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# DESIGN AND OPERATING GUIDELINES FOR THE TRENCHLESS REHABILITATION OF SEWER PRESSURE PIPELINES USING LINING WITH INSTERTED HOSES

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**ABSTRACT:** The paper discusses the design and operating conditions for the trenchless renovation of sewer pressure pipelines using lining with inserted hoses as referenced under ISO 11295:2018. It reviews the technical evaluation of the pipeline considering the installation specifications and outlines possibilities for various engineered modifications to allow for a renovation with inserted hoses. A solution of a flexible lining system is presented in the paper, including a detailed description of the corresponding connector technique. At the end of the paper, some case studies from installations of inserted hoses in Europe are presented, which will show examples of the previously discussed guidelines and modifications.

## 1. INTRODUCTION

Sewer pressure pipelines (or sewer rising mains, sewer force mains) are part of almost every typical sewer system. They transport wastewater under pressure, usually from a low point to a higher point of discharge using pump stations. They can connect to another section with gravity flow (downwards) or directly end at the wastewater treatment plant.

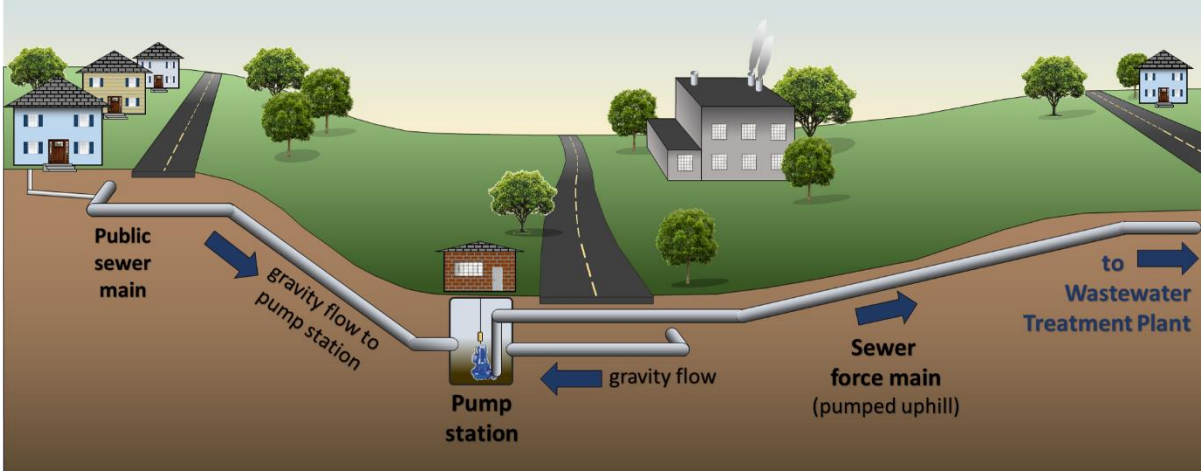


**Figure 1. Overview of a typical sewer network**

Sewer pressure pipelines can pose major challenges for asset owners. In a typical sewer network, several gravity sewers can come together at the pump stations from where the wastewater has to be transported on in direction to the treatment plants. If the force main is damaged and needs to be renovated, this has to be done in a short time window, since the wastewater can only be stored for a short time (if a reservoir is present at the pump station) or must be transported further at great expense (e.g. using an above-ground bypass).

Furthermore, access to the sewer pressure pipelines is often limited, since these run in urban areas with many houses, streets or railroads. River crossings or sensitive nature areas can also make rehabilitation difficult.
There are different types of damage to sewer pressure pipelines, such as internal and external corrosion holes or failures caused by mechanical stress, resulting in longitudinal cracks or misaligned connections. Leaking sewage pipes can cause pollution or contamination with high clean-up costs. This is why preventative renovation sometimes makes sense and in most of the cases, the stability of the existing line is still given.
The ISO 11295:2018 shows various rehabilitation options that can be used. One category is *lining with inserted hoses*, to which the Primus Line® system belongs and which will be focused on in the following considerations.

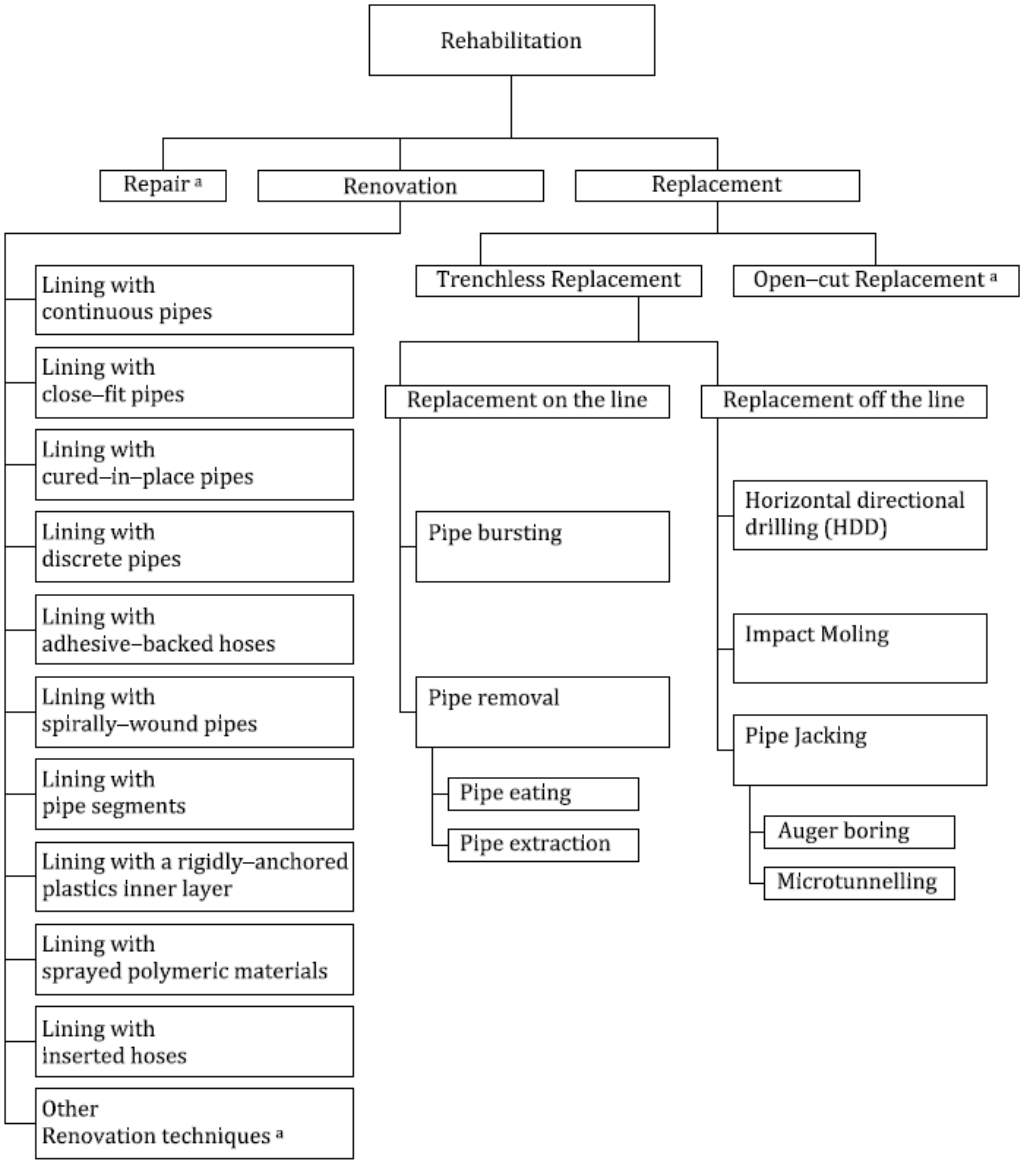


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**Figure 2. Renovation and trenchless replacement technique families**

## 2. LINING WITH INSERTED HOSES: THE PRIMUS LINE SYSTEM

The Primus Line® system consist of a flexible high-pressure liner and patented end fittings. Depending on the requirements of the application, different liner types can be used with corresponding connectors. The one to two layers of the inner fabric consist of seamlessly woven aramid fibers that are coated with polyethylene on the inside and outside. The inner coating seals the fabric from the transported fluid, and the outer coating protects the liner during the insertion into the existing host pipe. The inner coating can also be adapted to thermoplastic polyurethane for more aggressive media. The portfolio of Primus Line ranges from DN150 to DN500. Since the liner accommodates the operating pressure completely independently of the host pipe, Primus Line® is an independent pressure pipe liner according to ISO 11295.

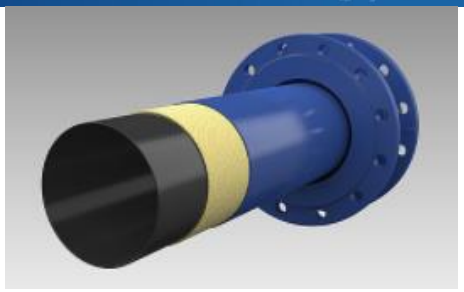

**Figure 3. The Primus Line System**

The connectors are also divided into two main groups depending on the application. The low-pressure or M-connector is made of cast iron and is protected from corrosion by a high-quality powder coating. Connector core and external sleeve are mechanically pressed together with a plastic contour sleeve, creating a pull-prove connection. For even higher demands, medium- or high-pressure connectors (R-design) can be used. A steel jacket is deformed by an epoxy resin injection in the external sleeve and pressed into the contour of the connector core.

## 3. DESIGN & OPERATIONS GUIDELINES WHEN USING LINING WITH INSTERTED HOSES IN SEWER PRESSURE PIPELINES

For a successful installation of inserted hoses like Primus Line in sewer pressure pipelines, several design and operating guidelines must be met. The operating case and the maintenance case must be distinguished. The following considerations refer to the operating case in which the following points are important:

The section to be renovated must not have a free inlet or outlet and must be completely filled with the transported fluid during all operating conditions. Also, a constant flow velocity is required for the entire section. If a free inlet is present, a mixture of air and wastewater can enter the pipe. As a result, the section is not completely filled and the flow velocity of the transported fluid is not constant. The condition is only met if there is a constant water column above the inlet. If a free outlet is present, the line is again only partially filled and the flow velocity is undefined.

**Figure 4. Free Outlet**

**Figure 5. Free Inlet**

Since the section of the line to be renovated must always be filled during all operating conditions, a longitudinal profile must be available for planning in addition to a ground view. The goal is to analyze the low and high points of the line and whether the line can drain after the pumps are switched off. To prevent the section from emptying, there must be a non-return valve present at the low point (usually near the pump station). The non-return valve closes immediately when the pumps stop and maintain a stable water column in the installed liner.

**Figure 6. Non-return valve – type: swing check valve**

Another point why the longitudinal section is crucial during the planning phase for the rehabilitation is to understand the overall profile of the line. The end point of the renovation section plays an important role as the connector at the end of the line must always be located at the highest point of the section to be renovated. If there is another absolute high point in between, this section (absolute high point to the end point of the line) behaves like a line with gravity flow. Since this line is not completely filled with the transported fluid and runs empty after the pumps are switched off, this section must be excluded from the rehabilitation with inserted hoses, unless modifications are made to the line.

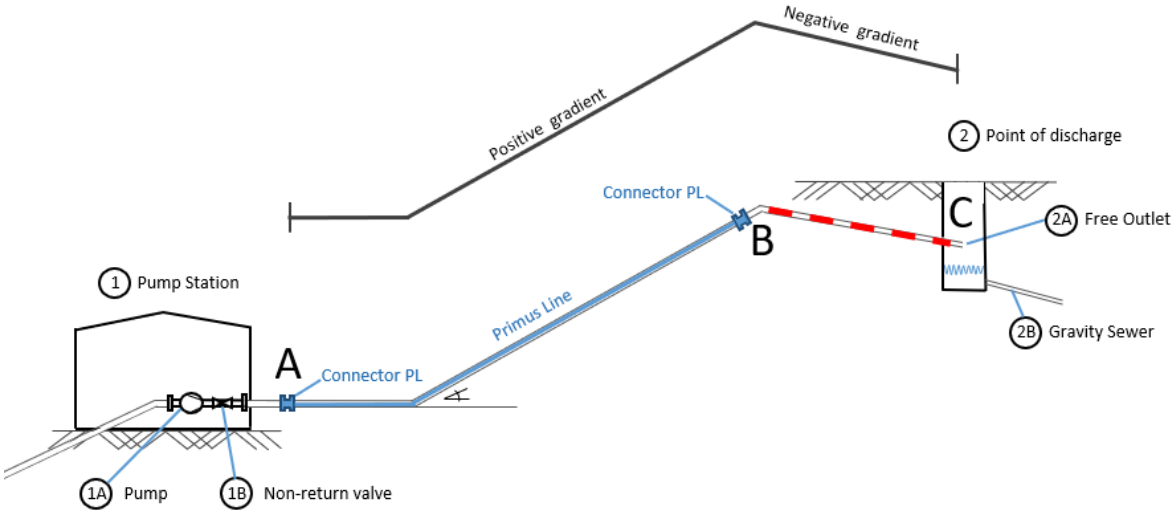


**Figure 7. Longitudinal profile I**

Figure 7 shows a typical profile of a sewer pressure pipeline. In this example, after the pump station (point A), the line rises to an absolute high point (point B). The gradient is positive. When the pump (1A) shuts off, the non-return valve (1B) keeps the line in that section completely filled with the transported fluid at all times.
In the following section from the absolute high point (point B) to the end of the line (point C), there is a negative gradient. Since there is also a free outlet (2A) at the point of discharge (2), the line will run empty after the pump is switched off. This section equals a gravity sewer and a rehabilitation using inserted hoses of this part is therefore not possible, if no changes are made.

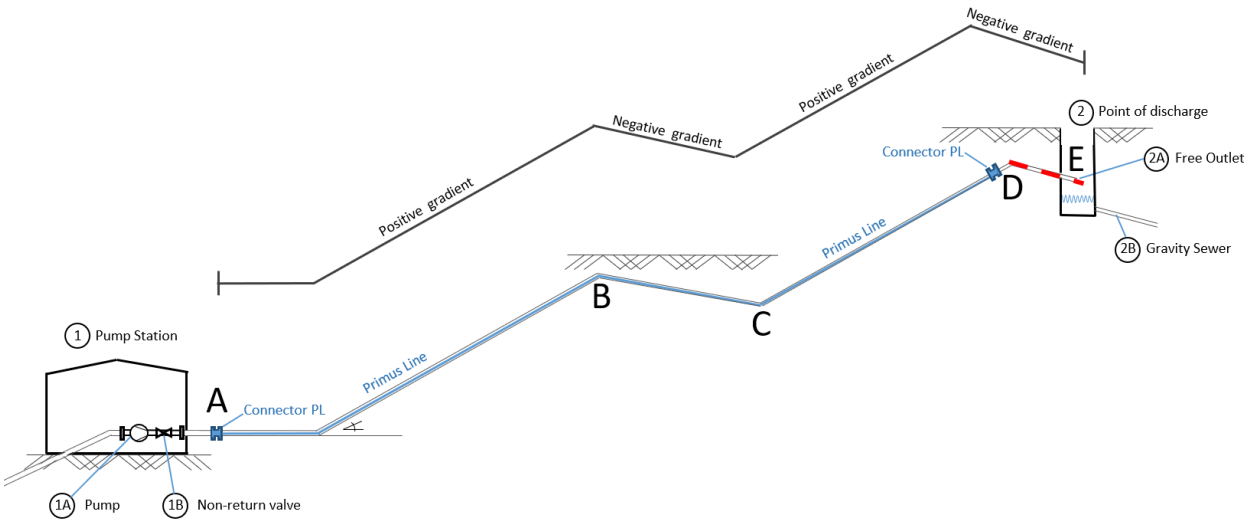


**Figure 8. Longitudinal profile II**

Figure 8 shows an expanded view of figure 7. Now follows the section with negative gradient (relative high point at point B to relative low point at point C), another section with a positive gradient to the absolute high point (point D). Even if the pump shuts off, this section between point B and point C will not run empty. It is always pressurized and completely filled with the transported fluid at all times. The rehabilitation using inserted hoses can be carried out up to the absolute high point (point D). The rest of the scenario remains the same - Since there is a free outlet in 2A at the point of discharge (2), the line will always drain after the pump is switched off. The section has gravity flow and will not be completely filled with the transported fluid at all times, so that a renovation using inserted hoses is not possible without modifications.

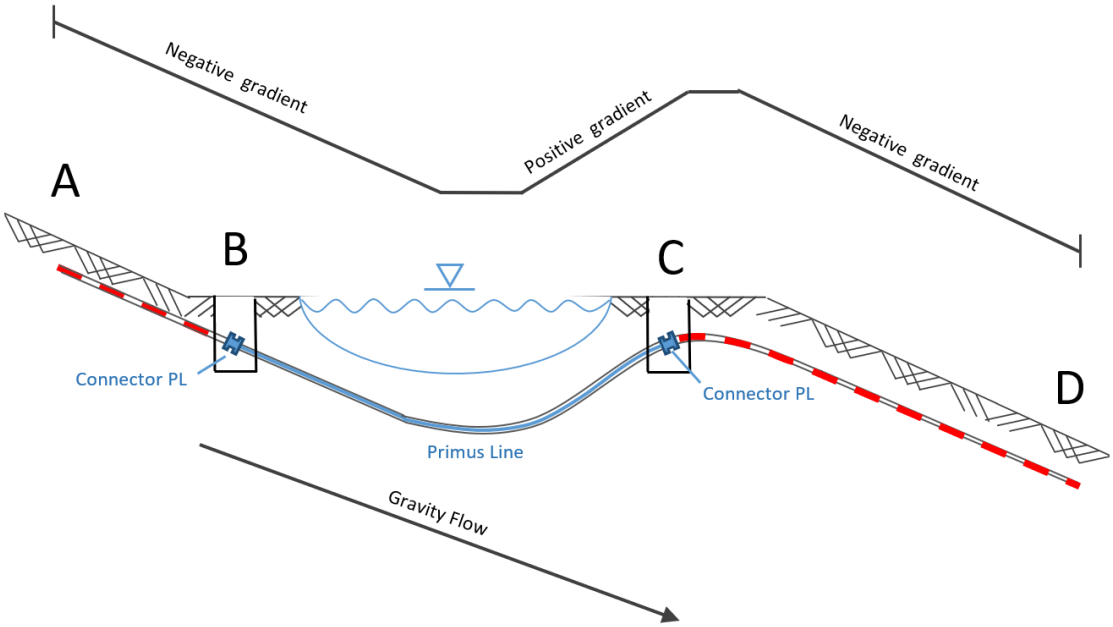


**Figure 9. Longitudinal profile III**

Figure 9 shows a special case of a possible renovation of a sewer line with inserted hoses. Although the complete section from the absolute high point (point A) to absolute low point (point D) is a gravity-operated sewer pipeline, the section between point B and the relative high point at point C is always completely filled with the fluid to be transported. This section cannot run empty. According to the previously discussed design guidelines, this section can also be rehabilitated using inserted hoses, although it is not a sewer pressure pipeline. This example shows, that it is important to take the longitudinal profile into account during the planning phase of the project.

After the rehabilitation of the section using inserted hoses, the pipe must be reintegrated into the existing network using a spool piece. Inserted hoses like Primus Line are installed with annular space. If groundwater is present, it can potentially penetrate the existing pipe through existing damaged areas and fill the gap between the liner and the old pipe. During maintenance, the liner could be emptied and become flat. This is not harmful for the liner and does not affect its longevity, but the infiltrated groundwater must be able to leave the annular space when the liner is pressurized again. For this purpose, a monitoring pipe or pressure release valve is installed at the connector at the lowest point of the renovated section. The groundwater can then leave the annular space in a controlled manner via this opening.

**Figure 10. Spool piece**

**Figure 11. Monitoring pipe / Pressure release valve**

## 4. ENGINEERED SOLUTIONS TO MEET DESIGN AND OPERATING GUIDELINES

As in figure 9, there are some special cases where rehabilitation is possible due to the profile of the pipe, even it is not a sewer pressure pipeline. For sections, which do not meet all requirements in the first step, there are also possibilities to carry out a rehabilitation with inserted hoses using engineered solutions. The aim is to change the characteristics of the line in such a way that the specified design and operating guidelines (no free in- or outlet, line always completely filled with transported fluid, etc.) are met, which makes a renovation with inserted hoses possible.

If there is a free outlet at the end of the section to be renovated or if the connector is not completely full with the fluid to be transported, the existing host pipe can be extended (figure 12) or the receiving manhole can be adjusted (figure 13). As a result, the water level is raised and the connector and thus the complete flexible liner is filled with sewage during all operating conditions. The design and operating guidelines are met.

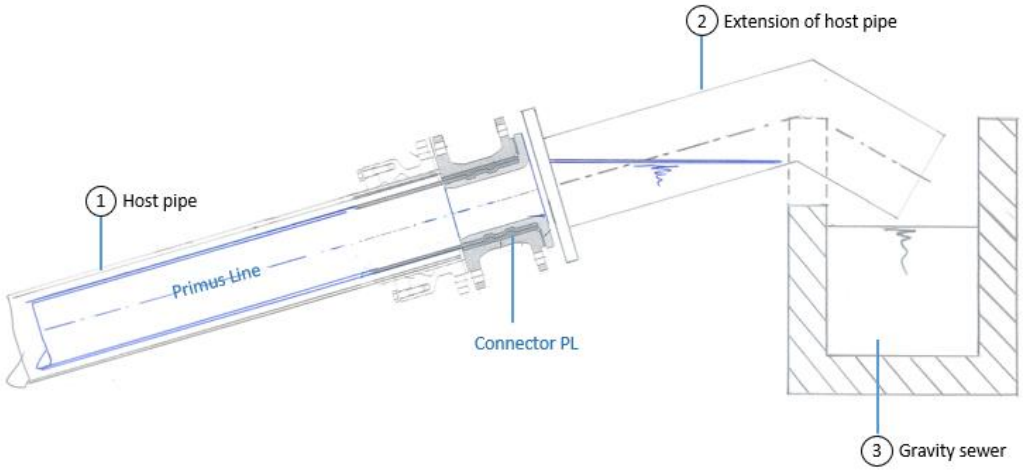


**Figure 12. Extension of host pipe**

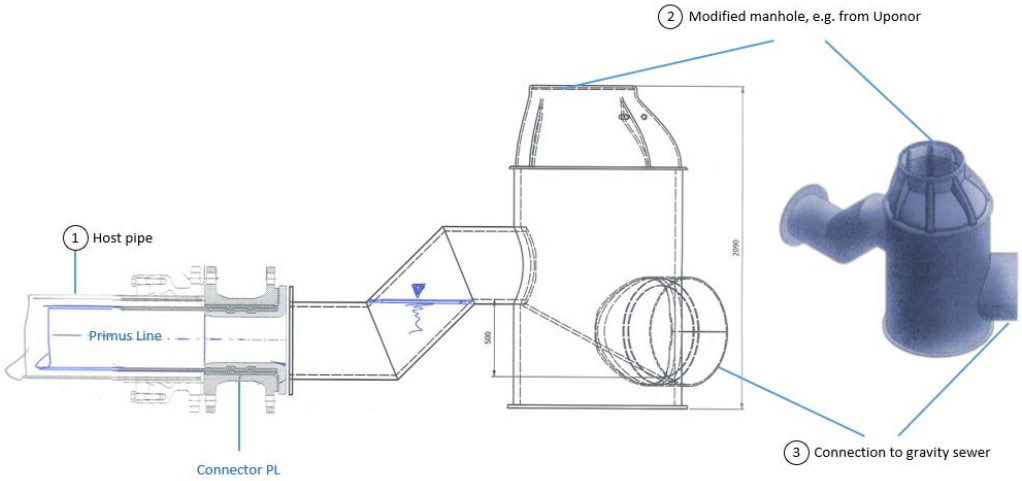


**Figure 13. Modification of manhole**

In sections with negative gradient or almost horizontal pipelines, the pipeline will always drain unless changes are made to meet the design guidelines. Again, the aim is to raise the water level above the connector, so that the system is completely filled during all operating conditions. Figure 14 shows a partition wall, which can be installed in the receiving manhole. As a result, the sewage is held back and the liner segment cannot run empty. If more wastewater is pushed in, it flows over the wall and into the gravity sewer.

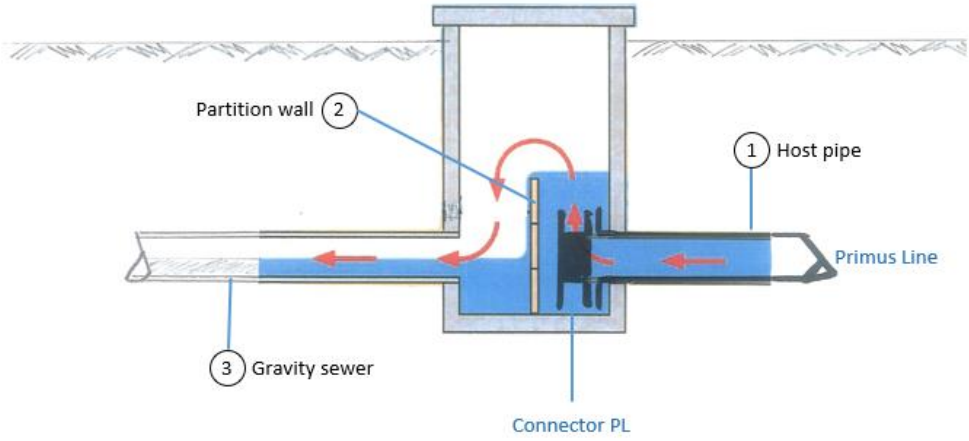


**Figure 14. Modification of manhole – Partition wall**

Figure 15 shows a similar modification. Here, too, the fluid to be transported is kept in the renovated section with a so-called goose neck or camel back. Due to the increased wastewater level, the connector and the complete system always remains filled.

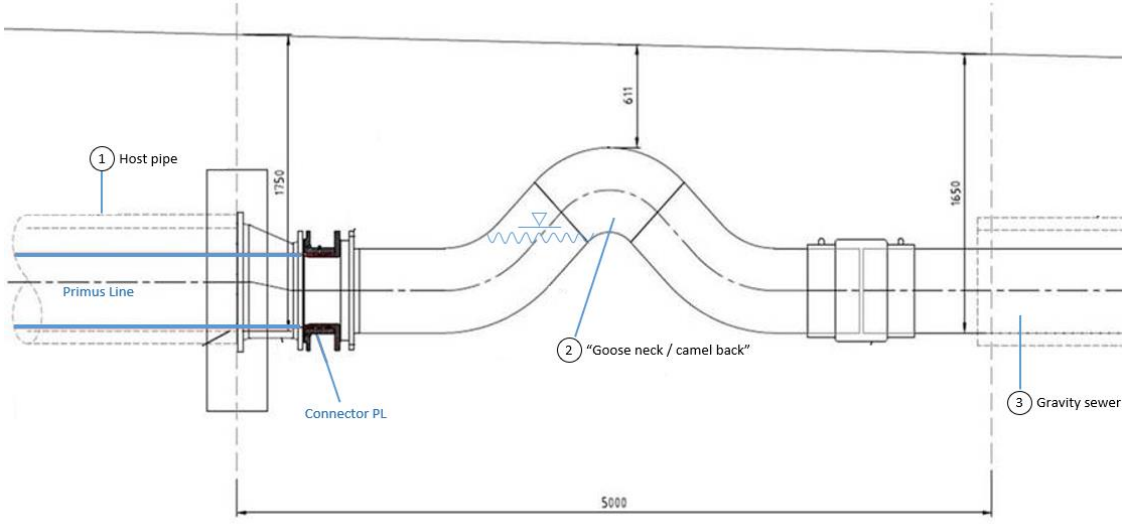


**Figure 15. Goose neck / Camel back**

For both modifications it must be noted that the height of the partition wall / goose neck is chosen so that it corresponds to the height of the first connector in the system at the beginning of the renovated section. Similar to figure 9, this creates an area that is always filled with the transported fluid and therefore fulfills the design and operation guidelines. The section can be renovated using inserted hoses.

## 5. CASE STUDIES: RENOVATION OF THREE SEWER PIPELINES USING THE PRIMUS LINE® SYSTEM

In the following part, three different case studies are briefly presented in which lining with inserted hoses with the Primus Line® system was used. All projects meet the previously discussed design and operating guidelines in chapter 4, which will be addressed in the review:

The first project was carried out in **Brandenburg, Germany** for *BRAWAG GmbH, Wasser- und Abwassergesellschaft, Brandenburg - Havel* in March 2013. The sewer siphon with four vertical bends of 22.5 degree under the river Havel showed the first signs of corrosion as well as small leaks. The existing DN700 pipeline was built in 1966 and made from steel. During the construction work, shipping traffic on the river was not to be affected. The 93m long section to be rehabilitated was only allowed to be out of service for a short time, as the capacity of the wastewater reservoir used was limited.
Considering the design and operating conditions, the section had no free inlet or outlet (figure 4 and 5) and cannot drain due to its longitudinal profile (siphon; figure 9). Technical modifications were therefore not necessary. Not only is the renovated pipeline constantly filled with the transported fluid during all operating conditions, also the existing host pipe was full of water during the installation. Since the Primus Line system® is installed with annular space and is not glued to the existing host pipe, the water penetrating from the river was not a problem. It could leave the annular space during the installation. In such cases of intruding ground water, it is recommended to install a monitoring pipe (figure 11) so that water can exit the annulus in a controlled manner. The system *Primus Line DN500 PN15* was installed within one working day and the section was integrated back into the existing sewage network using spool pieces. The line has now been in operation for ten years without incident.

**Figure 16 and 17. Reintegration of the Primus Line system® using spool pieces**

The second project was performed near **Copenhagen, Denmark**, for the local network operator *Novafos*. The sewer pressure pipeline transporting treated waste water ran under a street and several rails as well as a parking lot at the Holte train station. As a result, only a rehabilitation method using trenchless technologies was possible. During the renovation work, the waste water from the reservoir at the pump station was diverted using a bypass.

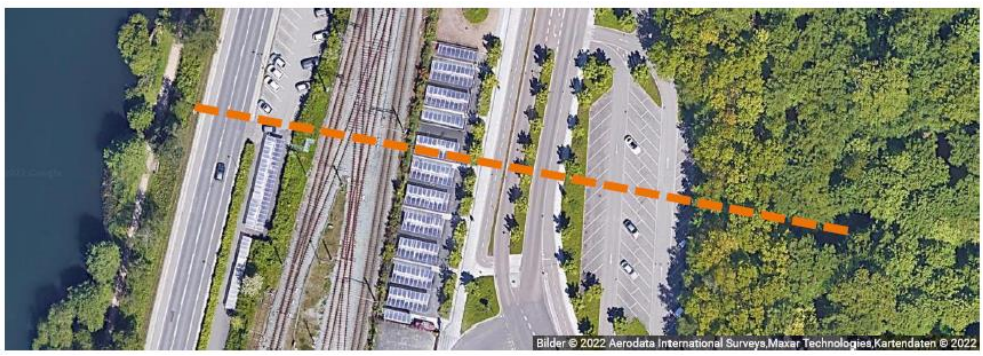


**Figure 18. Run of the sewer pressure pipeline under Holte train station**

Also in this case, all design and operating considerations were fulfilled: The section was integrated using spool pieces, leaving no free in- or outlet. Even though the profile of the renovated section was relatively flat, the subsequent longitudinal profile of the pipeline has a positive gradient. This in combination with the presence of a non-return valve (figure 6) in the pump station, leads to the fact that the pipeline is always completely filled during all operating conditions and cannot drain (figure 7). Also in this case, technical modifications were therefore not necessary.
The 165m of the system *Primus Line DN450 PN16* were installed into the DN500 host pipe made from PE SDR17 within one working day. After the pressure test of the section, the rehabilitated line could be reintegrated in the existing sewer system.

The third line was renovated in July 2016 for the network operator *United Utilities plc*, at **Lake Windermere, United Kingdom**. The existing DN300ductile iron host pipe was installed in the 1970s and had a significant reduced wall thickness of only 1-2mm, resulting in first pin holes (figure 19). The 770m long sewer pressure pipeline had an ascending profile with four 45-degree bends in the run. The line was renovated using the system *Primus Line DN300 PN12*, which was installed in one piece over the entire length.
With regard to the design and operation guidelines, the section to be renovated was always filled with the transported fluid due to the positive gradient of its profile (figure 7) and the presence of a non-return valve in the pump station at the bottom of the line. However, in the upper area the pipeline discharged directly into a gravity sewer with a free outlet (figure 20; in the front: end of pipe; in the back: gravity sewer). Since a free outlet is not permitted (figure 4), a technical modification had to be carried out in this position. By extending the existing pipeline after the Primus Line connector with a suitable steel construction (figure 12), the state of a completely filled Primus Line section during all operating conditions and without a free outlet could be achieved. The entire renovation project, including cleaning of the host pipe and the installation of the Primus Line® system required five working days.

**Figure 19. Pin holes in host pipe**

**Figure 20. End pit with connection to gravity sewer**

## 6. REFERENCES

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Figure 1: https://www.dmmwra.org/186/How-the-Sewer-Works

Figure 2: Classification and information on design and applications of plastics piping systems used for renovation and replacement (ISO 11295:2017); English version EN ISO 11295:2017, English translation of DIN EN ISO 11295:2018-06, p. 12: https://www.beuth.de

Figure 4: https://www.rbb24.de/studiocottbus/panorama/2020/06/abwasser-kosten-cottbus-bundesvergleich.html

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Figure 6. https://chemicalengineeringworld.com/types-of-check-valves-non-return-valve-nrv/

Figure 18. Bilder © 2022 Aerodata International Surveya Maxar Technologies, Kartendaten ©2022

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