 %)**

  For qualification to install a system, the installation personnel should have attended training courses in which the handling of the system could be learned and practical tips from the manufacturer's experience passed on. It was checked whether each manufacturer offers training courses for its renovation system for installation personnel. Ideally, the training courses cover both the theoretical basics and the practical application of the procedures. Evidence of attendance at such training courses by installation staff was checked in the form of certificates from training providers.

- **Test certificates (20 %)**

  The quality of the systems used should have been proven by independent, practical tests with respect to their application in wastewater pressure pipes.

- **Monitoring of quality assurance (20 %):**
  Self-monitoring (50 %) and third-party monitoring (50 %)

  Self-monitoring can serve to ensure the quality of the renovation method. Proof of self-monitoring was deemed to have been provided if an inspection video of the renovation method in the IKT-Comparative Product Test was available after completion of the renovation work and records made of the renovation installation, e.g., renovation protocol. In addition, the external monitoring of renovation method, which is often required in tenders, can serve quality assurance purposes. Therefore, the renovation systems used should be demonstrably offered on the market with qualified third-party monitoring (e.g., Güteschutz Kanalbau or comparable) for the wastewater sector.

- **Special anomalies (20 %)**
  In addition, the criterion "special anomalies (20 %)" was also assessed as part of the quality assurance evaluation. This was considered to be passed (+) if no anomalies concerning the installation process were observed during the installation of a system into the test rig by IKT.

The evaluation criterion **"quality assurance"** accounts for a total of 15 % of the overall grading scheme. The overall grade for “quality assurance” was derived from the scores for the criteria listed above. Each was evaluated with "+/-" (proven / not proven) or "+/o/-" (proven / partially proven / not proven) and were each weighted 20 % in the overall grade. For the evaluation criteria "training" and "monitoring", the two sub-criteria were weighted equally. The evaluation scheme for “quality assurance” is shown in Table 19 and the linear function used to determine grade for the evaluation in Figure 13.

Table 19. Evaluation scheme for the evaluation criterion "quality assurance".

Evaluation criterion	Evaluation	Weighting
Procedure manual	+ / o / -	20 %
Training courses: Training offers of the manu-facturer/ Training certificates held by the renovator, 50% each	+ / -	20 %
Test certificates	+ / o / -	20 %
Monitoring: In-house and external monitoring, 50% each	+ / o / -	20 %
Special conspicuous features	+ / -	20 %

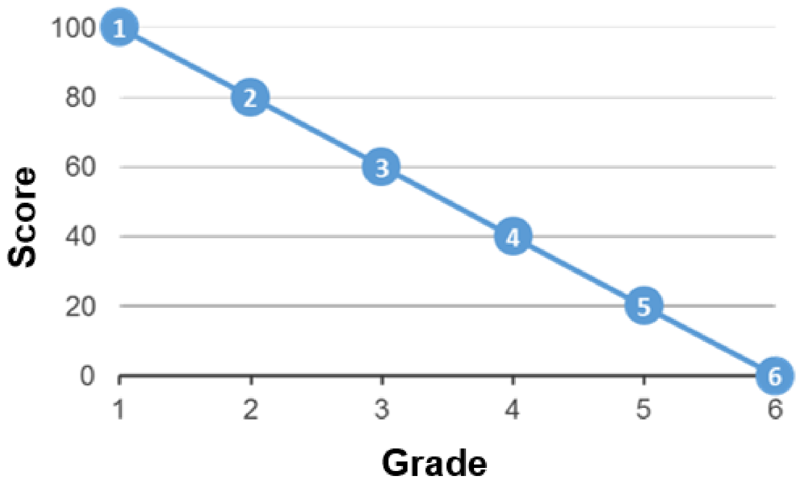


Figure 13. Linear function for evaluating grade for the criterion "quality assurance" from the overall score (%) from the five sub-criteria.

4.6 Additional information

In addition to the tests described, the items listed below were included in the overall assessment (without grading) as **"additional information"**:

- Robustness: performance against shard load / metal tip (double overlapping hole) / incrustation / angular deflection / max. bend
- Wall structure
- Wall thickness
- Installation procedure
- Curing method and time
- Connection (type/ manufacturer)
- Total working time/ days on site

5 Evaluation results

This section presents the results of the IKT-Comparative Product Test "Rehabilitation methods for wastewater pressure pipes - Class A liners". The overall grades were derived from the scores achieved for the key evaluation criteria "watertightness (45%)", "stability (25%)", "operational performance (15%)" and "quality assurance (15%)".

5.1 Overall results table

The following table summarises the results for the evaluation criteria and the gradings achieved by the liner systems. It also contains additional information on "robustness", "wall construction", "wall thickness", "installation method", "curing method and time", "connection (type/manufacturer)" and "total working time/days on site".

The overall result of the IKT-Comparative Product Test "Rehabilitation methods for wastewater pressure pipes - Class A liners" confirms that it is possible to achieve a qualitatively successful renovation result. However, the testing also showed that there were major differences in performance and quality between the individual systems as grades from "GOOD" to "INADEQUATE" were awarded.

The best result was achieved by the "Compact Pipe" system with the grade GOOD (1.8), closely followed by "egeLiner" with the grade GOOD (1.8) (unrounded values were decisive in the ordering).

The "Nordiflow W PE" and "Starline Structure-S" systems received the grade SATISFACTORY (2.6). The "Esders HPS Liner" system achieved a DEFICIENT result (grade 5.3). The "SaniPipe" system, was assessed by the Steering Committee as "not usable as a Class A liner" due to a collapse; as a result, the grade "INADEQUATE (6.0)" was awarded here.

The "IKT-Warentest" ("Product test") seal "Rehabilitation methods for wastewater pressure pipes - Class A liners" can be awarded to the system manufacturer with the manufacturer's own test mark at the manufacturer's request.

Overall Results: IKT–Comparative Product Test (IKT – Warentest) "Rehabilitation methods for wastewater pressure pipes - Class A liner".

Task:

Rehabilitation of an approx. 22 m long steel pipeline DN 200 with the following damage scenarios:
Leaking joints (4x), pitting (2x - with condition deterioration), single hole 48 mm (2x), shear load (with condition deterioration), longitudinal cracks (with condition deterioration), 15°, leaky bend (2x - with condition deterioration), abrasion in the invert, axially displaced socket joint, single hole 8/48 mm (2x - with condition deterioration), ovalisation by 6 %, double overlapping hole 2x 48 mm (optional), transverse cracks with angulation (optional), incrustation (optional), maximum rehabilitable bend (optional).

System		**Compact Pipe**	**egeLiner**	**Nordiflow W PE**	**Starline Structure-S**	**Esders HPS Liner**	**SaniPipe**
Manufacturer		Wavin GmbH	egeplast international GmbH	NordiTube Technologies SE	Karl Weiss Technologies GmbH	Esders Pipeline Service GmbH	Amex Sanivar AG
Renovation company undertaking installation		Diringer & Scheidel Rohr-sanierung GmbH & Co. KG	Esders Pipeline Service GmbH	Esders Pipeline Service GmbH	Karl Weiss Technologies GmbH	Esders Pipeline Service GmbH	Amex Sanivar AG
IKT - Test Rating*		**GOOD 1.8**	**GOOD 1.8**	**SATISFACTORY 2.6**	**SATISFACTORY 2.6**	**DEFICIENT 5.3**	**INADEQUATE 6.0**[1]
Statically independent class A liner? (knock-out criterion)		**yes**	**yes**	**yes**	**yes**	**yes**	**no** Not usable as class A liner due to system collapse
Watertightness[2] Devaluation due to rework after installation	**45%**	**1.0** none	**1.0** none	**2.0** Tight only after 1x rework[3] (-1.0)	**3.0** tight only after 2x rework[3] (-2.0)	**6.0** Leaky even after 2x rework[3]	**3.4** tight only after 1x rework[3] (-1.0)
Exfiltration watertightness	80%	1.0	1.0	1.0	1.0	5.0	2.8
Infiltration watertightness	20%	1.0	1.0	1.0	1.0	1.0	1.0
Stability	**25%**	**3.0**	**3.0**	**3.2**	**2.0**	**5.4**	**6.0**
Load bearing capacity of the structure	50%	2.0 Deformations in the bend	2.0 Deformations in the bend	4.0 Wrinkles in the bend, holes, air pockets	2.0 Wrinkles in the bend	5.0 Continuous longitudinal fold, wrinkles in the bend, holes, risk of failure	6,0 Continuous longitudinal fold, wrinkles in the bend, holes, risk of failure, system collapse
Static proof	30%	4,5	4,0	2,5	2,0	5,5	6,0
Material and geometry target/actual comparison	20%	3.0 2 Deviations	4.0 3 Deviations	2.0 1 Deviation	2.0 1 Deviations	6.0 6 Deviations	6.0 6 Deviations
Operational performance	**15%**	**2.3**	**2.4**	**3.3**	**2.7**	**4.1**	**4.5**
Overall visual impression after refurbishment, HP cleaning and end of testing	25%	1.0	1.0	3.4	2.7	5.0	4.7
Hydraulic performance loss after renovation in percent[4]	25%	3.0 - 6%	3.0 - 6%	4.0 - 8%	2.0 - 3%	3.0 - 5%	4.0 - 8%
Wrinkling / Obstacles	25%	1.0 none	1.0 none	3.0 > 6 mm in bend	3.0 > 6 mm in bend	5.0 > 6 mm in liner section & bend	5.0 > 6 mm in liner section & bend
Cross-section reduction of the host pipe DN 200: max. ball passage line / bend / connection	25%	4.3 160 / 155 / 160 mm	4.5 160 / 155 / 155 mm	3.0 180 / 170 / 155 mm	3.0 180 / 160 / 160 mm	3.3 170 / 170 / 160 mm	4.3 160 / 160 / 155 mm
Quality assurance Procedures manual, training, test certificate, monitoring, special anomalies	**15%**	**1.5**	**1.5**	**2.5**	**2.5**	**4.5** Continuous longitudinal fold	**5.5** Continuous longitudinal fold and execution defects
Additional information Not part of the grade							
Robustness: shard load, metal tip (double overlapping hole), incrustation, angular deflection, maximum bend		o | - | + | + | 22.5°	+ | - | - | + | 22,5°	+ | + | - | + | 15°	+ | + | + | + | 30°	o | + | + | + | 30°	o | + | + | + | 30°
Wall structure		PE pipe SDR17 PN10 PE100	PE pipe SDR17 PN10 PE100-RC	Preliner + GRP-reinforced needle felt + inner foil	Preliner + laminate with glass fibres + fabric sleeve + inner foil	Outer foil + laminate with needle felt + fabric hose + inner foil	Outer film + felt fabric and poly-ester fibres with resin casting + inner film
Wall thickness		approx. 13.4 mm	approx. 13.5 mm	approx. 4.9 mm	approx. 6.3 mm	approx. 7.3 mm	approx. 7.7 mm
Installation procedure		Close-fit insertion method	Close-fit insertion method	Inversion method with preliner	Inversion method with preliner	Insertion/Inversion Process	Insertion/Inversion Process
Curing method and time		Steam (120 C°), approx. 2 h	Steam (130 C°), approx. 1.5 h	Steam (80 C°), approx. 3.5 h	Hot water (40 C°), approx. 19 h	Steam (100 C°), approx. 1.5 h	Steam (80 C°), approx. 22 h
Connection type		PE flange/ electrofusion socket	PE flange / electrofusion socket	Amex liner end cuff	Kempe liner end sleeve	Amex liner end cuff	Amex liner end cuff
Total working time / days on site		14.5 h / 2 days	15.5 h / 3 days	15.5 h / 3 days	11.5 h / 2 days	11 h / 2 days	14.5 h / 4 days

[1] Due to system collapse, the IKT test rating of "INADEQUATE 6.0" was awarded by the Steering Committee independently of the other sub-ratings.
[2] For the difference in the evaluation of exfiltration and infiltration watertightness, see chapter 4.2, page 31.
[3] Rework on liner end seals
[4] Does not serve as a dimensioning reference.
*Note calculation based on unrounded values

Evaluation key of the test results: Very good = 1.0 - 1.5. Good = 1.6 - 2.5. Satisfactory = 2.6 - 3.5. Sufficient = 3.6 - 4.5. Deficient = 4.6 - 5.5. Inadequate = 5.6 - 6.0

5.2 Watertightness

The criterion **"watertightness"** was evaluated on the basis of the results of exfiltration permeability and infiltration permeability, which were weighted 80 % and 20 % respectively. The exfiltration watertightness was subdivided into the tests on the renovation system in the IKT - large-scale test facility ("before condition deterioration", 20 %, "after condition deterioration", 30 % and "special operating conditions", 30 %) and material tests on liner samples ("watertightness of test samples", 20 %). In addition, the final score of the evaluation criterion "watertightness" was devalued if rework due to leaks had to be carried out after completion of the installation work (Section 4.2).

The Table 20 shows the evaluation of exfiltration watertightness, infiltration watertightness and the devaluation as well as the overall grading for the evaluation criterion "watertightness".

Table 20. Overall grading of systems for the evaluation criterion "watertightness".

Watertightness (45%)						
System/ Evaluation	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Exfiltration watertightness, 80%[1]	1.0	1.0	5.0	1.0	2.8	1.0
Infiltration watertightness, 20%[2]	1.0	1.0	1.0	1.0	1.0	1.0
Score	1.0	1.0	4.2	1.0	2.4	1.0
Devaluation because of need for rework[3]	0.0	0.0	6.0[5]	1.0	1.0	2.0
Total score, 100%[4]	**1.0**	**1.0**	**6.0[5]**	**2.0**	**3.4**	**3.0**

Grade key: very good = 1.0-1.5 / good = 1.6-2.5 / satisfactory = 2.6-3.5 / sufficient = 3.6-4.5 / deficient = 4.6-5.5 and inadequate = 5.6-6.0

[1] The evaluation was based on the detailed results presented in Table 21.
[2] The evaluation was based on the detailed results presented in Table 22.
[3] The devaluation of scores was based on the detailed results presented in Table 23.
[4] The mean value calculation was undertaken with unrounded values.
[5] No successful rework, dripping or flowing visible, therefore the evaluation criterion "watertightness" was assessed with the rating 6.0.

“Exfiltration watertightness" results

Overall, the results for exfiltration are shown in Table 21 and can be summarised as follows:

<u>Results from testing in the IKT - large-scale test facility</u>

- Exfiltration was not observed in the "Compact Pipe", "egeLiner", "Nordiflow W PE" and "Starline Structure-S" systems in the course of the tests on system conducted in the IKT large-scale test facility over the entire loading period. Accordingly, no critique points were awarded (colour coding "green" throughout in Table 21).

- In the "SaniPipe" system, a visually conspicuous defect in the form of moisture (colour coding "yellow") was detectable at least once in all three operational conditions phases of testing. In total, moisture was detected 1x (17 %) "before condition deterioration", 6x (100 %) "after condition deterioration" and 5x (63 %) under "special operating conditions" (Figure 14).
- In the "Esders HPS Liner" system, at the "standard operating pressure" of approx. 2 bar, conspicuous features in the form of "drops" (colour code "orange") were visible on both liner sections "before condition deterioration" and in liner section 1 "after condition deterioration". Due to the existing leaks, the planned operating loads of 4 bar and above could not be implemented (target pressure was not reached - colour code "purple"). In addition, the loads "static maximum test pressure" with 9 bar and "abrasive contents" with 6 bar could not be carried out in the "special operating conditions" either. In the case of "Air overpressure loads I and II", conspicuous features in the form of "drops" were visible on one liner section in each case (Figure 15).

Laboratory material tests on liner samples

- The APS watertightness tests undertaken on samples were passed by all six systems. The tests undertaken on conspicuous defects observed on the "Esders HPS Liner", "SaniPipe" and "Nordiflow W PE" systems also showed no abnormalities (test passed).

The results for the criterion "exfiltration watertightness" are summarised in Table 21.

Conclusions for "exfiltration watertightness”

- The "Compact Pipe", "egeLiner", "Nordiflow W PE" and "Starline Structure-S" systems showed no abnormalities (liner sections and connections) over the entire observation period. Accordingly, the systems were each awarded the grade 1.0.
- The "SaniPipe" system showed conspicuous features in the form of "moisture", and so received an overall grade of 2.8. The "Esders HPS Liner" system showed "dripping". In addition, it was not possible to reach the target pressure according to the load and test programme due to leaks (probably circulation in the area of folds/ liner end sleeves). Accordingly, the system was graded 5.0.
- The APS leak tests on liner samples were passed by all six systems.

Table 21. Results of testing for the criterion “exfiltration waterwatertightness”.

Exfiltration watertightness (80%)												
Manufacturer	**Compact Pipe**		**egeLiner**		**Esders HPS Liner**		**Nordiflow W PE**		**SaniPipe**		**Starline Structure-S**	
Liner section (1 & 2)/ load	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Before damage deterioration, 20%												
Standard pressure												
Increased pressure												
Cyclic pressure												
Critique points	0	0	0	0	14	14	0	0	0	1	0	0
Interim grade	1.0	1.0	1.0	1.0	6.0	6.0	1,0	1,0	1,0	2,0	1,0	1,0
Note, 20%	**1.0**		**1.0**		**6.0**		**1.0**		**1.5**		**1.0**	
Following damage deterioration, 30%												
Standard pressure												
Increased pressure												
Cyclic pressure												
Critique points	0	0	0	0	14	10	0	0	3	3	0	0
Interim grade	1.0	1.0	1.0	1.0	6.0	6.0	1.0	1.0	4.0	4.0	1.0	1.0
Grade, 30%	**1.0**		**1.0**		**6.0**		**4.0**		**4.0**		**1.0**	
Special operating conditions, 30%												
Static max. pressure												
Abrasion												
Air overpressure I												
Air overpressure II												
Critique points	0	0	0	0	14	14	0	0	3	2	0	0
Interim grade	1.0	1.0	1.0	1.0	6.0	6.0	1.0	1.0	4.0	3,0	1.0	1.0
Grade, 30%	**1.0**		**1.0**		**6.0**		**1.0**		**3.5**		**1.0**	
Watertightness of laboratory test samples, 20%												
After installation	Passed		Passed		Passed		Passed		Passed		Passed	
After tipping trough abrasion	Passed		Passed		Passed		Passed		Passed		Passed	
After chemical resistance	Passed		Passed		Passed		Passed		Passed		Passed	
After cyclic loading	Passed		Passed		Passed		Passed		Passed		Passed	
Conspicuous features	Passed		Passed		Passed		Passed		Passed		Passed	
Note, 20%	**1.0**		**1.0**		**1.0**		**1.0**		**1.0**		**1.0**	
Total score, 100%	**1.0**		**1.0**		**5.0**		**1.0**		**2.8**		**1.0**	

Legend:
Green - no abnormality
Yellow - moisture
Orange - drops
Red - Flow/ Water Surge
Purple - target pressure was not reached

Figure 14 Exfiltration watertightness: Moisture on the "SaniPipe".

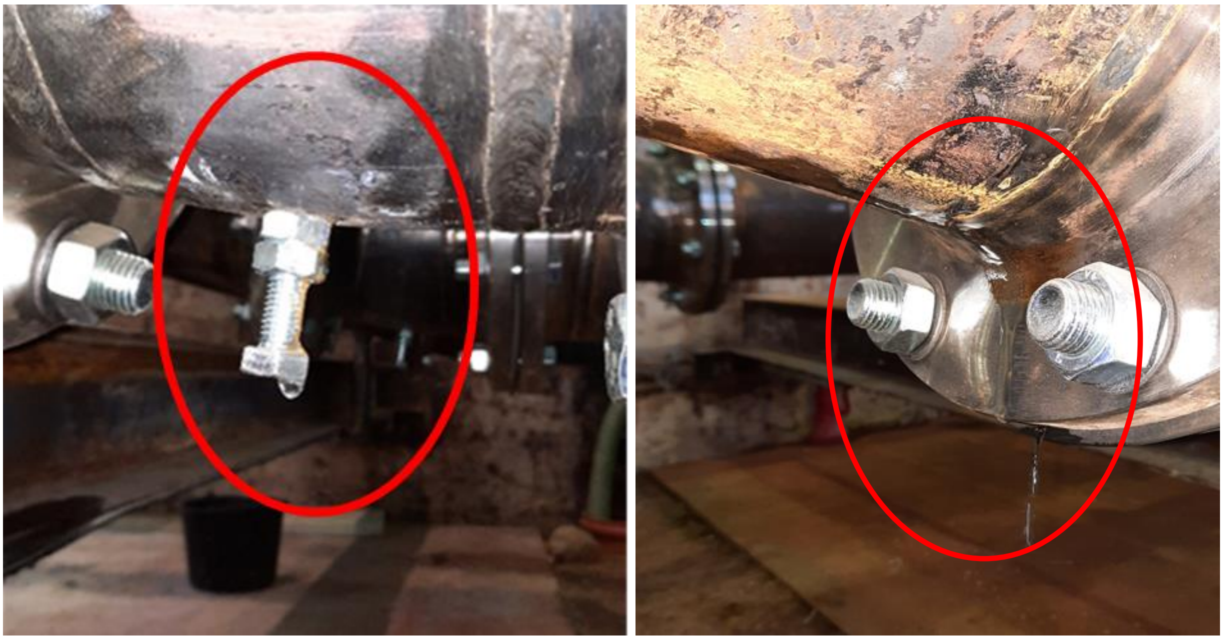


Figure 15. Exfiltration watertightness: Drops on the "Esders HPS Liner".

Results for "infiltration watertightness"

The results for the evaluation criterion "infiltration watertightness" are presented in Table 22 and can be summarised as follows:

- Infiltration was not observed in any of the six systems over the entire loading period. Accordingly, the systems were each awarded a grade of 1.0.

Table 22. Results of testing for the evaluation criterion “infiltration watertightness”.

Infiltration watertightness (20%)												
Manufacturer	**Compact Pipe**		**egeLiner**		**Esders HPS Liner**		**Nordiflow W PE**		**SaniPipe**		**Starline Structure-S**	
Liner section/ load	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Air overpressure I												
Negative air pressure												
Air overpressure II												
Critique points	0	0	0	0	0	0	0	0	0	0	0	0
Interim grade	1.0	1.0	1.0	1.0	1.0	1.0	1,0	1,0	1,0	1,0	1,0	1,0
Total score, 100%	**1.0**		**1.0**		**1.0**		**1.0**		**1.0**		**1.0**	

Legend:
Green - no abnormality
Yellow - moisture
Orange - drops
Red - Flow/ Water Surge

Devaluation of grades for the evaluation criterion "watertightness" because of observed abnormalities

The grades obtained for “watertightness” were lowered (devalued) if there were observed abnormalities that the Steering Committee considered significant with regard to overall performance.

The following observations were made:

- The "Compact Pipe" and "egeLiner" systems did not show any abnormalities when the water level test was carried out after installation, therefore no devaluation of their grade was made.

- The "Esders HPS Liner", "Nordiflow W PE", "SaniPipe" and "Starline Structure-S" systems each exhibited leaks after installation, so that a rework was necessary before carrying out the loading and testing programme.

- The "Nordiflow W PE" (Figure 16) and "SaniPipe" (Figure 17) systems passed the water level test after further work on the liner end seals (1st rework). With the "Starline Structure-S" system (Figure 18), a successful water level test was achieved after two reworks on the liner end seals (2nd rework). Accordingly, the grade for the evaluation criterion "watertightness" was devalued by 1.0 and 2.0 respectively for these systems.

- After two rework attempts on the liner-end seals, the "Esders HPS Liner" system (Figure 19) “dripping or flowing" was still visible during the water level test.

Therefore, the evaluation criterion "watertightness" was evaluated with the grade 6.0 independent of the results from the other criteria.

The results of the devaluation of the evaluation criterion "watertightness" due to the need for rework post installation are presented in Table 23.

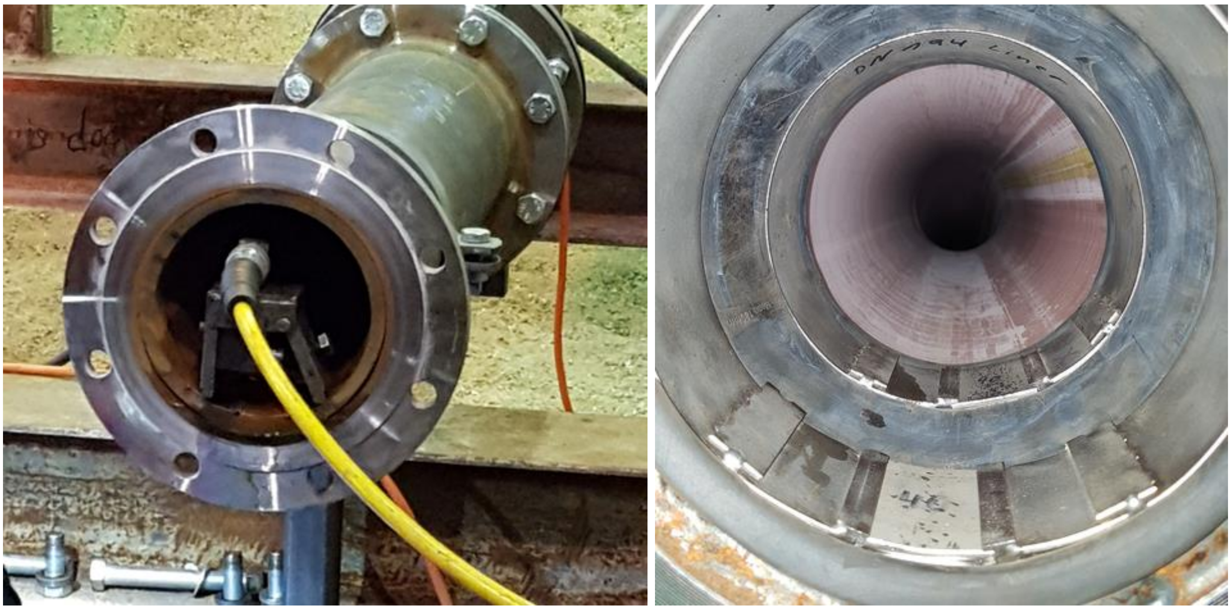


Figure 16. Retightening of the sleeves on "Nordiflow W PE": mechanical device for retightening (left), rework result (right).

Figure 17. Replacing the sleeves with acetate silicone with "SaniPipe": applying the sealant (left), rework result (right).

Figure 18. Replacing the sleeves with resin sealant on "Starline Structure-S": applying the sealant (left), rework result (right).

Figure 19. Replacing the sleeves with resin sealant on "Esders HPS Liner": application of sealant (left), rework result (right).

Table 23. Devaluation of the grading for the evaluation criterion "watertightness".

Devaluation of the evaluation criterion "watertightness" for rework												
Manufacturer	**Compact Pipe**		**egeLiner**		**Esders HPS Liner**		**Nordiflow W PE**		**SaniPipe**		**Starline Structure-S**	
Liner section/ load	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Level test after installation	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
Level test after rework 1	Green	Green	Green	Green	Red	Red	Green	Green	Green	Green	Red	Red
Level test after rework 2	Green	Green	Green	Green	Red	Red	Green	Green	Green	Green	Green	Green
Devaluation to	**0.0**		**0.0**		**6.0***		**1.0**		**1.0**		**2.0**	

*No successful rework, dripping or flowing visible, therefore the evaluation criterion "watertightness" was assessed with grade 6.0.
Legend: Green - Watertight during water level check; Red - Leaking during water level check

5.3 Stability

"Stability" was evaluated on the basis of the criteria "load-bearing capacity of the structure", "static proof" and "material and geometry", which were weighted 50 %, 30 % and 20 % respectively. .

Table 24 shows the results for the grading of "stability" of the systems.

Table 24. Overall grading of the systems for the evaluation criterion "stability".

Stability (25%)						
System/ Evaluation	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Load-bearing capacity of the structure (knock-out criterion), 50%[1]	2.0	2.0	5.0	4.0	6.0 (KNOCKOUT)[5]	2.0
Static proof, 30%[2]	4.5	4.0	5.5	2.5	6.0	2.0
Material and geometry, 20%[3]	3.0	4.0	6.0	2.0	6.0	2.0
Total score, 100%[4]	**3.0**	**3.0**	**5.4**	**3.2**	**6.0[5]**	**2.0**

Grade key: very good = 1.0-1.5 / good = 1.6-2.5 / satisfactory = 2.6-3.5 / sufficient = 3.6-4.5 / deficient = 4.6-5.5 and inadequate = 5.6-6.0

[1] The evaluation was based on the detailed results presented in Table 25.
[2] The evaluation was based on the detailed results presented in Table 26.
[3] The devaluation was based on the detailed results presented in Table 27.
[4] The mean value calculation was done with unrounded values.
[5] Due to system collapse, the rating of "INADEQUATE 6.0" was awarded by the Steering Committee independently of the other sub-ratings.

Results for "load-bearing capacity of the structure"

The criterion **"load-bearing capacity of the structure"** was evaluated over the entire testing period. If no abnormalities were found, grade 1.0 was awarded. If there was any abnormality in the form of deformation, wrinkling, holes or air pockets, the system received a grade of 2.0. If there were two or three abnormalities, the system received a grade of 3.0 or 4.0. A grade of 5.0 was given if potential risks of system failure (cracks, large deformations-wrinkles-flaws) were identified. In case of collapse or bursting, the grade 6.0 was awarded.

Table 25 shows the evaluation results for the criterion "loadbearing capacity of the structure".

Table 25. Results of the testing for the evaluation criterion "load-bearing capacity of the structure".

Load-bearing capacity of the structure (50%)						
System/ Evaluation	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Continuous longitudinal fold	no	no	yes	no	yes	no
Wrinkles in liner sections > 6mm	no	no	no	no	no	no
Wrinkles in bends > 6mm	no	no	yes	yes	yes	yes
Deformations in liner sections	no	no	no	no	no	no
Deformations in the bends	yes	yes	no	no	no	no
Holes	no	no	yes	yes	yes	no
Air pockets in the liner wall	no	no	no	yes	no	no
Risk of failure	no	no	yes	no	yes	no
Collapse	no	no	no	no	yes[1]	no
Number of anomalies	1	1	4	3	5	1
Overall grade	**2.0**	**2.0**	**5.0**	**4.0**	**6.0[1]**	**2.0**

[1] Due to a system collapse, test rating of "INADEQUATE 6.0" was awarded by the Steering Committee independently of the other sub-ratings.

Overall, the results for **"load-bearing capacity of the structure"** can be summarised as follows:

- The "Compact Pipe" and "egeLiner" systems both exhibited deformation through the bends, so both received a grade of 2.0.

- The "Starline Structure-S" and "Nordiflow W PE" systems showed wrinkles folds in bends > 6 mm. In addition, "Nordiflow W PE" had holes and air pockets in the liner wall. Accordingly, the "Starline Structure-S" system received the grade 2.0 and the "Nordiflow W PE" system received the grade 4.0.

- With "Esders HPS-Liner" there was a possible risk of failure of the system because there was a continuous longitudinal fold in the liner, so it was graded 5.0. In the case of the "SaniPipe" system, a continuous longitudinal fold in the liner and a collapse in the course of the negative air pressure and external water pressure load, and so a grade 6.0 was awarded. Due to this collapse, the Steering Committee decided for the knock-out criterion of "load-bearing capacity of the structure" that this system was "not usable as a Class A liner". Accordingly, the overall test rating "inadequate (6.0)" was awarded, independently of the grades achieved for other criteria.

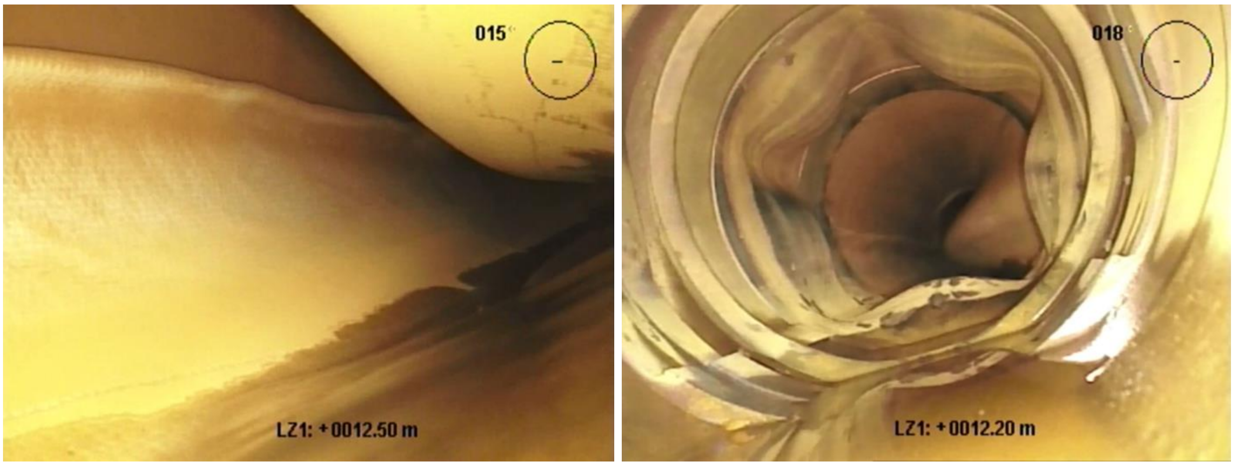


Figure 20. Load-bearing capacity of the "SaniPipe" structure: collapse due to negative air pressure and external water pressure loading.

Figure 21. Load-bearing capacity of the "SaniPipe" structure: cracks due to collapse caused by negative air pressure and external water pressure loading.

Results for "static calculation”

The criterion **"static calculation"** was evaluated by an IKT expert checking the calculation provided by the supplier of each system with regard to its plausibility, noting and deficiencies with critique points.

The critiques were related to deficiencies in the following performance dimensions:

- Consideration given to load cases (internal pressure and external pressure)
- Consideration given to damage scenarios (ovalisation, socket offset, single hole)
- Plausibility of the calculation method

A system was given a grade of 1.0 if there were no critique points (0 critique points). For four or five critique points, the grade 5.0 or 6.0 was awarded. If no static proof was available, the system received a grade of 6.0.

Table 26 shows the evaluation results for the evaluation criterion "static proof".

Table 26. Results for the evaluation criterion "static proof".

Static proof (30%)						
System/ Evaluation	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Consideration of load cases[1]						
Internal pressure, long-term, 6 bar	0 CP	1 CP	1 CP	0 CP	1 CP	0 CP
Internal pressure, short-term, 9 bar	1 CP	1 CP	0 CP	1 CP	1 CP	0 CP
External pressure, 1.0 bar	1 CP	0 CP	1 CP	0 CP	1 CP	0 CP
Sum CP	2 CP	2 CP	2 CP	1 CP	3 CP	0 CP
Consideration of damage scenarios						
Ovalisation[2]	1 CP	0.5 CP	1 CP	0.5 CP	1 CP	0.5 CP
Socket offset/ single hole[3]	0.5 CP	0.5 CP	0.5 CP	0 CP	0.5 CP	0.5 CP
Sum CP	1.5 CP	1 CP	1.5 CP	0.5 CP	1.5 CP	1 CP
Plausibility of the calculation[1]						
Plausible	0 CP	0 CP	1 CP	0 CP	1 CP	0 CP
Total critique points	3.5 CP	3 CP	4.5 CP	1.5 CP	5.5 CP	1 CP
Overall grade	**4.5**	**4.0**	**5.5**	**2.5**	**6.0**	**2.0**

[1] yes = 0 CP; no = 1 CP
[2] yes, ≥ 6% = 0 CP; yes, < 6% = 0.5 CP; no = 1 CP
[3] yes/yes and yes/no= 0 CP; no/no= 0.5

The overall results for **"static proof"** can be summarised as follows:

- The evaluation criterion "static proof" showed large differences between systems (grades 2.0 to 6.0). The "Starline Structure-S" and "Nordiflow W PE" systems received the grade "GOOD" (2.0 and 2.5). For the "egeLiner", "Compact Pipe" and "Esders HPS Liner" grades of 4.0, 4.5 and 5.5 were awarded. The manufacturer of the "SaniPipe" system did not provide any static proof and therefore received the grade 6.0.

Results for "material and geometry"

For the evaluation criterion **"material and geometry"**, an IKT assessor checked whether the material characteristics and geometry correspond to the static assumptions. The following points were checked and critiqued:

- Material parameters (tensile strength, bending strength, bending stiffness) according to the static assumptions
- Geometry (wall thickness, annular gap, ovalisation) according to the static assumptions

A system was given a grade of 1.0 if there were no critique points (0 critique points). From four or five critique points, the grade 5.0 or 6.0 was awarded.

Table 27 shows the results for the evaluation criterion "material and geometry".

Table 27. Results for the evaluation criterion "material and geometry”.

Deviations from static assumptions (20%)						
System/ Evaluation	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Target/actual comparison of material parameters						
Tensile strength (Target/ Actual)	0 CP	0 CP	1 CP	0 CP	1 CP	0 CP
Flexural strength (target/actual)	0 CP	0 CP	1 CP	0 CP	1 CP	0 CP
Bending stiffness (nominal/actual)	0 CP	0 CP	1 CP	0 CP	1 CP	0 CP
Sum CP	0 CP	0 CP	3 CP	0 CP	3 CP	0 CP
Target/actual comparison geometry						
Wall thickness (target/actual)	0 CP	1 CP	1 CP	0 CP	1 CP	0 CP
Ring gap (nominal/actual)	1 CP	1 CP	1 CP	0 CP	1 CP	0 CP
Ovalisation (target/actual)	1 CP	1 CP	1 CP	1 CP	1 CP	1 CP
Sum CP	2 CP	3 CP	3 CP	1 CP	3 CP	1 CP
Total critique points	**2 CP**	**3 CP**	**6 CP**	**1 CP**	**6 CP**	**1 CP**
Overall grade	**3.0**	**4.0**	**6.0**	**2.0**	**6.0**	**2.0**

[1] CP= Critique Point; complied with = 0 CP; not complied with = 1 CP

The overall results for **"material and geometry”** can be summarised as follows:

- The evaluation criterion "material and geometry" showed considerable differences between the different manufacturers (grades 2.0 to 6.0). As a result, two manufacturers received the grade "GOOD", one manufacturer the grade "SATISFACTORY", one manufacturer the grade "VERY GOOD" and two manufacturers the grade "INADEQUATE".

5.4 Results for operational performance

The evaluation of **"operational performance"** was assessed on the basis of the criteria: "overall visual impression", "hydraulic performance loss", "wrinkling/obstructions" and "cross-section reduction", each of which was weighted at 25 %.

The Table 28 shows the overall grading of the system tests for the evaluation criterion "operational performance".

Table 28. Grading of systems for the evaluation criterion "operational performance".

Operational performance (20%)						
System/ Evaluation	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Overall visual impression[1]	1.0	1.0	5.0	3.4	4.7	2.7
Hydraulic performance loss[2]	3.0	3.0	3.0	4.0	4.0	2.0
Wrinkling/ Obstacles[3]	1.0	1.0	5.0	3.0	5.0	3.0
Cross-section-reduction[4]	4.3	4.5	3.3	3.0	4.3	3.0
Overall grade	**2.3**	**2.4**	**4.1**	**3.3**	**4.5**	**2.7**

Grade key: very good = 1.0-1.5 / good = 1.6-2.5 / satisfactory = 2.6-3.5 / sufficient = 3.6-4.5 / deficient = 4.6-5.5 and inadequate = 5.6-6.0

[1] The evaluation was based on the detailed results presented in Table 29.
[2] The evaluation was based on the detailed results presented in Table 30.
[3] The evaluation was based on the detailed results presented in Table 31.
[4] The evaluation was based on the detailed results presented in Table 32.
[5] The mean value calculation undertaken with unrounded values

Results for "overall visual impression"

The evaluation criterion **"overall visual impression"** assessed whether the serviceability of the pipeline for conveying wastewater had been restored, i.e., the impression gained of the extent to which the renovated sewer section was free of obstacles to drainage performance and blockage hazards. The assessment for the awarding of grades was carried out by the Steering Committee members on the basis of photographic documentation provided to them (Table 15). A grade of "4" (SUFFICIENT) or better was considered a "pass". The scores awarded by each Steering Committee members were arithmetically averaged to give an overall result. The evaluation distinguishes between the state of the liners "after renovation", "after high-pressure cleaning" and "after the end of the test programme", which were respectively weighted 20%, 40% and 40%.

Table 29 shows the grading for "overall visual impression" and example photographs illustrating a range of the conspicuous features that were observed are shown in Figures 22 to 30. The overall results can be summarised as follows:

- The evaluation criterion "overall visual impression - after renovation" was assessed with grades between 1.0 (Compact Pipe, egeLiner) and 4.0 (Esders HPS Liner).
- The "visual impression - after high-pressure cleaning" remained unchanged for the close-fit liners (Compact Pipe, egeLiner) with an evaluation grade of 1.0.

The cured in place liner systems were scored between 2.7 (Starline Structure-S) and 4.8 (Esders HPS Liner).

- Scores between 1.0 (Compact Pipe, egeLiner) and 6.0 (SaniPipe) were awarded for the condition "Overall visual impression - after end of test programme".

Table 29. Results for the evaluation criterion "overall visual impression".

Overall visual impression (25%)						
System/ Evaluation	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
after renovation (20%)						
Grade	1.0	1.0	4.0	2.5	3.7	2.7
after high-pressure cleaning (40%)						
Grade	1.0	1.0	4.8	3.2	4.0	2.7
after the end of the test programme (40%)						
Grade	1.0	1.0	5.7	4.0	6.0	2.7
Overall grade	**1.0**	**1.0**	**5.0**	**3.4**	**4.7**	**2.7**

Figure 22. Overall visual impression: Compact Pipe without conspicuous anomalies (left), egeLiner without conspicuous anomalies (right).

Figure 23. Overall visual impression "Esders HPS Liner": continuous longitudinal fold (left), deposits on continuous longitudinal fold (right).

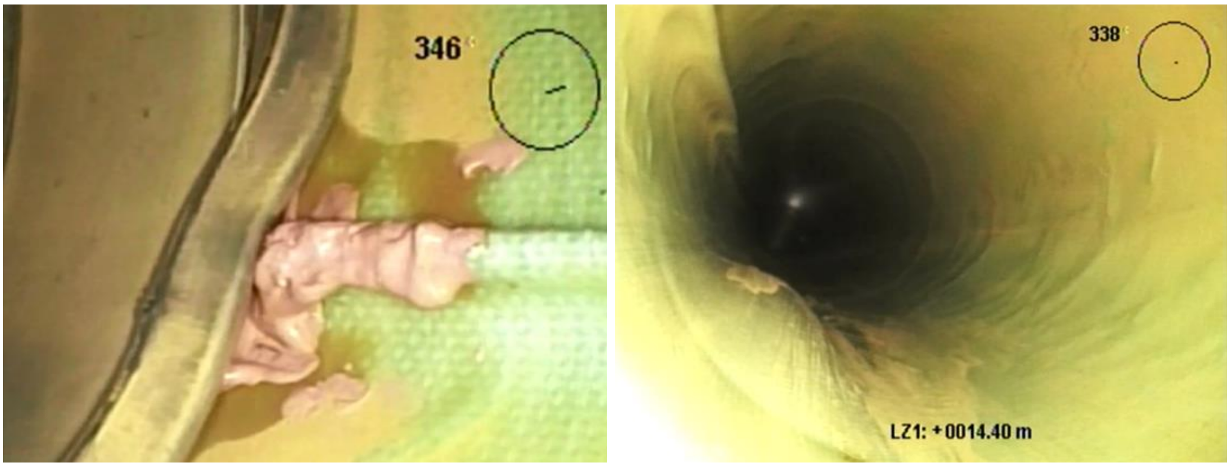


Figure 24. Overall visual impression "Esders HPS Liner": resin seal in the fold area at connection 3 (left), bulge in the liner (right).

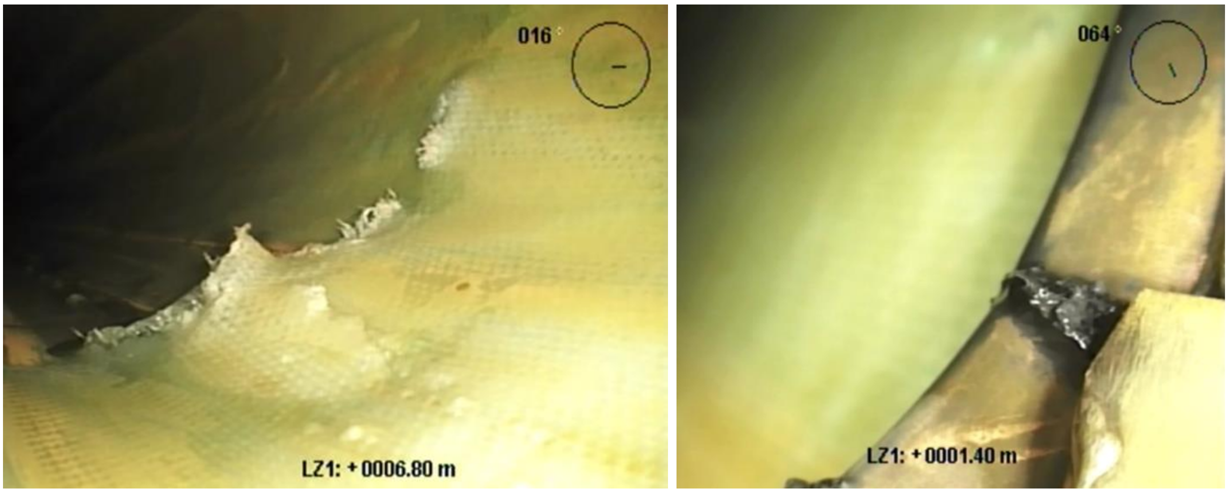


Figure 25. Overall visual impression of "Esders HPS Liner": holes after HP cleaning (left), holes in the rubber of the sleeves after HP cleaning (right).

Figure 26. Overall visual impression "Nordiflow W PE": No conspicuous features (left), wrinkles in a bend (right).

Figure 27. Overall visual impression "Nordiflow W PE": deposits (left), hole in the rubber of an end connection after hig pressure cleaning (right).

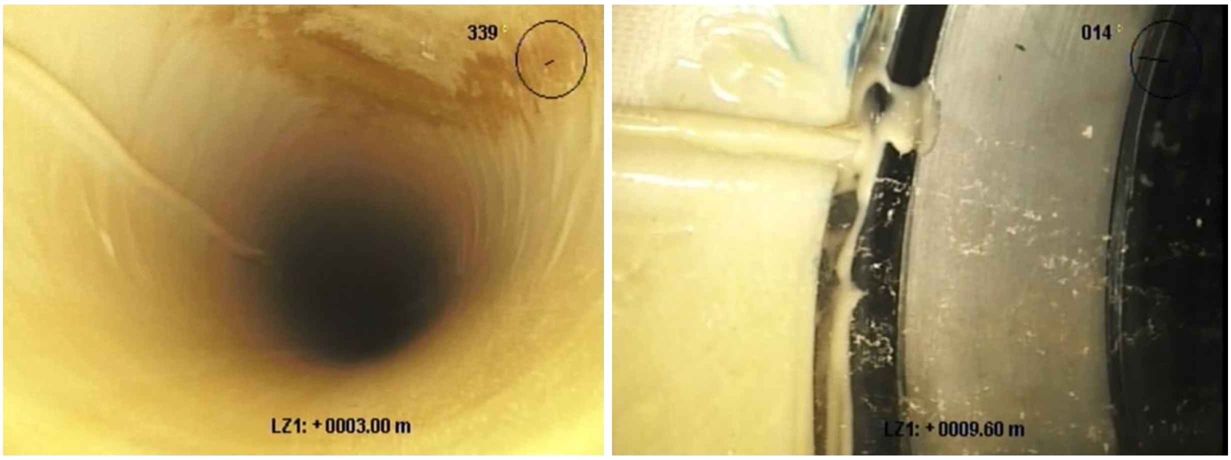


Image 28. Overall visual impression of "SaniPipe": continuous longitudinal fold (left), silicone seal in the fold area at connection 3 (right).

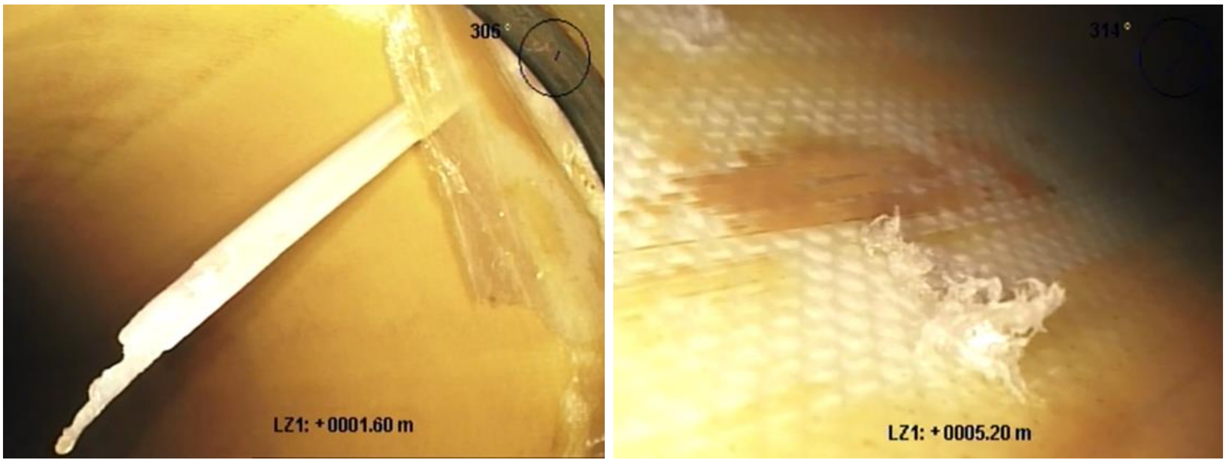


Figure 29. Overall visual impression of "SaniPipe": Damage to end connection after HP cleaning (left), holes in liner after HP cleaning (right).

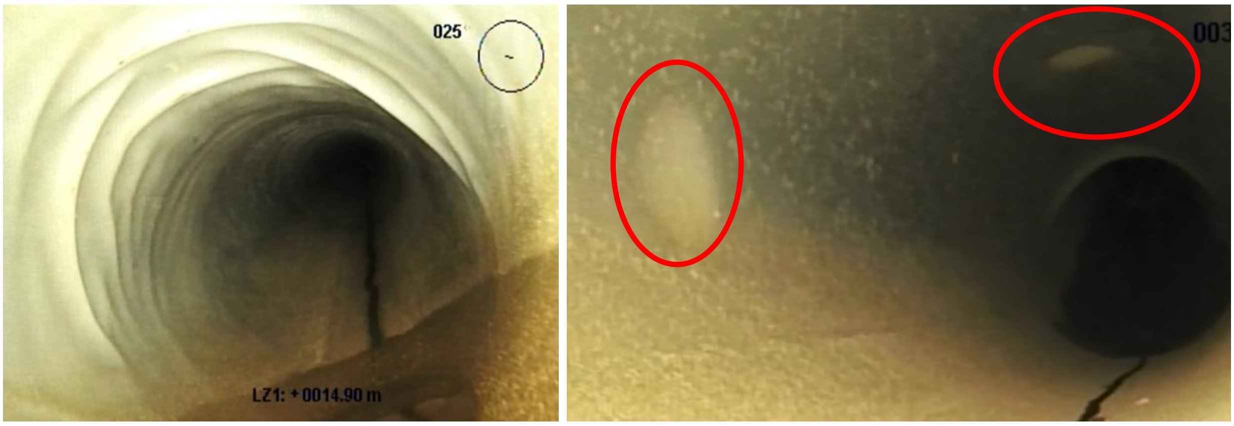


Figure 30. Overall visual impression "Starline Structure-S": wrinkles on a bend (left), discolouration (right).

Results for "hydraulic performance loss"

For the evaluation criterion **"hydraulic performance loss"**, one test was carried out before renovation (zero measurement) on the host pipe and six tests were carried out at different times after renovation and the recorded delivery losses were then compared with each other.

A system was rated "VERY GOOD (1.0)" if there was a hydraulic performance loss of less than 2.5 % in the test. For a hydraulic performance loss of more than 25 %, a grade of 6.0 (INADEQUATE) was awarded. Values in between were graded accordingly (Table 16).

The overall results are shown in Table 30 and can be summarised as follows:

- The evaluation criterion "hydraulic performance loss" showed differences between the various systems (grades 2.0 to 4.0). As a result, the "Starline Structure-S" system received a grade of 2.0. The "Compact Pipe", "egeLiner" and "SaniPipe" systems achieved a satisfactory result (3.0). The systems "Esders HPS-Liner" and "Nordiflow W PE" showed a hydraulic performance loss of 8 % after the installation, so consequently were awarded grade 4.0.

Table 30. Results for the evaluation criterion "hydraulic performance loss”.

Hydraulic performance loss (25%)						
System/ Evaluation	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Ø Loss [%]	6 %	6 %	5 %	8 %	8 %	3 %
Overall grade	**3.0**	**3.0**	**3.0**	**4.0**	**4.0**	**2.0**

Results for "Wrinkling/obstacles”

The evaluation criterion **"wrinkling/obstacles"** was separately assessed for liner sections (50 %) and bends (50 %) by measuring the wrinkles and assessing possible obstacles in the lined pipe. Here, the four available bends were considered together. A grading of 1.0 was awarded if lined sections and the bends were either wrinkle-free or all wrinkles present had a height of ≤ 6 mm. If there was at least one wrinkle greater than 6 mm, the system was awarded a grade of 5.0. If "unusual hydraulic obstructions", e.g., protruding fragments, were found, a grade of 6.0 was awarded.

The overall results for “wrinkles and bends” are shown in Figure 31 and can be summarised as follows:

- The evaluation criterion "wrinkling/obstacles" showed considerable differences between the different systems (grades 1.0 to 5.0).
- The "Compact Pipe" and "egeLiner" systems received the grade 1.0, as no wrinkles larger than 6 mm were discernible either in the liner sections or in the bends.
- In the "Nordiflow W PE" and "Starline Structure-S" systems, wrinkles larger than 6 mm were found in the bends. No wrinkles larger than 6 mm were present in the lined sections, so that a score of 3.0 was awarded.
- The "Esders HPS-Liner" and "SaniPipe" systems received a grade of 5.0, as there were wrinkles larger than 6 mm in both the sections and the bends.
- All six systems showed no unusual hydraulic obstructions, e.g., protruding fragments.

Figure 31. "Wrinkles/obstacles": no conspicuous features with "Compact Pipe" (top left) and "egeLiner" (top centre); longitudinal fold > 6 mm in "Esders HPS Liner" (top right) and "SaniPipe" (bottom left); folds > 6 mm in "Nordiflow W PE" (bottom centre) and "Starline Structure-S" (bottom right).

Table 31. Results for the evaluation criterion "Wrinkling/ Obstacles".

Wrinkling/ Obstacles (25%)						
System/ Evaluation	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Fold in liner section	None	None	> 6 mm	≤ 6 mm	> 6 mm	≤ 6 mm
Grade, 50%	1.0	1.0	5.0	1.0	5.0	1.0
Fold in bend	None	None	> 6 mm	> 6 mm	> 6 mm	> 6 mm
Grade, 50%	1.0	1.0	5.0	5.0	5.0	5.0
Overall grade	**1.0**	**1.0**	**5.0**	**3.0**	**5.0**	**3.0**

Results "cross-section reduction"

The evaluation criterion **"cross-section reduction"** was assessed by passing wooden balls with diameters of 150 mm to 185 mm through the renovated pipe. The wooden balls were pulled through the pipe with a maximum pulling force of 100 N using a cable winch (pulling speed: approx. 2 m/min). A separate assessment was made for the lined sections (50 %), bends (25 %) and connections (25 %). The grade was determined according to the diameter of the largest ball that could be drawn through the pipe (Table 18).

Table 32 shows the results for the criterion "cross-section reduction".

Table 32. Results for the evaluation criterion "cross-section reduction" showing the largest ball able to pass through the pipe.

Cross-section reduction (25%)						
System/ Evaluation	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Liner sections [mm]	160	160	170	180	160	180
Grade, 50%	4.0	4.0	3.0	2.0	4.0	2.0
Bends [mm]	155	155	170	170	160	160
Grade, 25%	5.0	5.0	3.0	3.0	4.0	4.0
Connections [mm]	160	155	160	155	155	160
Grade, 25%	4.0	5.0	4.0	5.0	5.0	4.0
Overall grade[1]	**4.3**	**4.5**	**3.3**	**3.0**	**4.3**	**3.0**

[1] The mean value calculation was done with unrounded values

The results for “cross section reduction” can be summarised as follows:

- The evaluation criterion "cross-section reduction" showed differences between the different systems (scores 3.0 to 4.5).
- Three systems achieved a satisfactory result ("Esders HPS-Liner", "Nordiflow W PE" and "Starline Structure-S"). The "Compact Pipe" and "SaniPipe" received the grade "4.3". A DEFICIENT result (grade 4.5) was found for the "egeLiner" system.
- With the Close-Fit systems ("Compact Pipe" and "egeLiner"), a continuous cross-section reduction was found regardless of the liner section, bends and connections. The maximum deviation was 10 mm. In contrast, with the four cured in place liners it could be determined that the greatest cross-section reduction takes place in the connections followed by bends. In the liner section area, there were sometimes considerable differences of up to 20 mm between the different systems.

5.5 Quality assurance

The evaluation criterion **"quality assurance"** examined the extent to which a manufacturer monitors the quality of its system or demonstrates quality assurance measures. The evaluation criteria "procedures manual", "training", "test certificates", "monitoring" and "special anomalies" were included in the assessment.

The overall results for the evaluation of "quality assurance" were given a weighting of 15% of the total evaluation of the products. The evaluation criteria "procedures manual", "training" and "monitoring" were recorded as "+/o/-" (proven/partially proven/not proven) and the evaluation criteria "test certificates" and "special anomalies" were recorded as "+/-" (proven/not proven). Each of these five criteria contributed 20% towards the overall grade for "quality assurance". For the evaluation criteria "Training" and "Monitoring", sub-criteria were included and weighted equally in each case. (Section 4.5).

All manufacturers responded to the IKT's request to submit or provide documentation on the quality assurance criteria. These were reviewed and checked with regard to their completeness and their relevance to the system under test.

Table 33 shows the results of the evaluation for the individual criteria and the resulting overall grades.

Table 33. Overal grades for systems for the evaluation criterion “quality assurance”.

Quality assurance (15% of final product score)						
Manufacturer/ Criteria	**Wavin GmbH**	**egeplast int. GmbH**	**Esders Pipe-line Service GmbH**	**NordiTube Techn. SE**	**Amex Sanivar Ltd**	**Karl Weiss Techn. GmbH**
System	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Procedure manual	+	+	+	+	o	+
Training and training records	+	+	-	o	-	+
Test certificates	+	+	-	-	-	-
Monitoring	o	o	o	+	-	o
Special Anomalies	None (+)	None (+)	Longitudinal fold (-)	None (+)	Longitudinal fold, execu-tion deficien-cies (-)	None (+)
Overall grade	**1.5**	**1.5**	**4.5**	**2.5**	**5.5**	**2.5**

Key: “+": proven / "o" partially proven / "-”: not proven.

The detailed assessment of the evaluation sub-criteria for "training" and "monitoring" are shown in Table 34 and 35.

Table 34. Results for the evaluation criterion "training”.

Training (20% of Quality assurance)						
Manufacturer/ Criteria	**Wavin GmbH**	**egeplast int. GmbH**	**Esders Pipe-line Service GmbH**	**NordiTube Techn. SE**	**Amex Sanivar Ltd**	**Karl Weiss Techn. GmbH**
System	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Training offers	+	+	-	+	-	+
Training records	+	+	-	-	-	+
Overall evaluation	**+**	**+**	**-**	**o**	**-**	**+**

Overall evaluation key: "+/+": proven (+) \| "+/o" and "+/-": partially proven (o) \| "o/-" and "-/-": not proven (-)

Table 35. Results for the evaluation criterion "monitoring".

Monitoring (20% of Quality Assurance)						
Manufacturer/ Criteria	**Wavin GmbH**	**egeplast int. GmbH**	**Esders Pipe-line Service GmbH**	**NordiTube Techn. SE**	**Amex Sanivar Ltd**	**Karl Weiss Techn. GmbH**
System	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Inspection video	-	-	+	+	-	+
Renovation protocol	+	+	-	+	-	+
Self-monitoring	o	o	o	+	-	+
Third-party monitoring	+	+	+	+	-	-
Overall evaluation	**o**	**o**	**o**	**+**	**-**	**o**

Overall evaluation key: "+/+": proven (+) | "+/o" and "+/-": partially proven (o) | "o/-" and "-/-": not proven (-)

In the overall results for quality assurance can be summarised as follows:

- The overall grades awarded for "quality assurance" ranged from "VERY GOOD (1.5)" to "DEFICIENT (5.5)" (Table 33).
- For the evaluation criterion "procedure manual", five out of six manufacturers were able to provide evidence. "Amex" could only partially prove the evaluation criterion.
- With regard to the evaluation criterion "training" (training offers and training certificates, Table 34), three manufacturers were able to provide complete evidence. "NordiTube" only provided partial evidence for the evaluation criterion. "Esders" & "Amex" were unable to provide evidence.
- "Wavin" and "egeplast" were able to prove the evaluation criterion "test certificates" for their systems "Compact Pipe" and "egeLiner". The other four manufacturers were not able to prove the evaluation criterion.
- "NordiTube" was the only manufacturer able to fully demonstrate the evaluation criterion "monitoring". Four manufacturers ("Wavin", "egeplast", "Esders" and "Karl Weiss") were able to partially demonstrate the evaluation criterion "monitoring" for the waste water sector. "Amex" could not prove the evaluation criterion. The detailed results for third-party and self-monitoring for the wastewater sector can be found in Table 35.
- For the evaluation criterion "special conspicuous features", the following were observed:
    - In the both "Esders HPS Liner" and "SaniPipe" systems, a continuous longitudinal fold was visible after completion of the renovation work due to incorrect fabrication of the inner hose.
    - In the course of the renovation work, deficiencies in the execution of the "SaniPipe" system by the manufacturer Amex were observed. The fabric hose required for the renovation was not available in sufficient length.

For this reason, two fabric hoses were connected with the help of cable ties and used for the renovation of the pipe. The interconnected part of the fabric hoses was inserted between liner sections 1 and 2 in the area of the access module. This was then removed during the renovation of the connections. In addition, the component resin was mixed by hand and the resin temperature was not measured.

- Overall, it can be stated that there were great differences between the individual manufacturers with regard to quality assurance.

5.6 Additional information

The following additional information criteria were was collected on the systems:

- Robustness: performance against shard load / metal tip (double overlapping hole) / incrustation / angular deflection / max bend
- Wall structure
- Wall thickness
- Installation procedure
- Curing method and time
- Connection (type/ manufacturer)
- Total working time/ days on site

The results for the individual evaluation criteria are presented in Table 36.

Table 36. Results and observations for the additional information collected on the systems.

Additional information						
Manufacturer/ Criteria	**Wavin GmbH**	**egeplast int. GmbH**	**Esders Pipe-line Service GmbH**	**NordiTube Techn. SE**	**Amex Sanivar Ltd**	**Karl Weiss Techn. GmbH**
System	**Compact Pipe**	**egeLiner**	**Esders HPS Liner**	**Nordiflow W PE**	**SaniPipe**	**Starline Structure-S**
Robustness: Shard load Metal tip Incrustation Angulation Maximum bend	o - + + 22.5°	+ - - + 22.5°	o + + + 30°	+ + - + 15°	o + + + 30°	+ + + + 30°
Wall structure	PE pipe (SDR 17 PN 10 PE 100)	PE pipe (SDR 17 PN 10 PE 100-RC)	Outer foil + laminate with needle felt + fabric tube + inner foil	Preliner + glass fibre reinforced needle felt + inner foil	Outer film + felt fabric and pol-yester fibres with resin casting + inner film	Preliner + lam-inate with glass fibres + fabric tube + inner foil
Wall thickness	13.4 mm	13.5 mm	Approx. 7.3 mm	Approx. 4.9 mm	Approx. 7.7 mm	Approx. 6.3 mm
Installation procedure	Close-fit insertion method	Close-Fit Insertion procedure	Insertion / in-version procedure	Inversion method + Preliner	Insertion / in-version procedure	Inversion method + Preliner

Curing method and time	Steam (120 °C) / approx. 2 h	Steam (130 °C) / approx. 1.5 h	Steam (100 °C) / approx. 1.5 h	Steam (80 °C) / approx. 3.5 h	Steam (80 °C) / approx. 22 h	Hot water (40 °C) / approx. 19 h
Connection type (type/ manufacturer)	PE flange / electrofusion socket	PE flange / electrofusion socket	Amex liner end cuff	Amex liner end cuff	Amex liner end cuff	Kempe liner end sleeve
Total working time/ days on site	14.5 h / 2 days	15.5 h / 3 days	11 h / 2 days	15,5 h / 3 days	14,5 h / 4 days	11.5 h / 2 days

Rating:

Shard load:
+ = no abnormalities after 188 days
o = abnormalities without significant restrictions on watertightness, stability and operational performance
- = impacts on watertightness, stability or operational performance

Metal tip/ incrustation/ angling:
+ = no anomalies
o = anomalies without expected restrictions to watertightness, stability and operational performance
- = not carried out or restriction to watertightness, stability or operational performance probable

Maximum bend
Indication of the maximum curve that could be renovated [°].

Results for robustness

For the evaluation criterion **"robustness",** liner performances in five damage scenarios were examined. The four damage scenarios "transverse crack with angulation", "incrustation", "maximum rehabilitable bend" and " metal tip (double overlapping hole)" were taken into account if the system manufacturer themselves classified them as being rehabilitable by their system (Figure 32 and Figure 33). If a manufacturer identified individual damage scenarios could not be renovated by their system, the damaged pipe section was replaced by an undamaged section of pipe in the test rig. All the systems had the damage scenario "shard load" applied because it was part of the main renovation task identified by the Steering Committee for the IKT-Comparative Product Test.

For the damage scenario "double overlapping hole" and "shard load", the planned loading and testing programme was carried out during the testing programme. In addition, the application of the "shard load" was continued after the completion of the large-scale tests up to a total load duration of 188 days. The other three damage scenarios served only as supplementary renovation tasks; these renovated sections of pipe were removed after installation before the test rig was put into operation.

All manufacturers renovated the damage scenario "transverse cracks with angular deflection" and "shard load". "Wavin", "Esders", Amex" and "Karl Weiss" renovated the damage scenario "incrustation". The "maximum rehabilitable bend" observed was 30°. "Norditube" refrained from installing into an additional bend. Therefore, 15° was recorded as the "maximum rehabilitable bend" for their product, as 15° bends were renovated in the course of the loading and testing programme (system tests). The damage scenario "double overlapping hole" was renovated by "Esders", "NordiTube", "Amex" and "Karl Weiss". "Wavin" and "egeplast" did not carry out the renovation of this damage scenario (Table 36). In the case of the "Compact Pipe", "Esders HPS Liner" and "SaniPipe" systems, anomalies without significant restrictions on watertightness, stability and operational performance were evident after the “shard load” testing.

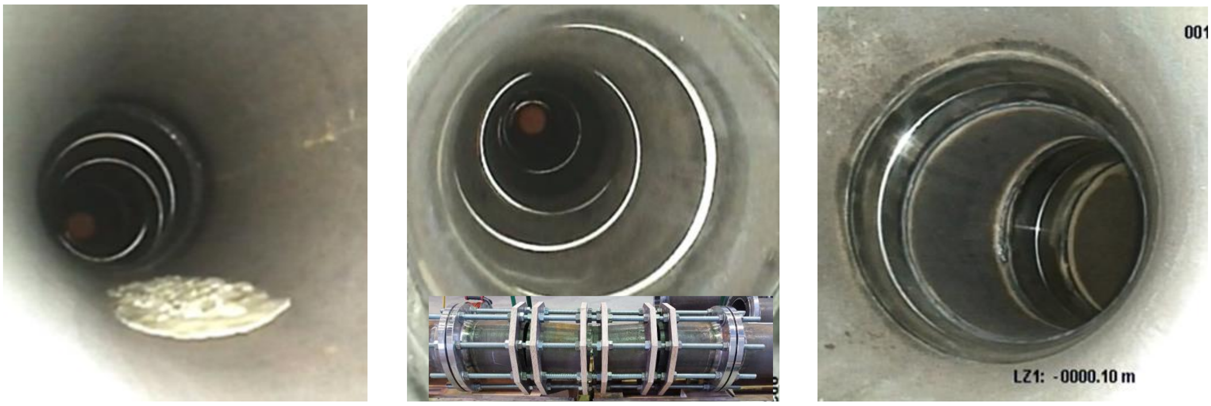


Figure 32. Damage scenarios "incrustation" (left), "transverse crack with angulation" (centre) and "max. rehabilitable bend" (right).

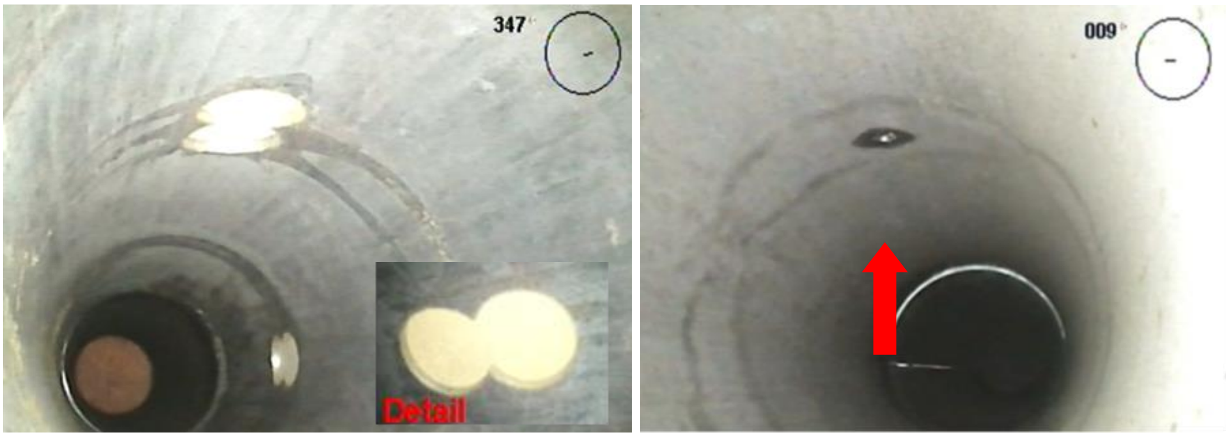


Figure 33. Damage scenario "double ovelapping hole" (left) and shard load, simulated by insertion of a weighted punch through a hole in the crown (F = 300 N, shard punch = ø shank 6 mm/ ø tip 2 mm) (right).

Wall structure

The wall construction of the renovation systems varies.

The "Compact Pipe" system consists entirely of PE 100 with a ratio of 17 between outer diameter and wall thickness (SDR 17) and nominal pressure rating 10 (PN 10).

The "egeliner" system is also described with a ratio of 17 between outer diameter and wall thickness (SDR 17) as well as nominal pressure of 10 (PN 10). In addition, however, it has a significantly higher resistance to slow crack propagation and is made of PE 100-RC.

The wall structure of the "Esders HPS Liner" system consists of an outer foil, the laminate with needle felt, a fabric hose and an inner foil (Figure 35).

The "NordiFlow W PE" system consists of a preliner, glass fibre reinforced needle felt and an inner foil (Figure 35).

The "SaniPipe" by "Amex" system contains an outer foil, felt fabric and polyester fibres with resin casting as well as an inner foil (Figure 36).

The "Starline Structure-S" is composed of a preliner + laminate with glass fibres, a fabric hose and an inner foil. (Figure 36)

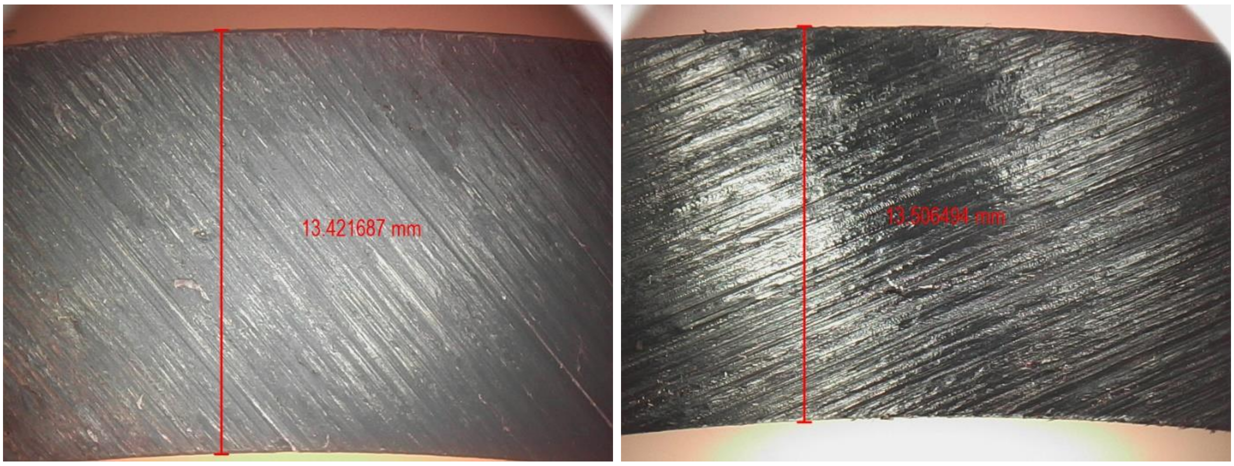


Figure 34. Sectional view: "Compact Pipe" (left), "egeLiner" (right).

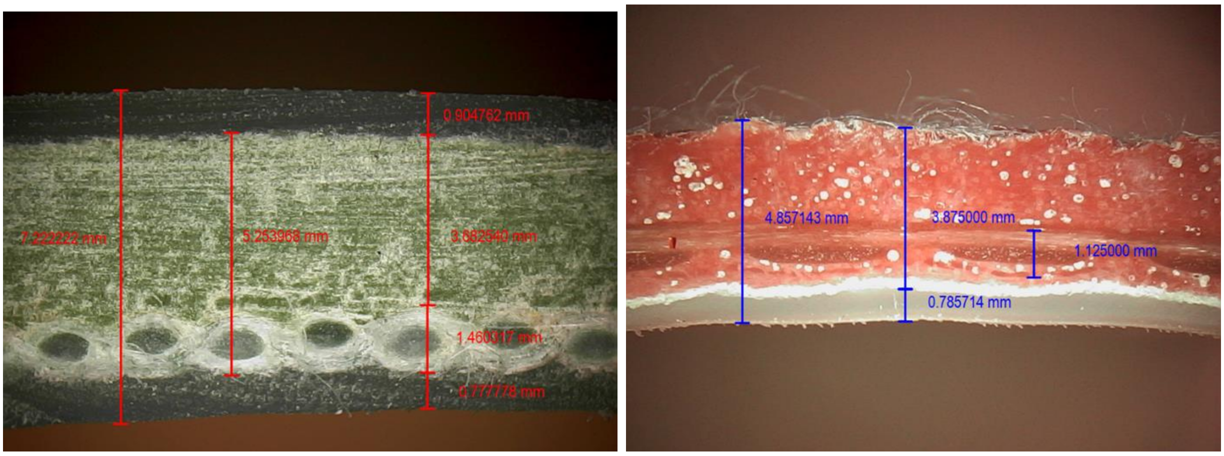


Figure 35. Sectional view: "Esders HPS Liner" (left), "Nordiflow W PE" (right).

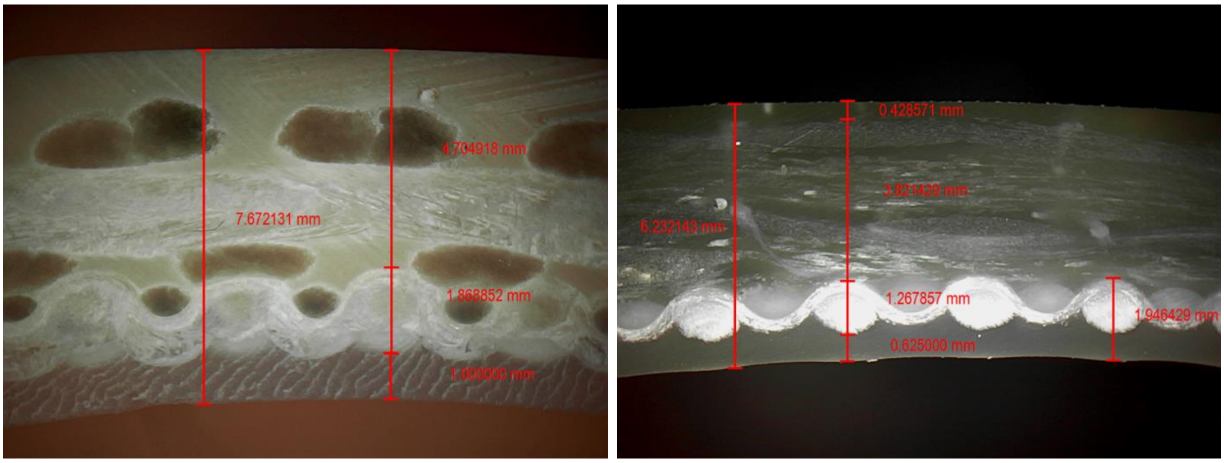


Figure 36. Sectional view: "SaniPipe" (left), "Starline Structure-S" (right).

Wall thickness

The wall thickness of the individual renovation systems ranges from 4.9 mm to 13.5 mm (see overall results Table on page 40).

Installation procedure

Close-fit insertion process

The "egeLiner" and "Compact Pipe" (both U-Liner) systems were installed with the help of a pull-in process (Figure 37). Before the pulling-in process starts, the winch cable was attached to the pulling head or directly to the pipe and then the pipe string is pulled in by the winch at an even speed. The liner is then heated, expands to its original shape and finally has to cool down.

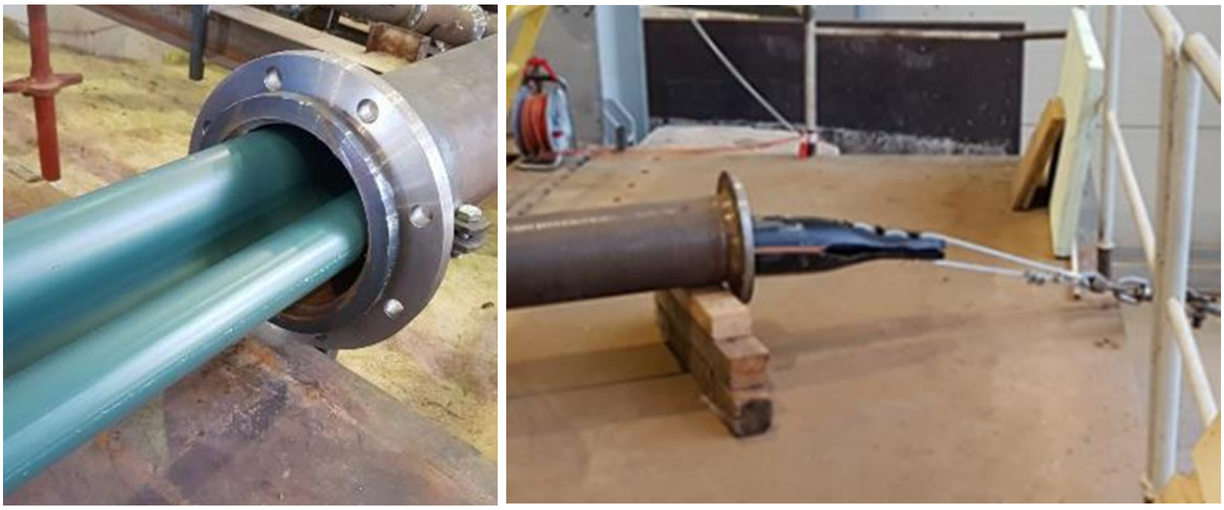


Figure 37. Close-fit insertion process: "Compact Pipe" (left) and "egeLiner" (right).

Insertion and inversion methods

The "Esders HPS Liner" and "SaniPipe" systems were installed using the insertion and inversion method with the liner installed in two parts. In the insertion and inversion process, the liner is pulled in with a winch and followed by the inversion of a fabric hose liner. The resin used ensures the connection of the two liners.

Figure 38. Pull-in and inversion process: "SaniPipe"(left) and "Esders HPS Liner" (right).

Inversion procedure

The "Nordiflow W PE" and "Starline Structure-S" systems were installed using the inversion method. First, a preliner was pulled into the pipe to be renovated and then the resin-impregnated liner was inverted through it.

Figure 39 Inversion method: "Starline Structure-S (left), "Nordiflow W PE" (middle/right)

Curing method and time

In five out of six cases, steam was used as the curing process. "Karl Weiss" used hot water for the curing process. The temperatures ranged between 40°C and 130°C. The curing time was between 1.5 h and 22 h (see overall results Table page 40).

Connections

For the "Compact Pipe" and "egeLiner" close-fit liners, PE flanged/ electrofusion sockets were used to connect to the host pipe. Liner end sleeves were used for the "Esders HPS Liner", "SaniPipe", "Nordiflow W PE" and "Starline Structure-S" systems (Figure 41).

Figure 40. PE flange/ electrofusion couplers: "egeLiner" (left) and "Compact Pipe" (right).

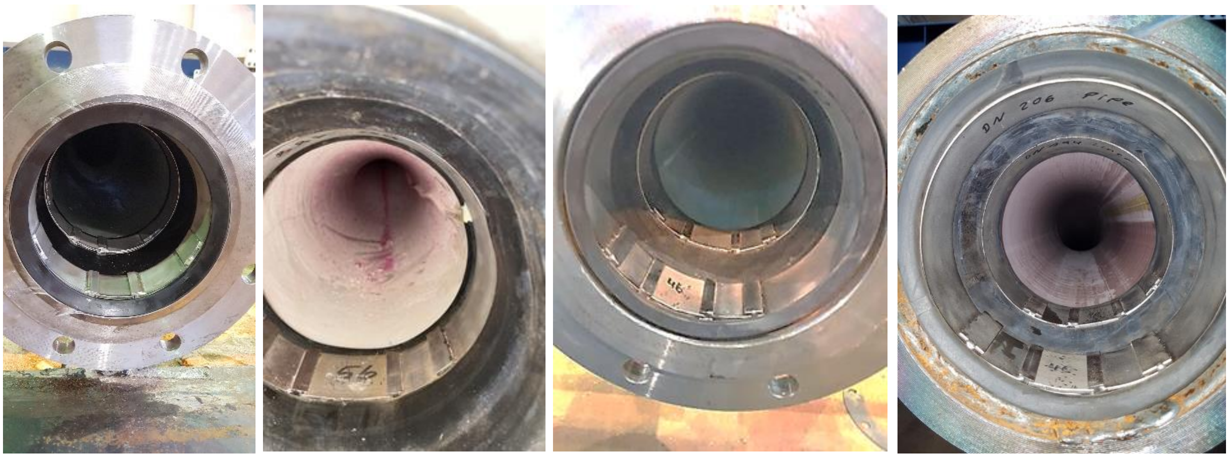


Figure 41. Liner end sleeves from left: "Starline Structure-S" (Kempe), "SaniPipe" (Amex), "Esders HPS Liner" (Amex) and "Nordiflow W PE" (Amex).

Total working time/ days on site

The working days on site ranged from two to four days with a total working time between 11 h and 15.5 h (see overall results Table page 40).

6 Test Certificates

6.1 Compact Pipe

Warentest - Test certificate

"Rehabilitation methods for wastewater pressure pipes - Class A liner"

Compact Pipe

Wavin GmbH

Renovation company: Diringer & Scheidel Rohrsanierung GmbH & Co. KG

TEST RESULT	
IKT - overall rating:	**GOOD (1.8)**
Watertightness (45 %):	**1.0**
Exfiltration watertightness (80 %):	1.0
Infiltration watertightness (20 %):	1.0
Devaluation because of rework:	0.0
Stability (25 %):	**3.0**
Load-bearing capacity of the structure (knock-out criterion) (50%)	2.0
Static proof (30%)	4.5
Material and geometry (20%)	3.0
Operational performance (15 %)	**2.3**
Overall visual impression (25 %)	1.0
Hydraulic performance loss (25 %)	3.0
Wrinkling/obstacles (25 %)	1.0
Cross-section reduction (25 %)	4.3
Quality assurance (15 %):	**1.5**

Overall impression

Watertightness was graded 1.0 overall. **Exfiltration watertightness** and **infiltration watertightness** were each graded with 1.0. No abnormalities were found.

The overall **stability** was assessed with the grade 3.0. The evaluation criteria "load-bearing capacity of the structure", "static proof" and "material and geometry" were graded with 2.0, 4.5 and 3.0 respectively.

With regard to **operational performance,** a good result (grade 2.3) was achieved. The evaluation criteria "overall visual impression", "hydraulic performance loss", "wrinkling/obstructions" and "cross-section reduction" were graded 1.0, 3.0, 1.0 and 4.3 respectively.

A grade of 1.5 was awarded for **quality assurance.** For the evaluation criterion "monitoring", no inspection video was available after the installation. All other verifications were fulfilled.

Additional information

- Robustness: shard load | metal tip | incrustation | angular deflection | max. bend: o | - | + | + | 22.5°
- Wall construction: PE pipe (SDR17 PN10 PE100)
- Wall thickness: Approx. 13.4 mm
- Installation method: Pull-in method
- Curing method and time: Steam (120 C°), approx. 2 h
- Connection (type/ manufacturer): PE flange/ electrofusion socket
- Total working time/ days on site: 14.5 h/ 2 days

6.2 egeLiner

Warentest - Test certificate
"Rehabilitation methods for wastewater pressure pipes - Class A liner"

egeLiner

egeplast international GmbH

Renovation company: Esders Pipeline Service GmbH

TEST RESULT

IKT - overall rating:	GOOD (1.8)
Watertightness (45 %):	**1.0**
Exfiltration watertightness (80 %):	1.0
Infiltration watertightness (20 %):	1.0
Devaluation because of rework:	0.0
Stability (25 %):	**3.0**
Load-bearing capacity of the structure (knock-out criterion) (50%)	2.0
Static proof (30%)	4.0
Material and geometry (20%)	4.0
Operational performance (15 %)	**2.4**
Overall visual impression (25 %)	1.0
Hydraulic performance loss (25 %)	3.0
Wrinkling/obstacles (25 %)	1.0
Cross-section reduction (25 %)	4.5
Quality assurance (15 %):	**1.5**

neutral independent non-profit
IKT Compare
rehabilitation procedures for sewage pressure lines
- Class A liner -
GOOD 1.8
November 2022
www.ikt.de

Overall impression

Watertightness was graded 1.0 overall. **Exfiltration watertightness** and **infiltration watertightness** were each graded with 1.0. No abnormalities were found.

The overall **stability** was assessed with the grade 3.0. The two evaluation criteria "static proof" and "material and geometry" were each graded with 4.0. The "load-bearing capacity of the structure" received a grade of 2.0.

With regard to **operational performance,** a good result (grade 2.4) was achieved. The evaluation criteria "overall visual impression", "hydraulic performance loss", "wrinkling/obstructions" and "cross-section reduction" were graded 1.0, 3.0, 1.0 and 4.5 respectively.

A grade of 1.5 was awarded for **quality assurance.** Only for the evaluation criterion "monitoring" was no inspection video available after the renovation. All other verifications were fulfilled.

Additional information

- Robustness: shard load | metal tip | incrustation | angular deflection | max. bend: + | - | - | + | 22.5°
- Wall construction: PE pipe (SDR17 PN10 PE100-RC)
- Wall thickness: Approx. 13.5 mm
- Installation method: Pull-in method
- Curing method and time: Steam (130 C°), approx. 1.5 h
- Connection (type/ manufacturer): PE flange/ electrofusion socket
- Total working time/ days on site: 15.5 h/ 3 days

6.3 Nordiflow W PE

Warentest - Test certificate
"Rehabilitation methods for wastewater pressure pipes - Class A liner"

Nordiflow W PE

NordiTube Technologies SE

Renovation company: Esders Pipeline Service GmbH

TEST RESULT

IKT - overall rating:	SATISFACTORY (2.6)
Watertightness (45 %):	**2.0**
Exfiltration watertightness (80 %):	1.0
Infiltration watertightness (20 %):	1.0
Devaluation because of rework:	1.0
Stability (25 %):	**3.2**
Load-bearing capacity of the structure (knock-out criterion) (50%)	4.0
Static proof (30%)	2.5
Material and geometry (20%)	2.0
Operational performance (15 %)	**3.3**
Overall visual impression (25 %)	3.4
Hydraulic performance loss (25 %)	4.0
Wrinkling/obstacles (25 %)	3.0
Cross-section reduction (25 %)	3.0
Quality assurance (15 %):	**2.5**

Overall impression

Watertightness was assessed with an overall grade of 2.0. **Exfiltration watertightness** and **infiltration watertightness** were each graded with 1.0. The evaluation criterion "watertightness" was devalued by 1.0 because a rework was carried out.

The overall **stability** was assessed with the grade 3.0. The evaluation criteria "load-bearing capacity of the structure", "static proof" and "material and geometry" were graded with 4.0, 2.5 and 2.0 respectively.

With regard to **operational performance,** a satisfactory result (grade 3.2) was achieved. The evaluation criteria "overall visual impression", "hydraulic performance loss", "wrinkling/obstructions" and "cross-section reduction" were graded 3.4, 4.0, 3.0 and 3.0 respectively.

A grade of 2.5 was awarded for **quality assurance.** The "training of the renovation personnel" in the evaluation criterion "training" and the evaluation criterion "test certificates" could not be verified. All other verifications were fulfilled.

Additional information

- Robustness: shard load | metal tip | incrustation | angulation | max. bend: + | + | - | + | 15°
- Wall construction: Preliner + glass-fibre reinforced needle felt + inner foil
- Wall thickness: Approx. 4.9 mm
- Installation method: Inversion method with preliner
- Curing method and time: Steam (80 C°), approx. 3.5 h
- Connection (type/ manufacturer): Amex liner end cuff
- Total working time/ days on site: 15.5 h/ 3 days

6.4 Starline Structure-S

Warentest - Test certificate
"Rehabilitation methods for wastewater pressure pipes - Class A liner"

Starline Structure-S

Karl Weiss Technologies GmbH

Restructuring company: Karl Weiss Technologies GmbH

TEST RESULT

IKT - overall rating:	SATISFACTORY (2.6)
Watertightness (45 %):	**3.0**
Exfiltration watertightness (80 %):	1.0
Infiltration watertightness (20 %):	1.0
Devaluation because of rework:	2.0
Stability (25 %):	**2.0**
Load-bearing capacity of the structure (knock-out criterion) (50%)	2.0
Static proof (30%)	2.0
Material and geometry (20%)	2.0
Operational performance (15 %)	**2.7**
Overall visual impression (25 %)	2.7
Hydraulic performance loss (25 %)	2.0
Wrinkling/obstacles (25 %)	3.0
Cross-section reduction (25 %)	3.0
Quality assurance (15 %):	**2.5**

Overall impression

Watertightness was rated 3.0 overall. **Exfiltration watertightness** and **infiltration watertightness** were each graded with 1.0. The evaluation criterion "watertightness" was devalued by 2.0 because two reworks were carried out.

The overall **stability** was assessed with the grade 2.0. The evaluation criteria "load-bearing capacity of the structure", "structural analysis" and "material and geometry" were each graded with 2.0.

With regard to **operational performance**, a satisfactory result (grade 2.7) was achieved. The evaluation criteria "overall visual impression", "hydraulic performance loss", "wrinkling/obstructions" and "cross-section reduction" were graded 2.7, 2.0, 3.0 and 3.0 respectively.

A grade of 2.5 was awarded for **quality assurance.** The "external monitoring" in the evaluation criterion "monitoring" and the evaluation criterion "test certificates" could not be verified. All other verifications were fulfilled.

Additional information

- Robustness: shard load | metal tip | incrustation | angulation | max. bend: + | + | + | + | 30°
- Wall construction: Preliner + laminate with glass fibres + fabric sleeve + inner foil
- Wall thickness: Approx. 6.3 mm
- Installation method: Inversion method with preliner
- Curing method and time: Hot water (40 C°), approx. 19 h
- Connection (type/ manufacturer): Kempe liner end sleeve
- Total working time/ days on site: 11.5 h/ 2 days

6.5 Esders HPS Liner

Warentest - Test certificate

"Rehabilitation methods for wastewater pressure pipes - Class A liner"

Esders HPS Liner

Esders Pipeline Service GmbH

Renovation company: Esders Pipeline Service GmbH

TEST RESULT

IKT - overall rating:	DEFICIENT (5.3)
Watertightness (45 %):	**6.0**
Exfiltration watertightness (80 %):	5.0
Infiltration watertightness (20 %):	1.0
Devaluation because of rework:	6.0
Stability (25 %):	**5.4**
Load-bearing capacity of the structure (knock-out criterion) (50%)	5.0
Static proof (30%)	5.5
Material and geometry (20%)	6.0
Operational performance (15 %)	**4.1**
Overall visual impression (25 %)	5.0
Hydraulic performance loss (25 %)	3.0
Wrinkling/obstacles (25 %)	5.0
Cross-section reduction (25 %)	3.3
Quality assurance (15 %):	**4.5**

Overall impression

Watertightness was rated 6.0 overall. For **exfiltration watertightness**, a grade of 5.0 was given because "drops" were visible and the target pressure could not be reached. The **infiltration watertightness** was graded 1.0. In addition, the evaluation criterion "watertightness" was downgraded to 6.0, as after two reworks there were still conspicuous features in the form of drops or flow.

The overall **stability** was assessed with the grade 5.4. For the sub-criterion "load-bearing capacity of the structure", a grade of 5.0 was given because of the possible risk of failure due to presence of a continuous longitudinal fold. A static proof was not provided by the manufacturer, so the evaluation criterion "material and geometry" could not be checked either. This resulted in the scores 5.5 and 6.0.

With regard to **operational performance,** a sufficient result (grade 4.1) was achieved. The evaluation criteria "Overall visual impression", "Hydraulic performance loss", "Wrinkling/obstructions" and "Cross-section reduction" were graded 5.0, 3.0, 5.0 and 3.3 respectively.

For **quality assurance,** only the evaluation criterion "procedure manual" could be fully verified and the evaluation criterion "monitoring" could be partially verified. In addition, one particular anomaly (longitudinal fold) was found. This resulted in the grade 4.5.

Additional information

- Robustness: shard load | metal tip | incrustation | angular deflection | max. bend: o | + | + | + | 30°
- Wall construction: Outer foil + laminate with needle felt + fabric hose + inner foil
- Wall thickness: Approx. 7.3 mm
- Installation method: Pull-in/inversion method
- Curing method and time: Steam (100 C°), approx. 1.5 h
- Connection (type/ manufacturer): Amex liner end cuff
- Total working time/ days on site: 11 h/ 2 days

6.6 SaniPipe

Warentest - Test certificate
"Rehabilitation methods for wastewater pressure pipes - Class A liner"

SaniPipe

Amex Sanivar Ltd

Renovation company: Amex Sanivar AG

TEST RESULT

IKT - overall rating: INADEQUATE (6.0)

Cannot be used as class A liner due to a collapse

Watertightness (45 %):	**3.4**
Exfiltration watertightness (80 %):	2.8
Infiltration watertightness (20 %):	1.0
Devaluation because of rework:	1.0
Stability (25 %):	**6.0**
Load-bearing capacity of the structure (knock-out criterion) (50%)	6.0
Static proof (30%)	6.0
Material and geometry (20%)	6.0
Operational performance (15 %)	**4.5**
Overall visual impression (25 %)	4.7
Hydraulic performance loss (25 %)	4.0
Wrinkling/obstacles (25 %)	5.0
Cross-section reduction (25 %)	4.3
Quality assurance (15 %):	**5.5**

Overall impression

The **watertightness** was rated 3.4 overall. For **exfiltration watertightness,** a grade of 2.8 was given because "dampness" was visible. The **infiltration watertightness** was graded with 1.0. In addition, the evaluation criterion "watertightness" was devalued by 1.0 because a rework need to be carried out post installation.

The overall **stability** was assessed with the grade 6.0. For the sub-criterion "load-bearing capacity of the structure", a grade of 6.0 was awarded because a collapse of the system was detected. A static proof was not provided by the manufacturer, so that the evaluation criterion "material and geometry" could not be checked. This resulted in a grade of 6.0 for both criteria.

With regard to **operational performance**, a still sufficient result (grade 4.5) was achieved. The criteria "overall visual impression", "hydraulic performance loss", "wrinkling/obstructions" and "cross-section reduction" were graded 4.7, 4.0, 5.0 and 4.3 respectively.

For **quality assurance,** only the evaluation criterion "procedure manual" could be partially verified. In addition, special conspicuous features (longitudinal fold, installation execution deficiencies) were found. This resulted in a grade of 5.5.

Due to the collapse in the knock-out criterion "load-bearing capacity of the structure", the Steering Committee members unanimously assessed that the system was not applicable as a Class A liner. As a result, the system was awarded the IKT test rating "inadequate (6.0)" regardless of the other sub-ratings.

Additional information

- Robustness: shard load | metal tip | incrustation | angular deflection | max. bend: o | + | + | + | 30°
- Wall construction: Outer film + felt fabric and polyester fibres with resin casting + inner film
- Wall thickness: Approx. 7.7 mm
- Installation method: Pull-in/inversion method
- Curing method and time: Steam (80 C°), approx. 22 h
- Connection (type/ manufacturer): Amex liner end cuff
- Total working time/ days on site: 14.5 h/ 4 days

7 Conclusions

Test results show major differences in performance

Grades from "GOOD" to "INADEQUATE" were awarded across the six liner systems that were evaluated. The best result was achieved by the "Compact Pipe" system with the grade GOOD (1.8), closely followed by "egeLiner" with the grade GOOD (1.8) (unrounded values were used for this ordering). The "Nordiflow W PE" and "Starline Structure-S" systems received the grade SATISFACTORY (2.6). The "Esders HPS Liner" system achieved a DEFICIENT grade (5.3). The "SaniPipe" system was assessed by the Steering Committee as "not usable as a class A liner" due to a system collapse; as a result, the grade "INADEQUATE (6.0)" was awarded. The Overall Results table on Page 40 shows the detail behind these gradings.

The rehabilitation of wastewater pressure pipes involves more than just renovation with a liner

Overall, the rehabilitation of wastewater pressure sewers involves more than just renovation using a liner. This is especially true if the damage to be renovated is caused or partially caused by pressure surges in the operation of the pipe or faults in the its aeration and ventilation. In such cases, further measures are required, for example the use of suitable fittings. The use of a liner primarily serves to protect the pipeline against corrosion and to seal it. The class A liners examined in the test should also be able to withstand the expected internal and external pressure independently. Four out of six of the systems examined met this requirement to at least a satisfactory degree.

Watertightness: the end connections of liners were the main weak point

All four of the cured in place systems exhibited leaks in end connections when the water level test was carried out after installation. Consequently, a rework had to be arranged by the manufacturer. In the case of the "Esders HPS Liner" system, watertightness could not be established even after two rework attempts, because of a continuous longitudinal fold in the liner. In contrast, the PE flange/electrofusion socket connections of the two close-fit liners were consistently watertight.

Liner fabrication issues led to a collapse

Two systems exhibited a continuous longitudinal fold along the length of the liner due to fabrication issues. In one case, this led to a collapse in the liner under negative internal pressure and external water pressure loads. In the other case, no collapse was observed in the test, but the longitudinal fold represented a fundamental risk of failure. In addition, these two manufacturers did not provide any static proof, so it appears that the liner was dimensioned without static proof. In the other four systems, no or only minor conspicuous features, such as wrinkling, were visible.

Liners were mostly unaffected by further deterioration of the condition of the host pipe

The further deterioration of the host pipe condition that was simulated during the testing generally had no effect on the performance of the liner. This applied in particular to corrosion phenomena such as the simulated development of pitting holes and application of point loads. In one case the simulated complete loss of the host pipe led to failure of the liner under external water pressure.

Bends can be renovated up to 30°

All manufacturers in the test were able to pass the required four 15° bends that were included in the test pipelines with their system. Three manufacturers were also able to rehabilitate through a 30° bend. Manufacturers of GRP lining systems who were consulted in advance of the testing stated that their systems were not suitable for use in 15° bends and so could not be included in the test.

Operational performance guaranteed after refurbishment

Usual operating conditions such as pressure fluctuations, bed load, static pressure, etc. could generally be absorbed by the systems without any problems, but clear limits became apparent during high-pressure cleaning, where holes and delamination occurred in some cases. Chemical loads did not affect the watertightness of the liners in laboratory tests.

Loss of hydraulic performance and major reduction in cross-section noticeable after refurbishment

Hydraulic performance loss due to the installation of the liner systems was measurable for all six systems (up to 8 %) and this should be taken into account in the hydraulic dimensioning for a renovation. The passage of a ball through the pipe was reduced by more than 20% (diameter) in some cases. Wrinkles > 6 mm were present in all the cured in place pipe liners (in 2 of the 4 systems the straight sections, in 4 of the 4 systems in the bends). In contrast, the two close-fit liners did not show any wrinkles, but there was clear ovalisation in their bends.

Major differences in quality assurance

With regard to quality assurance, there were great differences in the grades awarded across the systems (from 1.5 to 5.5). Although the installation manual was available from all manufacturers, considerable deficits were found in some cases in the evaluation criteria "training", "test certificates" and "monitoring". In addition, for the manufacturers "Esders" and "Amex" particular anomalies were recorded in the form of a continuous longitudinal fold along the installed liners. In the case of the manufacturer "Amex", there were also anomalies in the execution of the installation.

8 Appendix

Annex I:
E-mail from Wavin GmbH (26.05.2021)

Annex II:
II-A: E-mail from egeplast international GmbH (18.06.2021)
II-B: E-mail from egeplast international GmbH (10.03.2021)

Annex III:
E-mail from NordiTube Technologies SE (24.01.2021)

Annex IV:
E-mail from RELINE APTEC GmbH (15.01.2021)

Annex V:
E-mail from Saertex multiCom GmbH (29.01.2021)

Annex VI:
VI-A: E-mail from Pipe-Aqua-Tec GmbH & Co.KG (19.04.2021)
VI-B: E-mail from IKT gGmbH on behalf of the Steering Committee (26.06.2021)
VI-C: E-mail from Pipe-Aqua-Tec GmbH & Co.KG (26.07.2021)

Annex VII:
E-mail from REHAU AG + Co (17.12.2021)

Annex I:
E-mail from Wavin GmbH (26.05.2021)

Sehr geehrter Herr Ulutas, sehr geehrter Herr Gillar,

leider haben wir gestern unsere Installation mit D&S nicht durchführt. Wir teilen die Bedenken unseres Lizenznehmers D&S zur Schadensstelle „Doppelloch 2 x 48 mm“. Diese Schadensstelle haben wir im Vorfeld besprochen und unsere Bedenken dazu angemeldet. Die Schadensstelle beinhaltet zwei Metallspitzen und sollte entgratet werden. Eine Entgratung der inneren Schnittflächen ist auch erfolgt, jedoch haben wir bei den Vorbereitungen gestern vor Ort gesehen, das die Spitzen trotzdem in der Lage sind die Compact Pipe PE Wandungen zu beschädigen.

Wir tempern das PE Rohr mit ca. 100°C Aussentemperatur und einem Innendruck von ca. 1.5 bar in der Stahlrohr - Aussenschalung. Das PE 100 Material, SDR 17 ist dickwandig und solide, dehnt sich während der Installation in die Fehlstelle hinein. Die scharfkantigen Spitzen der Schadensstelle „Doppelloch 2 x 48 mm“ sind dabei in der Lage das erwärmte Material zu beschädigen. Die Wärmebeaufschlagung (ca. 1.5 bar Wasserdampf) und die anschliessende Kühlung (ca. 6 bar Luftdruck) sind daher nicht bedenkenlos ausführbar. Der Installationsprozess und die Arbeitssicherheit in der Halle sind nicht zu 100% gewährleistet. Diese Aspekte gelten nicht nur für Compact Pipe. Sie werden auch bei den folgenden Wettbewerbsverfahren in Betracht gezogen müssen.

Wir waren nun die Ersten auf Ihrem Prüfstand und hätten die Installation gerne durchgeführt. Unser Vorschlag die Installation zu machen und die fragliche Schadenstelle vorher aus der Prüfstrecke zu nehmen, entspricht leider nicht Ihren Prüfvorgaben. Hierfür haben wir Verständnis. Bitte überdenken Sie unsere Einwände und informieren Sie uns über etwaige Änderungen.

Wir halten das Compact Pipe, die PE Standardrohrlängen und alle erforderlichen PE Bauteile / Fittings für den Warentest einbaubereit.

Viele Grüsse

Ralf Glanert

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Advancing life together

English translation of E-mail from Wavin GmbH (26.05.2021) using DeepL Translator

Dear Mr Ulutas, Dear Mr Gillar,

Unfortunately, we did not carry out our installation with D&S yesterday. We share the concerns of our licensee D&S regarding the damage point "double hole 2 x 48 mm". We discussed this damage site in advance and raised our concerns about it. The damage site contains two metal points and should be deburred. Deburring of the inner cut surfaces has also been carried out, but during the preparations on site yesterday we saw that the points are still capable of damaging the Compact Pipe PE walls.

We temper the PE pipe with approx. 100°C outside temperature and an internal pressure of approx. 1.5 bar in the steel pipe outer formwork. The PE 100 material, SDR 17 is thick-walled and solid, expands into the defect during installation. The sharp-edged tips of the defect "double hole 2 x 48 mm" are capable of damaging the heated material. The heat application (approx. 1.5 bar water vapour) and the subsequent cooling (approx. 6 bar air pressure) can therefore not be carried out without hesitation. The installation process and work safety in the hall are not 100% guaranteed. These aspects do not only apply to Compact Pipe. They will also have to be taken into account in the following competition procedures.

We were now the first on your test bench and would have liked to carry out the installation. Unfortunately, our proposal to carry out the installation and to remove the damaged area in question from the test section beforehand does not comply with your test specifications. We have understanding for this. Please reconsider our objections and inform us of any changes.

We have the Compact Pipe, the PE standard pipe lengths and all the necessary PE components / fittings ready for installation for the product test.

Best regards

Annex II-A

E-mail from egeplast international GmbH (18.06.2021)

Sehr geehrter Herr Ulutas,
sehr geehrter Herr Gillar,

wie gerade telefonisch bereits besprochen nachstehend der Sachverhalt als kurze schriftliche Zusammenfassung.

Die Unterdruckbeaufschlagung (-0,9bar) + Außendruckbelastung (0,1bar) haben wir rechnerisch geprüft und sind zum Schluss gekommen, dass eine Unterdruckbelastung von 1h bei einer Temperatur ≤20°C für einen egeLiner SDR17 kurzzeitig möglich ist.

Nach Sichtung aller Schadensbilder der Anlage II aus der Sanierungsaufgabe sind uns bsp.-weise auf S.18 „Doppelloch 2x48mm" extrem scharfe Kanten an der Bohrung aufgefallen.
Wenn beim IKT Warentest die scharfen Kanten der Bohrungen als Prüfkriterium getestet werden soll, müssen wir von einer Teilnahme absehen, da diese nicht repräsentativ bzw. nicht der Praxis entsprechen.
Ob der Liner beschädigt wird oder nicht ist dann rein dem Zufall geschuldet.

Oder sollen diese Bohrungen das Prüfkriterium Lochfraß/Fehlstellen darstellen?
Hierbei sind innere scharfe Kante vorher zu entgraten.
Grundsätzlich ist durch eine ordnungsgemäße Vorarbeit sicherzustellen, dass keine Hindernisse den egeLiner beim Einziehen/Reversieren (Prozesssicherheit) und späteren Betriebszustand (Betriebssicherheit) gefährden.

Wir bitten um Stellungnahme.

i.A. Dipl. Ing. (FH) Jan Franke
Senior Product Manager International Business
Certified Sewer Rehabilitation Consultant

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Future-proofed Pipe Systems

English translation of E-mail from egeplast international GmbH (18.06.2021) using DeepL Translator

Dear Mr Ulutas
Dear Mr Gillar,

As we have just discussed on the phone, the following is a brief written summary of the facts.

We have checked the negative pressure (-0.9bar) + external pressure (0.1bar) by calculation and have come to the conclusion that a negative pressure of 1h at a temperature ≤20°C is possible for an egeLiner SDR17 for a short time.

After reviewing all the damage images of Annex II from the rehabilitation task, we noticed extremely sharp edges on the borehole, for example on p.18 "double hole 2x48mm".

If the sharp edges of the boreholes are to be tested as a test criterion in the IKT product test, we must refrain from participating, as these are not representative or do not correspond to practice.
Whether the liner is damaged or not is then purely down to chance.

Or are these holes supposed to represent the test criterion pitting/missing?
In this case, inner sharp edges must be deburred beforehand.
In principle, it must be ensured through proper preparatory work that no obstacles endanger the egeLiner during retraction/reversal (process safety) and later operating condition (operational safety).

We ask for your opinion.

Annex II-B

Letter from egeplast international GmbH (10.03.2021) – declaration of conformity.

egeplast

IKT - Institut für Unterirdische Infrastruktur gGmbH
z.Hd. Hrn Dipl.-Ing. (FH) Serdar Ulutaş, MBA
Exterbruch 1
D - 45886 Gelsenkirchen

Ihre Zeichen	Unsere Zeichen	Ihr Ansprechpartner	Datum
	PM / JF	Jan.franke@egeplast.de +49 2575 9710 251	10.03.2021

Konformitätserklärung egeLiner

Sehr geehrte Damen und Herren,

bezugnehmend auf den anstehenden IKT Warentest "Sanierungsverfahren von Abwasserdruckleitungen" möchten wir Ihnen hiermit bestätigen, dass die Unterschiede der verschiedenen Close-Fit egeLiner für Abwasser-, Gas- und Trinkwasserdruckanwendungen darin besteht, dass die Farbe der äußeren Streifen sowie die Signierung sich unterscheiden.
Der Werkstoff und die Abmessungen bleiben unverändert.

Wir hoffen, Ihnen hiermit geholfen zu haben und stehen Ihnen bei weiteren Fragen gern zur Verfügung.

Mit freundlichen Grüßen

Dipl.-Ing. (FH) Jan Franke
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Annex III:
E-mail from NordiTube Technologies SE (24.01.2021)

Für das Produkt r.tec Close-Fit kann ich Ihnen leider kein Angebot für diese Teststrecke unterbreiten. Wie schon bei unserem Telefonat erwähnt, wurde mir bestätigt, dass die Bögen zu dicht bei einander liegen und grundsätzlich eine Dükerleitung nicht zu empfehlen ist. Leider ist die Materialdicke, die erst bei SDR17 für 10bar Anwendung erreicht ist, sehr nachteilig. Der Liner würde sich mit hoher Wahrscheinlichkeit nicht vollends aufstellen und oval verbleiben. Es sind zwar Bögen mit 15° soweit möglich, jedoch nicht in diesem Fall. In der Praxis würden wir das nie anbieten. Es könnte nur mit erheblicher Querschnittsverengung (Installation eines DN150) funktionieren – das ist hier aber nicht Sinn der Sache.

English translation of E-mail from NordiTube Technologies SE (24.01.2021) using DeepL Translator

Unfortunately, I cannot make you an offer for this test track for the product r.tec Close-Fit. As already mentioned in our telephone conversation, it was confirmed to me that the bends are too close together and that, in principle, a culvert line is not recommended. Unfortunately, the thickness of the material, which is only reached at SDR17 for 10 bar application, is very disadvantageous. The liner would most likely not fully rise and remain oval. It is possible to make bends with 15° as far as possible, but not in this case. In practice, we would never offer this. It could only work with considerable cross-section narrowing (installation of a DN150) - but that is not the point here.

Annex IV:
E-mail from RELINE APTEC GmbH (15.01.2021)

Sehr geehrter Herr Ulutas

ich hatte leider nur den Ausführungstermin in Q1/2021 gesehen. Die Aussage mit dem Terminlichen nehme ich hiermit zurück.

Bezüglich der Ausführung:
Unser System ist derzeit nur für Bögen mit max. 5° ausgelegt, daher können wir die geforderte Leitung nicht in diesem Umfang sanieren.
Wenn es hier Änderungen des Versuchsaufbaus gibt, dann sind wir gerne bereit an dem Warentest teilzunehmen.

Viele Grüße
Andreas Bichler

Andreas Bichler

COO

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English translation of E-mail from E-mail from RELINE APTEC GmbH (15.01.2021) using DeepL Translator

Dear Mr Ulutas

Unfortunately, I had only seen the execution date in Q1/2021. I hereby retract the statement about the deadline.

Regarding the design:
Our system is currently only designed for bends of max. 5°, so we cannot rehabilitate the required pipe to this extent.
If there are any changes to the test setup, we would be happy to participate in the product test.

Many greetings

Annex V:
E-mail from Saertex multiCom GmbH (29.01.2021)

Sehr geehrter Herr Ulutaş,

entschuldigen Sie bitte die späte Rückmeldung.

Wir produzieren unsere Druckliner aktuell ab DN 250. Um dennoch am Warentest DN 200 teilnehmen zu können, würden wir eine Sonderlösung anbieten bei der die UV-Schutzfolie vor Einzug vollständig entfernt oder zumindest im Scheitel geschlitzt würde.

Mit dem klaren Hinweis, dass unser System für gerade Strecken konzipiert ist und als solches vermarktet wird, würden wir zunächst den Versuch starten die Bögen zu sanieren. Falls es beim Einbau zu Schwierigkeiten käme, könnte man auf die gerade Strecke umschwenken.

Reicht es, wenn ich Ihnen das Angebotsformular nächste Woche zukommen lasse? Gibt es Neuigkeiten zum Prüfprogramm?

Freundliche Grüße

Timo Münstermann M.Sc.
Produktmanager

English translation of E-mail from Saertex multiCom GmbH (29.01.2021) using DeepL Translator

Dear Mr Ulutaş,

I apologise for the late response.

We currently produce our pressure liners from DN 250. In order to be able to participate in the DN 200 product test, we would offer a special solution in which the UV protective film would be completely removed or at least slit at the apex before insertion.

With the clear indication that our system is designed for straight sections and is marketed as such, we would first attempt to renovate the bends. If there were any difficulties in installation, we could switch to the straight section.

Will it be sufficient if I send you the quotation form next week? Any news on the testing programme?

Kind regards

Annex VI-A:
E-mail from Pipe-Aqua-Tec GmbH & Co.KG (19.04.2021)

Sehr geehrter Herr Ulutas,

hiermit bestätigen wir, dass wir das angeordnete Schadenbild „ Doppelloch" nicht sanieren werden. Da Sie Ihrerseits auf die Sanierung des Schadens bestehen, stimmen wir einer einvernehmlichen Rückgabe des Auftrages zu.

Begründung:

Das im Versuchsaufbau angeordnete Schadensbild „Doppelloch" stellt eine erhebliche Beschädigung der Rohrleitung dar, die bei in Betrieb befindlichen Druckleitungen grundsätzlich nicht auftreten kann. Ein Loch dieser Größenordnung führt zum unmittelbaren Totalverlust der Betriebsfähigkeit und ist mit einem Rohrbruch vergleichbar. Eine Systemprüfung an einer in der Praxis nicht vorkommenden Schadstelle ist nicht sinnvoll.

Des Weiteren stellt die besondere Ausprägung des „Doppellochs" mit den mittig angeordneten spitzen Ecken einen zusätzlichen Stresspunkt dar, dessen Langzeitauswirkung auf den eingesetzten Druckschlauchliner nicht abgesehen werden kann. In der Sanierungspraxis würde eine solche Beschädigung daher zwingend vorbehandelt werden, z.B. mittels Verpresstechnik, Kurzliner oder punktueller Aufgrabung.

Eine Sanierung des Schadensbildes „Doppelloch" ohne die notwendigen Vorarbeiten entspricht nicht dem Stand der Technik und widerspricht dem praktischen Sachverstand. Wir lehnen sie daher zum Schutz von Produkt und Anwender mit Entschiedenheit ab.

Auch entspricht das Ansinnen, auf Grundlage eines realitätsfern und willkürlich konstruierten Szenarios die vermeintliche Robustheit eines Sanierungssystems testen zu wollen, weder den wissenschaftlichen Grundsätzen der Produktprüfung noch einem seriösen Ansatz für einen praxisorientierten Produkttest.

Mit freundlichen Grüßen

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Pers.haft. Ges.: Pipe-Aqua-Tec Verwaltungs GmbH, Sitz Mannheim, AG Mannheim HRB 722121
Geschäftsführer: Markus Brechwald, Tobias Volckmann

English translation of E-mail from E-mail from Pipe-Aqua-Tec GmbH & Co.KG (19.04.2021) using DeepL Translator

Dear Mr Ulutas,

We hereby confirm that we will not rehabilitate the ordered damage " double hole". Since you, for your part, insist on the remediation of the damage, we agree to return the order by mutual consent.

Reason:

The damage pattern "double hole" ordered in the test setup represents considerable damage to the pipeline, which cannot occur in principle in pressure pipelines in operation. A hole of this size leads to the immediate total loss of operational capability and is comparable to a pipe burst. A system test at a point of damage that does not occur in practice does not make sense.

Furthermore, the particular shape of the "double hole" with the centrally arranged pointed corners represents an additional stress point whose long-term effect on the pressure pipe liner used cannot be foreseen. In rehabilitation practice, such damage *would therefore have to be pre-treated, e.g., by means of grouting technology, short liner or selective excavation.*

A rehabilitation of the damage pattern "double hole" without the necessary preliminary work does not correspond to the state of the art and contradicts practical expertise. We therefore firmly reject it for the protection of the product and the user.

Furthermore, the attempt to test the alleged robustness of a rehabilitation system on the basis of a scenario that is far removed from reality and arbitrarily constructed corresponds neither to the scientific principles of product testing nor to a serious approach for a practice-oriented product test.

Yours sincerely

Annex VI-B:
E-mail from IKT gGmbH on behalf of the Steering Committee (26.06.2021)

Sehr geehrter Herr Brechwald,
die Lenkungskreismitglieder haben in der letzten Sitzung beschlossen, dass für das Sanierungslos „Pipe-Aqua-Tec GmbH & Co. KG“ die Sanierung der Abwasserdruckleitung ohne das Schadensbild „Doppelloch“ durchgeführt werden kann. Anstatt dem Rohrstück mit dem Schadensbild „Doppelloch“ wird ein Rohrstück ohne Schadensbild eingebaut. Alles Weitere an der Versuchsstrecke und den Schadensbildern bleibt wie vorher kommuniziert.
Darüber hinaus sende ich Ihnen in der Anlage Informationen zum Prüfprogramm mit dem Schwerpunkt „Betriebsbelastungen“ zu.

Die Sanierungsarbeiten können voraussichtlich ab Oktober 2021 durchgeführt werden.

Wann darf ich Sie kontaktieren, um die Details zu besprechen?

Mit freundlichen Grüßen
Serdar Ulutaş

P.S.: Das neue IKT-Weiterbildungsprogramm für 2021 ist da! Schauen Sie doch mal rein: IKT-Weiterbildung 2021

Dipl.-Ing. (FH) Serdar Ulutaş, MBA
- Leiter IKT-Warentest -

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Geschäftsführer: Dipl.-Ök. Roland W. Waniek
Vorsitzender des Aufsichtsrates: Ltd. Baudirektor Hans-Joachim Bihs

English translation of E-mail from IKT gGmbH on behalf of the Steering Committee (26.06.2021) using DeepL Translator

Dear Mr Brechwald,

At the last meeting, the steering committee members decided that for the rehabilitation lot "Pipe-Aqua-Tec GmbH & Co. KG" the rehabilitation of the wastewater pressure pipe can be carried out without the damage pattern "double hole". Instead of the pipe section with the damage pattern "double hole", a pipe section without damage pattern is installed. Everything else about the test section and the damage patterns remains as previously communicated.

In addition, I am enclosing information on the testing programme with the focus on "operational loads".

It is anticipated that the remedial works can be carried out from October 2021.

When may I contact you to discuss the details?

Yours sincerely

Serdar Ulutaş

Annex VI-C:
E-mail from Pipe-Aqua-Tec GmbH & Co.KG (26.07.2021)

Sehr geehrter Herr Ulutas,

nach sorgfältiger Prüfung unserer Kapazitäten haben wir leider kein verfügbares Zeitfenster zur Durchführung der Sanierungsarbeiten frei. Die Winterpause nutzen wir für Tests zur Optimierung unserer Produkte, so dass wir vor Ende Februar keine Einbauten vornehmen könnten. Sollte dieser Zeitraum für Sie noch eine Option sein, stehen wir für weitere Gespräche gerne zu Ihrer Verfügung. Ansonsten bedauern wir an Ihrem Warentest diesmal nicht teilnehmen zu können.

Mit freundlichen Grüßen

PIPE-AQUA-TEC
GmbH & Co. KG

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Geschäftsführer: Markus Brechwald, Tobias Volckmann

English translation of E-mail from Pipe-Aqua-Tec GmbH & Co.KG (26.07.2021) using DeepL Translator

Dear Mr Ulutas,

After careful examination of our capacities, we unfortunately do not have an available time window to carry out the refurbishment work. We are using the winter break for tests to optimise our products, so we would not be able to carry out any installations before the end of February. Should this period still be an option for you, we would be happy to discuss the matter further with you. Otherwise, we regret not being able to participate in your product test this time.

With kind regards

Annex VII:
E-mail from REHAU AG + Co. (17.12.2021)

Sehr geehrter Herr Ulutas,

am 15.07. hatte ich die Möglichkeit, mich in Ihrem Hause zu den geplanten Tests und der Versuchstrecke zu informieren.
Leider sind die Platzverhältnisse in der Halle sehr beengt, so dass wir keine Möglichkeit sehen, mit dem Baustellenequipment wie beispielsweise dem 6m langen Dampfcontainer, dem Trommelwagen, einer Rohrsanierungswinde zum Einziehen der Rohre und Kompressor die Verlegung der Rohre anforderungsgerecht durchzuführen. Wir müssen Ihnen leider daher unsere Teilnahme an dem Warentest absagen und wünschen dem IKT sowie den teilnehmenden Firmen viel Erfolg bei den Ausführungen.

Vielen Dank & beste Grüße

i.A. Frank Krause
WATER AND TELECOMMUNICATIONS
PROJECTS PRESSURE PIPES AND RENOVATION SYSTEMS

REHAU

English translation of E-mail from REHAU AG + Co. (17.12.2021) using DeepL Translator

Dear Mr Ulutas,

On 15.07. I had the opportunity to inform myself in your company about the planned tests and the test track.

Unfortunately, the space in the hall is very limited, so that we do not see any possibility to carry out the laying of the pipes with the construction site equipment such as the 6m long steam container, the drum car, a pipe rehabilitation winch for pulling in the pipes and compressor in accordance with the requirements. Unfortunately, we have to cancel our participation in the product test and wish the IKT and the participating companies every success in their work.

Many thanks & best regards

9 Literature

[1] DIN EN 752: Drainage systems outside buildings - Sewer management, Deutsches Institut für Normung e.V., Berlin, July 2017.

[2] DIN EN ISO 11295: Classification and information for the planning and application of plastic piping systems for renovation and replacement, Deutsches Institut für Normung e.V., Berlin, June 2018.

[3] Bosseler, B.; Liebscher, M.: Report on the research project "Replacment with the bursting method - dimensioning, testing and quality assurance of wastewater pipes", IKT - Institute for Underground Infrastructure, Gelsenkirchen, November 2003.