Pipeline Rehabilitation
for gas, water, sewer and industrial applications

Compact Pipe
Compact SlimLiner
Neofit
Wavin TS
Wavin PE
Since September 2005, ‘us’ – Utility Services performs rehabilitation of existing pressure sewer pipeline for South East Water Ltd using the Wavin close-fit lining technique known as Compact Pipe. Compact Pipe enables sections of ageing pipe to be renewed without the need for open excavation. The existing pipe in the ground receives a close-fit insertion of polyethylene, effectively placing “a new pipe within the old pipe”.

The result is a structurally independent pressure pipe with the quality and durability of a newly installed pipeline which is suitable for water, sewerage and gas services.

The environmental benefits of this technology are significant. Not only is the local environment, other infrastructure assets and public protected from open excavation, but the product has a lifespan of more than 100 years, ensuring network performance for future generations. The liner’s high durability reduces potential failure of the asset in the future. This leads to significant cost savings that previously authorities would have encountered through leaking water mains and sewerage spills into the environment.

‘us’ – Utility Services operates under an exclusive license from Wavin, covering Australia and New Zealand.

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1. Why rehabilitation of pipelines?

1.1. Introduction

In industrialised countries, most households are connected to pipeline systems. However, in Europe alone 25 to 40 per cent of the existing network is in poor condition, endangering human lives and the environment. Rehabilitation of pipelines has become an indisputable necessity.

With increasing costs of replacing pipelines, and work in the road getting more difficult with growing traffic intensity, no-dig techniques to restore performance by renovating pipelines are economically and environmentally desirable.

In the late sixties, the first so-called sliplining techniques were introduced using plastic pipes as liners. They provided renovation options to cure leaking joints and allowed a new durable pipe to be laid effectively within an old one. Considerable development has taken place since then, and a number of renovation techniques using plastic linings have become available.

In the UK, breaking up roads is discouraged by law. Here, nearly 80 per cent of the manufactured polyethylene pipes are applied for no-dig rehabilitation of existing pipelines, either by trenchless replacement (pipe bursting) or by renovation.

1.2. Problems in existing pipelines

Nowadays, pipeline inspection by remotely controlled TV cameras at regular intervals is normal practice in many countries. Even pipes with inner diameters smaller than 100 mm are no problem.

The issues in existing pipeline networks can be summarised as follows:

**Potable water supply lines**

<table>
<thead>
<tr>
<th>Problems</th>
<th>Consequences</th>
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<tbody>
<tr>
<td>pipe material (e.g. lead)</td>
<td>poor water quality (taste, colour)</td>
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<td>leakage</td>
<td>low pressures, blocked supply</td>
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<td>incrustations</td>
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<td>pipe fractures</td>
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**Gas supply lines**

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<td>corrosion</td>
<td>low pressure</td>
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<td>pipe fractures</td>
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**Sewers**

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<th>Consequences</th>
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<td>leaking joints</td>
<td>blocked supply</td>
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<td>root intrusion</td>
<td>water ingress</td>
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<td>sedimentation</td>
<td>pollution of the underground</td>
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<td>sliming</td>
<td>flooding</td>
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<td>protruding laterals</td>
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<td>misalignments</td>
<td>road collapse</td>
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<td>under-dimensioning</td>
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<td>corrosion/chemical attack</td>
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<tr>
<td>cracks (structural failure)</td>
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<td>collapse</td>
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</table>

Fig. 2: Incrustations in a potable water main.

Fig. 3: Heavily corroded gas pipeline.

Fig. 4: Structural failure and sedimentation in a sewer.

Fig. 5: Root intrusion in a sewer.

Fig. 6: Heavily damaged sewer.
2. How to rehabilitate pipelines?

2.1. Rehabilitation options

When problems are limited to obstacles inside the pipeline, different methods of cleaning are applicable to tackle this:
- high-pressure jet cleaning
- cutting robots
- scratch brushes
- chain dragging and scrapers

When problems are of structural nature, the traditional rehabilitation options were either localised repair or, in severe cases, open-cut replacement of the complete pipeline system. Today there are many more options for rehabilitation which can be seen in Fig. 8. Renovation by lining and trenchless replacement with plastics pipes, both no-dig methods, enjoy increasing popularity.

Fig. 7: Cleaning devices: scraper (left) and chain dragging.

Fig. 8: Pipeline rehabilitation options

What speaks in favour of renovation rather than traditional open-cut methods is the following:
- less social inconvenience (traffic, commerce)
- less interference with cables and other services
- less disruption of nature and the environment (trees, waterways)
- independent organisation (no work on other services under ground required)
- less time and money needed

When the structural state of the old pipeline or its capacity is extremely poor (e.g. collapse), there is often no alternative to open-cut replacement. But when e.g. leaking joints or corrosion problems need to be tackled, both renovation and trenchless replacement evidently offer benefits. Major benefits of renovation and trenchless replacement compared with open cut replacement are significantly less excavation work and shorter renovation time. This reduces environmental impact, disruption to commercial activity and social inconvenience.

2.2. Renovation techniques

2.2.1. Coating

Coating can be applied to renovate water lines, where the structural condition of the existing pipeline is still sufficient, but problems with water quality have to be tackled. Depending on water hardness and durability requirements, either a cement coating or an epoxy coating may be applied. Cement coating, which is the older form, is still used a lot in e.g. Germany, whilst in the UK epoxy has almost replaced cement. Leakages cannot be cured with coating.

2.2.2. Lining

Among lining methods (all using plastic pipes/components) the most popular ones are:
- lining with continuous pipes, also known as sliplining
- lining with cured-in-place pipes
- lining with close-fit pipes

Lining with continuous pipes (sliplining)

Insertion of a single continuous pipe lining made of polyethylene pipes which are pre-welded and then pulled in strings.

Example: Sliplining with Wavin PE 100 pipes

Fig. 9: Sliplining.
Lining with cured-in-place pipes
Lining with a flexible tube impregnated with a thermosetting resin which produces a pipe after resin cure. Examples: Insituform, Phoenix.

Lining with close-fit pipes
Lining with a continuous plastic pipe with reduced cross-section to facilitate installation. After installation it is reverted to provide a close fit to the host pipe. Many new techniques of this type have been developed since the mid-eighties. The first generation comprises methods using site-reduced pipes (examples: Swagelining, Rolldown).

The second generation comprises methods using factory-reduced pipes (examples: Compact Pipe, Compact SlimLiner).

Plastic pipes used for renovation of non-pressure pipelines, like sewers and drains, are generally considered as “independent”, since they have to be designed to cope with (part) of the external loads.

Plastic pipes used for renovation of pressure pipelines are classified structurally as either “independent” or “interactive” according to the way the tensile hoop stresses associated with internal pressurisation are carried.

An independent pipe is capable of carrying the long-term internal pressure stresses as though it is completely free from radial restraint.

An interactive pipe transfers all or part of the internal pressure stress by radial contact to the existing pipe wall, but retains a long-term capability to span any corrosion holes or joint gaps in the existing pipeline system.

The short and long term effects of installation loads must also be taken into account, and steps taken in the design process to ensure that limits are set for these loads during installation.

Whilst renovation using plastic pipes may solve structural problems and leakage, the renovated pipe must be able to provide adequate flow capacity. Therefore the first thing to establish is the hydraulic performance required of the rehabilitated pipe, and not simply seek to achieve the ‘as new’ performance of the original pipe.

The required performance fixes the minimum internal diameter of the lining pipe, whilst its maximum external diameter is fixed by the existing pipe.

As regards flow capacity, there may be additional benefits of hydraulic smoothness and continuity of invert provided by the plastic lining system. Further details on design are presented in Chapter 5.

2.3. Trenchless replacement techniques
Where the system requirements do not permit the application of a renovation technique, e.g. because of flow limitations, and replacement is necessary, the old pipeline can be replaced with a no-dig method. Generally trenchless replacement is defined as:

Construction of a new pipeline, on the line of the existing one, the function of the new line incorporating that of the old.
2.4. Decision guide

The flow chart in Fig. 15 helps decision makers to find the appropriate solution for a particular problem.

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**Fig. 15:** Decision guide
3. Wavin Pipeline rehabilitation systems

For trenchless pipeline rehabilitation, Wavin as one of the pioneers in this industry in Europe, offering innovative solutions to tackle the various problems in gas, water, sewer and industrial pipelines.

3.1. Wavin PE pipes for slilining

Lining with continuous strings of standard dimension Wavin pipes has been carried out since the mid sixties. Originally, polyvinyl chloride (PVC) pipes were cemented together and then pulled in in one go.

From the late sixties polyethylene (PE) pipes were used for this purpose.

Polyethylene as a material is highly suitable because of its lower modulus of elasticity, giving the pipeline string the desirable longitudinal flexibility.

The lengths of the individual pipes depend on the transport possibilities. The standard length of PE pipes is 12 m (in some countries 10 m). With diameters up to incl. 160 mm, continuous lengths are available in coils or on drums.

The wall thickness is determined by the structural conditions the liner has to face (see Chapter 5.3.) as well as by the connection possibilities. Welding fittings to the pipes requires minimum wall thickness.

For pulling in pipes an insertion trench is required. The size of this trench is determined by the diameter and the allowable bending radius of the pipe, the depth of the existing pipeline and temperature. As a rule of thumb, the trench size as represented in Fig. 17, should be calculated as follows:

Trench length: \( L = 8 \times H \) [m]

Trench width: \( W = OD + 1.0 \) [m]

The pipeline to be renovated needs to be cleaned and freed from any obstacles that might hinder insertion of the pipe string. Camera inspection and use of probing pigs is strongly recommended.

The pipe string is formed by butt welding individual pipes together. Depending on the wall thickness of the lining pipe, each welding procedure takes 30 to 60 minutes. Detailed welding prescriptions can be provided on request.

The welding should be checked by visual inspection for weld beads. The weld beads on the outside may hinder insertion and it is recommended to remove them to prevent difficulties afterwards. Removal of the inside weld beads may be demanded by the end user also.

The pulling end of the string is provided with a pulling head. This may consist either of a metal assembly which is bolted to the pipe, or a PE end-cap with a pulling eye. The end-cap is butt-welded to the pipe.

A swivel between pulling end and winch cable prevents torsion of the cable and thus provides more durability to the cable. Rollers are placed underneath the pipe string to facilitate insertion and to prevent damage when pulling the string. Insertion takes place with a winch at a pulling speed up to 15 m/min. The entry of the existing pipeline is provided with insertion guides. In order to further reduce insertion forces, applying a lubricant is recommended. Just wetting the pipes with water also helps.

The maximum pulling forces depend on the PE pipe applied (see Chapter 5.2.). The applied pulling forces shall be recorded and included in the installation report.
Table 1: Product range gas pipes for slip lining

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<th>DA mm</th>
<th>DN</th>
<th>PE 80 Gas SDR 17.6</th>
<th>PE 80 Gas SDR 11</th>
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Table 2: Product range portable water pipes for slip lining

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*on request

Table 3: Product range waste water pipes for slip lining

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<td>20.5</td>
<td>13.4</td>
<td>20.5</td>
</tr>
<tr>
<td>250</td>
<td>250</td>
<td>14.8</td>
<td>22.7</td>
<td>14.8</td>
<td>22.7</td>
<td>14.8</td>
<td>22.7</td>
</tr>
<tr>
<td>280</td>
<td>250</td>
<td>16.6</td>
<td>25.4</td>
<td>16.6</td>
<td>25.4</td>
<td>16.6</td>
<td>25.4</td>
</tr>
<tr>
<td>315</td>
<td>300</td>
<td>18.7</td>
<td>28.6</td>
<td>18.7</td>
<td>28.6</td>
<td>18.7</td>
<td>28.6</td>
</tr>
<tr>
<td>355</td>
<td>350</td>
<td>21.1</td>
<td>32.2</td>
<td>21.1</td>
<td>32.2</td>
<td>21.1</td>
<td>32.2</td>
</tr>
<tr>
<td>400</td>
<td>400</td>
<td>23.7</td>
<td>36.3</td>
<td>23.7</td>
<td>36.3</td>
<td>23.7</td>
<td>36.3</td>
</tr>
<tr>
<td>450</td>
<td>500</td>
<td>26.7</td>
<td>40.9</td>
<td>26.7</td>
<td>40.9</td>
<td>26.7</td>
<td>40.9</td>
</tr>
<tr>
<td>500</td>
<td>500</td>
<td>29.7</td>
<td>45.4*</td>
<td>29.7</td>
<td>45.4*</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>630</td>
<td>600</td>
<td>33.2</td>
<td>50.8*</td>
<td>33.2</td>
<td>50.8*</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

*on request
Where the lining pipe is substantially smaller than the inside of the existing pipeline, insulators can be assembled around the lining pipe, but only when the bore of the host pipe is smooth enough.

Once the lining pipe has been pulled in, the finishing-off work needs to be carried out:
• grouting the annulus
• reconnecting to the laterals/service lines and the network.

The annulus between old and new pipe is usually grouted with a cementious mix. Where the annulus is relatively small, grouting with a polyurethane foam is possible. Grouting is mainly done to fixate the new line in its position, e.g. to prevent longitudinal movements of the liner, and assist only marginally to create a strong structure. Grout may be applied from the highest point of the section to the lowest, making use of the existing gradient of the pipeline, or it may be applied from the lowest point upwards by pumping it in under pressure.

During grouting the liner is exposed to the following loading effects:
• floating pressures; a heavy grout pushes the liner up, causing line loading on the top; insulators around the pipe prove to be of help here also to keep the pipe on its place relatively in the centre
• hydrostatic pressure from outside, with a risk of collapse of the liner.

Precautions should be taken to prevent these from happening. Detailed prescriptions on types of grout that may be used and how to apply grouting correctly are presented by D. Stein et al. [25].

The laterals are generally reconnected from outside, by butt welding pipe end stubs or electrofusion saddles on to the pipe. From here reconnection can easily take place. Nowadays it is also possible to reconnect from inside, using remote-controlled cutters and special hat profiles electrofusion-welded to the inside of the PE liner pipe. For this, exact relocation of the laterals is a must, as well as means to cut through liner pipe wall as well as through the grout around it.

For reconnection to the existing network the standard connecting facilities are appropriate, e.g. flanged ends.

Over the years sliplining has gained popularity especially in rehabilitating damaged pressure pipelines. It is a quick, relatively simple and cost-effective method.

However, there are a few limitations to this traditional method of lining with continuous strings:
• Reduction in flow capacity; the diameter of the new pipe is substantially smaller than the existing size.
• Large access pits; considerable access pits are needed to enable insertion
• Space above ground, for laying out the pipe string prior to insertion
• Bends in the pipeline track; negotiating bends in the existing pipeline is problematic
• Grouting causes problems with (re-)connecting services

These limitations have lead to the development of Compact Pipe, Compact SlimLiner and Neofit, all close-fit lining systems.

3.2. Compact Pipe  
3.2.1. System description and applications

Compact Pipe has proven to be the ideal technology for the trenchless rehabilitation of damaged water, sewer, gas and industrial pipelines made of traditional materials such as cast iron, steel, concrete, clay or asbestos-cement.

Compact Pipe is especially advantageous where the pipeline is not accessible or where there is heavy traffic so that open trench construction is not possible. Construction work is restricted to small start and end pits, which can even be omitted completely in the case of a sewer pipe rehabilitation where the existing manholes can be used.
A circular PE pipe is folded along its length during the extrusion process to become C-shaped. Thus the cross section of the pipe is reduced by 35 per cent so that it can easily be inserted in the pipeline which has to be rehabilitated. Once inserted the Compact Pipe is reversed with steam. Due to the “memory effect” of polyethylene the pipe regains its original shape. Using pressurised air during the cooling process the liner is brought in close contact with the inner wall of the host pipe (close-fit). Inner diameter tolerances of the host pipe can be balanced by up to 7 %. The result of this close-fit technique is a structurally independent pipe with the quality and durability of a newly installed pipe.

Changes of direction in the pipeline can be realised with Compact Pipe as follows:

<table>
<thead>
<tr>
<th>Kind of change</th>
<th>Angle °</th>
<th>Min. radius of host pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>bends and junctions</td>
<td>&lt; 22.5°</td>
<td>without restrictions</td>
</tr>
<tr>
<td>bends</td>
<td>&lt; 45°</td>
<td>5 x DN Compact Pipe</td>
</tr>
<tr>
<td>bends</td>
<td>&lt; 90°</td>
<td>8 x DN Compact Pipe</td>
</tr>
</tbody>
</table>

For rehabilitation of sewers, the minimum size of manholes is presented in Table 5:

<table>
<thead>
<tr>
<th>DN (mm)</th>
<th>Min. size of manhole (cm x cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 - 200</td>
<td>80 x 80</td>
</tr>
<tr>
<td>250 - 500*</td>
<td>100 x 100</td>
</tr>
<tr>
<td>* With DN 450 and 500 the shaft cone has to be removed.</td>
<td></td>
</tr>
</tbody>
</table>

In case of misalignments the use of Compact Pipe is possible in principle. It has to be guaranteed, however, that the smallest cross-section of the host pipe is larger than the folded Compact Pipe or the pulling head. With the help of a calibre or a burster the critical parts can be extended.

The reduced cross-section as a result of close-fit lining is at least compensated due to absence of obstructions such as root penetrations or incrustations and of a much smoother inner pipe so that in most cases hydraulic behaviour and thus flow capacity even improve (see Fig. 51).

### 3.2.2. Product range

Compact Pipe is available in diameters ranging from 100 to 500 mm. Per diameter, different wall thicknesses/SDR classes are available to fulfil the various requirements in terms of e.g. coverage, groundwater table and internal pressure.

Compact Pipe is designed to be an independent liner capable of bearing any pressure by itself. Theoretically, the host pipe could be removed after renovation.

<table>
<thead>
<tr>
<th>DN*</th>
<th>Nominal wall thickness*</th>
<th>Renovation diameters (mm)</th>
<th>Maximum length m**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SDR 26</td>
<td>SDR 17.8</td>
<td>SDR 17</td>
</tr>
<tr>
<td>100</td>
<td>3.9</td>
<td>5.7</td>
<td>5.9</td>
</tr>
<tr>
<td>125</td>
<td>7.4</td>
<td>121-129</td>
<td>121-127</td>
</tr>
<tr>
<td>150</td>
<td>5.8</td>
<td>8.6</td>
<td>8.9</td>
</tr>
<tr>
<td>175</td>
<td>10.3</td>
<td>170-182</td>
<td>170-179</td>
</tr>
<tr>
<td>200</td>
<td>7.7</td>
<td>11.4</td>
<td>11.8</td>
</tr>
<tr>
<td>225</td>
<td>13.3</td>
<td>217-232</td>
<td>217-228</td>
</tr>
<tr>
<td>250</td>
<td>9.7</td>
<td>14.2</td>
<td>14.8</td>
</tr>
<tr>
<td>280</td>
<td>16.2</td>
<td>280-300</td>
<td>280-294</td>
</tr>
<tr>
<td>300</td>
<td>11.6</td>
<td>17.1</td>
<td>17.7</td>
</tr>
<tr>
<td>350</td>
<td>13.5</td>
<td>20.0</td>
<td>20.6</td>
</tr>
<tr>
<td>400</td>
<td>15.4</td>
<td>22.8</td>
<td>23.6</td>
</tr>
<tr>
<td>450</td>
<td>17.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>500</td>
<td>19.3</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Further DN/SDR/PE types on request.
** Depending on the SDR class. With larger wall thickness, maximum length is not quite achieved.

Compact Pipe is coiled on drums. The pipe length per drum depends on the nominal diameter of Compact Pipe.

Fig. 21: For renovation of sewers existing manholes can be used.

Fig. 22: Compact Pipe: From C-shape to close fit.
3.2.3. Technical data

Material
Compact Pipe is made of regular PE 80 or PE 100.

Chemical resistance
Compact Pipe is resistant to public waste water with a pH between 2 (acid) and 12 (alkaline). In case of industrial waste water, chemical resistance data published by Wavin shall be taken into account (download possible from www.wavin.de).

Colour
White (opaque): sewer and industrial applications
Yellow/Orange: gas applications
Blue: potable water applications

Structural capability
Compact Pipe provides an independent pipe system with the quality and the structural performance of a conventional PE pipeline built in open-cut installations.
For non-pressure pipes normally SDR 26 or SDR 32 pipes are used, depending on the required load-bearing capacity. If the load-bearing capacity needs to be very high (e.g. due to a very high groundwater table), SDR 17 pipes may be used.
For pressure pipes the choice of the material and the SDR class depend on the operational pressure, complying with the international ISO and CEN standards. For more detailed information, see chapter 5.3.

Marking
Compact Pipe from Wavin is marked as follows:
Producer, product name, application, material, nominal diameter, SDR class, approval, date of production, running meter, machine number, shift/material code.
Example: Wavin, Compact Pipe, Water, PE 100 (MRS 10), DN 300, SDR 17, DVGW AU 2109, 080403, 00103, 42, 067870.

Approvals
Compact Pipe holds several national approvals including the German DVGW approval for the rehabilitation of water and gas pipelines.

3.2.4. Equipment

The Compact Pipe system has the following main components:
drum trailer
winch
steam unit with integrated process control
condense separator
various standard tools, equipment and auxiliaries.

Compact Pipe is delivered on drums which can be held by drum trailers especially developed for Compact Pipe. From there the pipe is pulled directly into the manhole or pit. Using the drum trailer for handling at the installation site is recommended as well. Other equipment is allowed provided the pipe is not damaged.

Recommended is a winch with a pulling force of 10 tons and automatic pulling force limitation, which can pull the pipe at a maximum speed of 20 m/min into the host pipe. Using special insertion aids (guide tools) reduces pulling forces.

The steam unit – the “heart” of the installation system – provides steam and air for the reversion process. Main components are the steam generator and the water treatment unit that are installed in a mobile 20 feet container. During the reversion of Compact Pipe the inside and outside temperatures on both pipe ends as well as the pressure in the pipe are continuously measured, shown in the operator’s display and recorded for later analysis.

Steam and condense water are safely discharged via the condenser. This is particularly important when working in residential districts or busy roads to avoid inconveniences to people and guarantee traffic safety.

For Compact Pipe installation various tools, equipment and auxiliaries are required such as welding equipment, pipe expander and window cutter.
3.2.5. Installation process

Excavation work for lining with Compact Pipe is limited to small start and end pits. In case of sewers the existing manholes can be used. Therefore only little space is required at the building site with minimal traffic disruption.

Compact Pipe does not impose high requirements on the condition of the pipeline to be rehabilitated. Dirty pressure pipelines are cleaned with high pressure jet cleaning, with scratching and brushing tools or with a chain sling to get rid of incrustations and sediments. Weld beads can be removed using a cutter robot. Pipe wall fragments and sediments in sewers are removed by high pressure jet cleaning or towing cleaning disks through the pipe. Root penetrations or inlet protrusions can be taken away by a cutter robot. Then the C-shaped liner can be inserted in one continuous string directly into the pipeline to be rehabilitated. Large lengths up to 1,000 meters enable rapid installation.

This is how it works:
- a. Construction of start and end pits or preparation of manholes
- b. TV inspection and cleaning.
- c. Insertion of the pipe.
- d. Feeding the pipe with steam.
- e. The pipe “remembers” and regains its original circular cross section (memory effect).
- f. Expansion and cooling of the pipe (reversion) using compressed air.
- g. The pipe is pushed closely against the wall of the host pipe (close-fit) and fixed.
- h. Fixation of the pipe at the ends, by electrofusing a PE pipe segment onto the pipe.
- i. Reconnection to the existing pipeline.
- j. Reconnection of laterals.

Fig. 28: Existing manholes can be used for rehabilitating sewers.

Fig. 26: Compact Pipe installation process

Fig. 28a: Setting up Compact Pipe in Governor Road.

Fig. 28b: 375mm sewer rising main.

Fig. 28c: Connection pit in Governor Road.
Sewer pipelines: end connections
Between two Compact Pipe ends the flow profile in the manhole bottom can be adjusted.

Sewer pipelines: trenchless technique for lateral connections
The existing laterals can be reconnected to the main using either open-cut or trenchless techniques. When using the trenchless technique, a remote-controlled cutter opens the Compact Pipe at the spots where laterals are. A tight connection can be made using a hat-profiled fitting which is electro-fused to the inside of the Compact Pipe, protruding with a liner into the lateral.

Pressure pipelines: end connections
For connecting Compact Pipe to existing pipe sections, a regular PE pipe of the appropriate size and SDR class is used as transition piece. This PE transition pipe is connected with Compact Pipe by usual electro-fusion sockets. If the nominal diameter of Compact Pipe (e.g. DN 100) is smaller than the nominal diameter of the usual PE transition pipe (e.g. DN 110), the Compact Pipe has to be enlarged with an expander. Alternatively a purpose-made transition piece can be applied. If Compact Pipe is to be connected to a non-PE pipeline or with a strongly deviating outside diameter, a flanged connection is beneficial. This technique may also be applied when installing ancillary components such as valves.

Sewer pipelines: open-cut technique for lateral connections
When using the open-cut technique a PE connection element is welded with electrofusion on the Compact Pipe. The onward connection is made with a regular fitting.

Pressure pipelines: service lines
With pressure pipelines service connections are made via open-cut excavation. Prior to lining a section of the old pipe is cut out at the desired location of the service connection. If a service connection shall be established after lining, access to the pipeline is created with a window cutter. Electrofusion saddles are top-welded on the Compact Pipe and the service line is connected.
3.3. Compact SlimLiner
3.3.1. System description and applications

Compact SlimLiner is a cost-effective thin-wall PE pipe system for trenchless rehabilitation of pressure pipelines with a nominal diameter between 75 and 300 mm. It is the optimum solution where old pipelines are structurally sound but show minor damages (e.g. small holes, leaking sockets). Flow capacity is significantly increased due to minimum reduction of diameter and smoother bore. And what is even more important for water pipelines: the consumer gets healthy and clean drinking water.

A thin-wall PE pipe is folded during the manufacturing process into a C-shape and wrapped with protective film. Thanks to the reduced pipe diameter, the pipe can be inserted easily and quickly into the host pipe to be renovated. The film protects the pipe against abrasion during insertion. In a cold process, Compact SlimLiner is expanded using pressure until it is close-fit with the host pipe. No heating equipment is required.

Thanks to the well-proven material polyethylene and to the sophisticated close-fit technology, pipes rehabilitated with Compact SlimLiner have a lifetime of at least 100 years. Total installed costs are very low. Compact SlimLiner is installed without expensive specialised equipment. One working day is more than enough to completely rehabilitate one section including all connections.

3.3.2. Product range

Compact SlimLiner is produced in diameters from DN 75 to DN 300. Due to the small wall thickness (normally SDR 51), the pipe is an interactive liner which needs the host pipe for structural reasons. However, loads due to small corrosion holes or leaking sockets can be accommodated by the Compact SlimLiner itself.

Table 7: Product range Compact SlimLiner

<table>
<thead>
<tr>
<th>DN</th>
<th>Nominal wall thickness (mm)</th>
<th>Diameter range (mm)</th>
<th>Standard length per drum (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>2.8</td>
<td>69 – 76</td>
<td>1000</td>
</tr>
<tr>
<td>100</td>
<td>2.8</td>
<td>93 – 102</td>
<td>1000</td>
</tr>
<tr>
<td>150</td>
<td>3.1</td>
<td>142 – 157</td>
<td>600</td>
</tr>
<tr>
<td>200</td>
<td>4.1</td>
<td>191 – 210</td>
<td>600</td>
</tr>
<tr>
<td>250</td>
<td>5.1</td>
<td>241 – 260</td>
<td>400</td>
</tr>
<tr>
<td>300</td>
<td>6.2</td>
<td>279 – 307</td>
<td>400</td>
</tr>
</tbody>
</table>

Other diameters and/or wall thicknesses are available on request.

Fittings

Especially for rehabilitation, Wavin developed the Compact Endfitting. It is available in same sizes as Compact SlimLiner Pipes (see Table 6). The Compact Ferrule for service connections is available in two sizes: 3/4" and 1".

3.3.3. Technical data

Material
Compact SlimLiner is made of polyethylene.

Colour
Compact SlimLiner is of black colour. The protective film is blue and white.

Chemical resistance
If used for industrial applications, chemical resistance data published by Wavin shall be taken into account (download possible from www.wavin.de).

Marking
Compact SlimLiner pipes from Wavin are marked as follows: Producer, product name, application, material, nominal diameter, SDR class, date of production, length, machine number, shift/material code. Example: Wavin, Compact SlimLiner, water, PE 80 (MRS 8.0), DN 150, SDR 51, =100403=, 00103, =34=067856

Approvals
Compact SlimLiner holds several national approvals.
3.3.4. Equipment

Compared to Compact Pipe, Compact SlimLiner is a relatively simple lining system, not requiring complicated equipment. Apart from standard available equipment, such as a winch and a water pump, only a few specialised devices are required:

**Drum trailer**

Compact SlimLiner is delivered on drums which can be held by a dedicated drum trailer. From there the pipe is pulled directly into the pipeline.

**Water pump with reversion control**

With the water pump, pressure is supplied to the inserted pipe liner. A pressure control and a unit to register and store the pressures applied is part of this equipment.

**Tool kit for fitting assembly**

The Compact SlimLiner tool kit includes assembly tools for both end and service connections.

3.3.5. Installation process

Excavation work for lining with Compact SlimLiner is limited to small start and end pits. Therefore only little space is required at the building site and traffic is hardly disturbed. Compact SlimLiner does not impose high requirements on the condition of the pipeline to be rehabilitated. Dirty pipelines are cleaned with high pressure jet cleaning, with scratching and brushing tools or with a chain sling to get rid of incrustations and sediments. Weld beads can be removed using a cutter robot. Pipe wall fragments are removed by high pressure jet cleaning or towing cleaning disks through the pipe. Root penetrations or inlet protrusions can be taken away by a cutter robot.

Compact SlimLiner is inserted into the host pipe at a speed of 20 meters per minute. Depending on the condition of the pipeline, up to 600 meters is easily possible in a single insertion.

In the start and end pit, the Compact SlimLiner pipe is cut to length in such a way that the pipe end protruding outside the existing pipe can expand during the reversion process on a length as long as possible – and aligned to the old pipe. Then the expansion process of the pipe is commenced. The pipe is squeezed off in the start and in the end pit. To fill the Compact SlimLiner pipe, the filling inlet is positioned at the deepest point of the pipeline section. At the highest point the ventilation outlet is set in the same manner. The pressure recording unit is assembled to the pressure control which is set at the required pressure. The water hose is connected to the filling inlet and the pipe is pressurised during at least half an hour. The film around the pipe stretches but does not break. Then the pressure is let off by opening the ventilation outlet and the line is emptied (in the start pit).

Finally the squeeze-offs and the filling inlet and ventilation outlet are removed.

**Connections**

Because of the thin wall character of the lining, the connections on the end and to the sides are made in a mechanical manner with clamping connectors:

- Compact Endfitting for the ends of the lined section
- Compact Ferrule for the service lines

The Compact Endfitting consists of a PE body which on the one end is assembled inside the installed Compact SlimLiner and on the other end provides a SDR11 pipe end. Inside the Compact SlimLiner a mechanical joint is created by means of a steel cylindrical bush around the liner and on the inside of the fitting a steel conical bush. An incorporated rubber seal and a grip ring provide tightness and tensile strength. This pipe end of the coupler can be connected to standard PE pipes with regular electrofusion or butt fusion, or via a PE pipe with a flanged end, to the remains of the existing pipeline.

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**Fig. 35:** Only small start and end pits are needed to insert Compact SlimLiner.

**Fig. 36:** Compact SlimLiner is expanded in a cold process.

**Fig. 37:** Connecting Compact SlimLiner to the existing pipeline using the Compact Endfitting.
The Compact Ferrule consists of a brass body with a movable mushroom-type head which is pushed through the liner and then retrieved, thus clamping the pipe wall in a fixed position. At the top a saddle-like connection is provided in PE.

3.4. Neofit

3.4.1. System description and applications

Neofit is a lining method especially developed for lining potable water service pipelines of various materials such as lead, steel and copper, which still have enough structural capability to resist the inside pressure. It is of particular interest where lead service pipes are still common place.

The demand for such a system resulted from the World Health Organisation and the European Community requirements for water supply companies to comply with more stringent regulations on lead contamination of drinking water supply. According to the European Directive 98/83 the lead threshold in drinking water will be reduced from 50 to 10 microgram per litre.

The Neofit principle is very simple: A small flexible pipe made of PET material, provided with longitudinal ribs on the outside, is inserted and subsequently inflated up to 2.2 times the original size to form a closely fitting thin walled liner. An effective barrier between water supply and pipe material is thereby provided. Furthermore, the thin liner provides leak tightness in bridging socket gaps and holes in the wall, i.e. it is a true interactive liner.

The operation is very quick. From disconnection of water supply to end of treatment takes one hour. Complete housing estates can be renovated in a few weeks.

3.4.2. Product range

The Neofit pipes provided are available in 4 sizes. They are supplied on coils.

Table 8: Product range Neofit.

<table>
<thead>
<tr>
<th>Neofit diameter</th>
<th>Pipe length on a coil</th>
<th>Diameter of a coil</th>
<th>Weight of a coil</th>
<th>Range of internal diameters of existing service pipe</th>
<th>Minimum wall thickness of expanded pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>[mm]</td>
<td>[m]</td>
<td>[mm]</td>
<td>[kg]</td>
<td>[mm]</td>
<td>[mm]</td>
</tr>
<tr>
<td>7</td>
<td>200</td>
<td>550</td>
<td>2.9</td>
<td>12 - 16</td>
<td>0.15</td>
</tr>
<tr>
<td>10</td>
<td>200</td>
<td>600</td>
<td>7.1</td>
<td>17 - 22</td>
<td>0.20</td>
</tr>
<tr>
<td>15</td>
<td>100</td>
<td>950</td>
<td>7.4</td>
<td>23 - 33</td>
<td>0.30</td>
</tr>
<tr>
<td>20</td>
<td>100</td>
<td>1180</td>
<td>13.8</td>
<td>34 - 44</td>
<td>0.40</td>
</tr>
</tbody>
</table>

3.4.3. Technical data

Material

The liner pipes are made from PET: polyethylene terephthalate, a thermoplastic polyester, known from various packaging applications in the food industry.

PET provides the following benefits:
- flexibility during insertion
- stretch-ability for expansion
- strength for operational use

Colour

The colour of the pipe is natural opaque.

Chemical resistance

PET material, like many of its fellow polyesters, is resistant to many hazardous fluids. Chlorinating the pipes, as often applied in water networks (with NaClO), does not cause any problem. Care is needed when working in hot water applications.

Hygiene

From a toxicological point of view, Neofit is very suitable for contacts with potable water and food stuffs. The directives, which differ from country to country, are fulfilled by Neofit.

Structural capability

In general Neofit is applied as a liner depending on the existing pipe for its structural support. Consequently, in general, the PET pipe after expansion is to be considered as a liner which interacts with the existing pipe in this respect: an interactive pressure pipe liner.

An unsupported, expanded Neofit pipe with dimensions 12 mm x 0,2 mm, on its own (without support of the existing pipe) can resist an internal pressure of 8 bar for 50 years. The strength is comparable to that of a PVC or PE service pipe.
The existing pipe is needed however, to provide stiffness. The lining would collapse under external loading when not supported. The lining does have the capability to span gaps, e.g. because of pit corrosion. The capability of the expanded pipe to withstand internal pressures has been thoroughly analysed in simulated host pipes with holes, 2/3 x internal diameter of host pipe (e.g. a hole of 30 mm in a 45 ID pipe). The expanded linings then have to withstand pressures of at least 25 bar.

**Marking**

Neofit from Wavin is marked with a label on the coil as follows:

Producer, product name, application, diameter range, extrusion diameter, date of production, meter codification.

Example: Wavin SA, Neofit, W, (12-16), 7.0, 080203, 100.

**Approvals**

Neofit holds approvals from several national authorities such as the French LHRSP, Nancy, the Belgian Belgacqua and the Dutch KIWA for drinking water applications. For Australia, an application with WSAA has been made.

### 3.4.4. Installation process

The lining operation is as quick as simple. Neofit pipes are supplied in small coils so that working areas are minimised. Access is required at each end of the service pipe that is to be lined. After cleaning, the liner pipe is simply pulled out by hand until it is completely inserted.

A compact, custom-built automatic expansion unit is connected to the pipe, and a specific cycle of hot water and compressed air is passed along the length of the liner. This has the effect of expanding the liner pipe to provide a smooth continuous close-fit liner to the host pipe. Because of its high flexibility the pipe can easily be inserted through bends. The small longitudinal ribs on the outside of the pipe create a venting possibility for trapped air when expanding. The lining system can deal with lengths of up to 25 metres so that even long supply pipes can be treated.

**Connections**

Compression fittings are used at each end of the service pipe to make a mechanical connection to the outside of the existing pipe and to seal against the liner. An effective barrier between the water supply and the wall of the existing pipe is thereby provided. The system is not critical towards the type and make of compression fitting. Many commercially available and commonly applied fittings are compatible with Neofit.

### 3.5. Wavin TS

#### 3.5.1. System description and applications

Wavin TS is a co-extruded three-layer pipe with an inner and outer protection layers made of the extreme robust PE 100 material XSC 50, and a middle layer made of PE 100 (inner and outer layers make up 25 per cent of total wall thickness each). The three layers are integrated and cannot be separated mechanically. While the outer layer prevents damage from scratches whilst being pulled in, the inner layer prevents crazes or cracks on the inside from point loads caused by the fragmented old pipeline.

![Fig. 41: Wavin TS for pressure pipes transporting gas, potable water and waste water.](image)

Apart from other applications, it is therefore highly suitable for rehabilitation of gas, potable water and waste water pressure pipelines using the pipe bursting technology.

![Fig. 43: Wavin TS is highly suitable for pipe bursting.](image)
Pipe Bursting is particularly applied when the existing pipeline consists of breakable material and when the diameter cannot be reduced. With pipe bursting the existing pipeline can be replaced with a new PE pipe of the same size or even of a larger size. Contrary to traditional replacement with open cut trenching, here only two excavations need to be made at either end of the pipeline section to be replaced, for entry and exit of the pipe bursting machine. A torpedo-shaped, hammer action pipe breaker, is pulled and/or pushed through, meanwhile impacting on the existing pipeline. Typically, up to 100 metres of pipeline can be broken up at a time.

Since the material of the existing pipeline is broken and pushed outside, there is a potential risk of causing damage to other underground pipes and/or cables. For the assessment of danger of damage, accurate records of underground networks are required.

Although pipe bursting has been used for a variety of applications, including sewer replacement, it can generally be stated, that pipe bursting is limited to pressure pipelines DN 100 because of this reason, particularly in city centres. In some cases, however, larger diameters are possible.

For the bursting operation, two types of bursting units are offered to the market:
- pneumatically operating machines
- hydraulically operating machines

With both, breaker arms in the nose of the breaker, shatter not only the pipes, but are also capable of handling joints, sockets and junctions.

A variation of pipe bursting, often called pipe splitting, can be applied when pipelines have to be handled that do not fracture, e.g. steel or PVC pipelines.

### 3.5.2. Product range

Table 9: Product range Wavin TS

<table>
<thead>
<tr>
<th>OD mm</th>
<th>Wavin TS Waste Water SDR 17</th>
<th>Wavin TS Waste Water SDR 11</th>
<th>Wavin TS Potable Water SDR 17</th>
<th>Wavin TS Potable Water SDR 11</th>
<th>Wavin TS Gas SDR 17</th>
<th>Wavin TS Gas SDR 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>2.9</td>
<td>2.9</td>
<td>3.7</td>
<td>3.7</td>
<td>2.9</td>
<td>2.9</td>
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<tr>
<td>40</td>
<td>3.7</td>
<td>3.7</td>
<td>4.6</td>
<td>4.6</td>
<td>3.7</td>
<td>3.7</td>
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<tr>
<td>50</td>
<td>4.6</td>
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<td>5.8</td>
<td>5.8</td>
<td>4.6</td>
<td>4.6</td>
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<tr>
<td>63</td>
<td>5.8</td>
<td>5.8</td>
<td>6.8</td>
<td>6.8</td>
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<td>5.8</td>
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<tr>
<td>75</td>
<td>6.8</td>
<td>6.8</td>
<td>8.2</td>
<td>8.2</td>
<td>6.8</td>
<td>6.8</td>
</tr>
<tr>
<td>90</td>
<td>8.2</td>
<td>8.2</td>
<td>10.0</td>
<td>10.0</td>
<td>8.2</td>
<td>8.2</td>
</tr>
<tr>
<td>110</td>
<td>10.0</td>
<td>10.0</td>
<td>11.4</td>
<td>11.4</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>125</td>
<td>11.4</td>
<td>11.4</td>
<td>12.7</td>
<td>12.7</td>
<td>11.4</td>
<td>11.4</td>
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<tr>
<td>140</td>
<td>12.7</td>
<td>12.7</td>
<td>14.6</td>
<td>14.6</td>
<td>12.7</td>
<td>12.7</td>
</tr>
<tr>
<td>160</td>
<td>14.6</td>
<td>14.6</td>
<td>16.4</td>
<td>16.4</td>
<td>14.6</td>
<td>14.6</td>
</tr>
<tr>
<td>180</td>
<td>16.4</td>
<td>16.4</td>
<td>18.2</td>
<td>18.2</td>
<td>16.4</td>
<td>16.4</td>
</tr>
<tr>
<td>200</td>
<td>18.2</td>
<td>18.2</td>
<td>20.5</td>
<td>20.5</td>
<td>18.2</td>
<td>18.2</td>
</tr>
<tr>
<td>225</td>
<td>20.5</td>
<td>20.5</td>
<td>23.4</td>
<td>23.4</td>
<td>20.5</td>
<td>20.5</td>
</tr>
<tr>
<td>250</td>
<td>22.7</td>
<td>22.7</td>
<td>25.4</td>
<td>25.4</td>
<td>22.7</td>
<td>22.7</td>
</tr>
<tr>
<td>280</td>
<td>25.4</td>
<td>25.4</td>
<td>28.6</td>
<td>28.6</td>
<td>25.4</td>
<td>25.4</td>
</tr>
<tr>
<td>315</td>
<td>28.6</td>
<td>28.6</td>
<td>32.2</td>
<td>32.2</td>
<td>28.6</td>
<td>28.6</td>
</tr>
<tr>
<td>355</td>
<td>32.2</td>
<td>32.2</td>
<td>36.3</td>
<td>36.3</td>
<td>32.2</td>
<td>32.2</td>
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<tr>
<td>400</td>
<td>36.3</td>
<td>36.3</td>
<td>38.3</td>
<td>38.3</td>
<td>36.3</td>
<td>36.3</td>
</tr>
<tr>
<td>450</td>
<td>40.9</td>
<td>40.9</td>
<td>40.9</td>
<td>40.9</td>
<td>40.9</td>
<td>40.9</td>
</tr>
</tbody>
</table>

Wavin TS is delivered in 12 m lengths or in coils.
3.5.3. Technical data

**Material**
OD 90 to 450 mm: inner and outer protection layers made of XSC 50, middle layer made of PE 100.
OD 32 to 63 mm: solid-wall pipe made of XSC 50.

**Colour**
Protection layers royal blue (potable water), yellow (gas) or dark green (waste water), middle layer black (potable and waste water) or orange (gas).

**Connections**
Wavin TS has the same welding characteristics as PE 100 pipes. The pipes and fittings can be connected by butt fusion or electrofusion.

**Approvals**
Wavin TS holds approvals for potable water and gas applications from several national authorities such as DVGW or ÖVGW.

4. Quality assurance

4.1. European standards
The European Standards Organisation CEN develops standards for renovation of existing pipelines.
- Guidance on definitions, classifications and guidelines for design: EN 13689
- System standards for underground renovation with plastics pipes, dealing with the following applications are either available or in preparation:
  - for non-pressure sewerage networks: EN 13566;
  - for water supply networks: prEN 14409;
  - for gas supply networks: prEN 14408.
- Functional requirements on rehabilitation/renovation, are presented:
  - for non-pressure sewerage networks: EN 752-5, EN 12889 and EN 13380
  - for water supply networks: prEN 805;
  - for gas supply networks: prEN 12007-4.
For detailed references see chapter 7.

The national standards organisations of the following countries are bound to implement the European Standards to the status of national standards and conflicting existing national standards shall be withdrawn: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. It is very likely that other countries are to join soon.

One of the new concepts in the renovation standards is the differentiation in two pipe stages:
- the “M-stage”, the pipe in its manufactured state,
- the “I-stage”, the pipe in its installed state.
This differentiation had to be made since, depending on the renovation technique used, the plastics materials may be subject to a significant amount of site processing. This is relevant for lining with close-fit pipes.

It implies that the finished product characteristics (various geometric, mechanical and physical properties) in fact would need to be verified on the pipe in its “I”-stage, in addition to verification of relevant component characteristics in its “M”-stage.
This creates a problem because it is undesirable to take samples from a just installed liner pipe; it would mean serious destructive testing. Simulated installations, performed in a quality control laboratory, offer the way to demonstrate that the system is capable of conforming with the “I”-requirements.
In a simulated installation ‘as installed’ samples are produced under conditions incorporating all relevant circumstances which may affect the end-product characteristics. Examples of relevant conditions include installation parameters such as temperature and pressure.

4.2. Wavin specifications
Wavin supplies its products according to national and international standards. In the case of renovation, where site processing has significant influence on the quality of the end product, dedicated specifications, Wavinorms, describe in detail the characteristics and test requirements:
- Wavinorm 302: Compact Pipe for non-pressure applications
- Wavinorm 303: Compact Pipe for pressure applications; part W, water applications; part G, gas applications
- Wavinorm 304: Neofit for lining small diameter pipelines
- Wavinorm 310: Compact SlimLiner for pressure applications
These specifications prescribe amongst others:
- requirements for material compound (e.g. density, thermal stability, melt flow rate)
- geometric, mechanical and physical requirements of the pipes and fittings (e.g. dimensions, hydrostatic internal pressure, memory ability)
- frequencies of type testing and batch release testing

The Wavin systems regularly undergo comprehensive testing. Results are available on request. Examples of test equipment are shown in figures 44 to 47.

- Fig. 44: OIT test equipment for material testing.
- Fig. 45: Memory test of Compact Pipe (“M-stage” test).
- Fig. 46: Simulated installation of Compact Pipe in the laboratory.
- Fig. 47: Hydrostatic pressure testing (“I-stage” test).
5. System design aspects

Functional requirements and recommendations are given in EN 752-4, EN 805 and EN 12007-4 for drain and sewer applications, water supply applications and gas supply applications, respectively.

Reasons for rehabilitation may be:

- Need to separate the pipe wall from the fluid to prevent damage from the one to the other (e.g. internal corrosion, or water contamination)
- Need to stop leakage, either infiltration of ground water or exfiltration of transported fluid
- The pipeline is structurally not sound
- The pipeline is hydraulically not suitable anymore.

The choice of the adequate rehabilitation system will depend upon which performance parameters the pipe fails to meet and why the failures occur.

Consequently the following main design criteria can be distinguished:

1. Condition of existing pipeline
2. Installation aspects
3. Structural aspects
4. Hydraulic aspects

In general, each system of rehabilitation has its own limiting parameters of structural strength. The economics of each system need to be assessed as part of the design process.

5.2. Installation aspects

During insertion, caution shall be taken to avoid over-stressing of the liner pipe. The pulling force is limited by applying the following formula:

\[ F \leq \frac{n}{4} \cdot (du^2 - di^2) \cdot \sigma_t \]

where: 
- \( F \) = Maximum pulling force \([N]\)
- \( \sigma_t \) = Allowable pulling stress \([\text{MPa}]\)
- \( du \) = Nominal outside diameter liner \([\text{mm}]\)
- \( di \) = Nominal inside diameter liner \([\text{mm}]\)

The values for the allowable pulling stress are material dependent (see table 9).

Table 10: Allowable pulling stress depending on material.

<table>
<thead>
<tr>
<th>Material</th>
<th>Pulling stress [mPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE 80</td>
<td>8.0</td>
</tr>
<tr>
<td>PE 100</td>
<td>10.0</td>
</tr>
</tbody>
</table>

For a range of nominal diameters of PE pipes the allowable pulling forces are presented in table 10. The pulling head configuration may set lower limits.

Table 11: Allowable pulling forces depending on pipe material and geometrics, at 20 °C

<table>
<thead>
<tr>
<th>PE type</th>
<th>SDR</th>
<th>Pulling force (kN) per pipe diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE 80</td>
<td>32</td>
<td>8  17  31  48  69  94  122  154  191</td>
</tr>
<tr>
<td>17 8</td>
<td>26</td>
<td>9   21  37  59  84  114  148  186  232</td>
</tr>
<tr>
<td>11 21</td>
<td>14</td>
<td>12  30  54  84  122  151  205  262  331</td>
</tr>
<tr>
<td>PE 100</td>
<td>32</td>
<td>10  21  38  59  86  115  152  193  239</td>
</tr>
<tr>
<td>26 12</td>
<td>12</td>
<td>26  47  73  105  143  185  235  290</td>
</tr>
<tr>
<td>17 17 7</td>
<td>17</td>
<td>39  70  100  136  213  278  351  435</td>
</tr>
<tr>
<td>11 25</td>
<td>11</td>
<td>58  104  162  234  318  416  527  650</td>
</tr>
</tbody>
</table>

Depending on the technique applied, there may be other installation aspects to take into account. In such cases, the installer shall follow the instructions in the relevant installation documentation.

5.3. Structural aspects

5.3.1. General

The main design criterion for pipes used for rehabilitation of existing pipelines is the ability to withstand load, both internal and external, in operation. Compared to pipes buried directly with traditional open trenching, loads acting on a liner are different, because the lining pipe is installed without disturbing the equilibrium between existing pipe and its surround. Because of this, external soil and traffic loads generally are of considerably less significance and the designer should focus more on the effects of groundwater pressure in combination with any negative internal pressure (vacuum).
5.3.2. Non-pressure pipe applications

Plastic lining pipes used for rehabilitation of sewers and other non-pressure pipelines require independent ring stiffness to fulfil the structural function.

The Wavin systems for renovating non-pressure applications, Compact Pipe, Wavin TS and conventional PE pipe provide an independent new pipe system with the quality and the structural performance of a conventional PE pipeline built in an open-trench installation.

Detailed design shall follow the appropriate calculation methods as described, for example, in the German ATV A127 and M127 [19, 20]. In these, the different kinds of loading are dealt with in detail, e.g. earth and traffic loads, groundwater pressure, support from the host pipe (depending on the closeness of fit of the liner).

Application of these calculation methods leads to the following rules of thumb:

a) When the existing pipeline is surrounded with a stable, consolidated surround, where the depth of cover is less than 5 m, and where the ground water table is less than 4 m over the pipe, a durable, long term (> 50 years) solution is provided with PE 80 pipe SDR 26.

b) When the existing pipeline faces more serious damages, thicker liners are required: PE 80 pipe SDR 17. This pipe type generally withstands ground water pressure up to 10 m over the pipe.

5.3.3. Pressure pipe applications

As explained in clause 2.2.2. of this Technical Manual, from a structural point of view distinction is made between independent and interactive pressure pipe liners.

Independent pressure pipe liners, such as Compact Pipe, are capable on their own of resisting without failure all applicable internal loads throughout their design life, without relying on the existing pipeline for radial support. They also provide the ring stiffness and the capability to resist external loads.

Interactive pressure pipe liners, such as Compact SlimLiner and Neofit, are not capable on their own of resisting without failure all applicable internal loads throughout their design life, and therefore rely on the existing pipeline for radial support. Specifically, an interactive liner transfers all or part of the internal pressure stress by radial contact to the existing pipe wall, but retains a long-term capability to span any corrosion holes or joint gaps in the existing pipeline.

Internal pressure

For pressure pipes the choice of the material and the SDR class depend on the operational pressure, complying with the international standards EN 1555 and EN 14401.

Background for design is the relationship between internal pressure on the one hand and material and geometric characteristics of the pipe on the other:

Barlow’s formula

\[
P = \frac{20 \cdot \sigma}{(SDR-1)}
\]

with:

\[
\sigma = \frac{MRS}{c}
\]

where:

- \( P \) = operating pressure \([\text{MPa}]\)
- \( \sigma \) = tangential wall stress \([\text{MPa}]\)
- \( MRS \) = minimum required strength \([\text{MPa}]\)
- \( c \) = design coefficient

This can be worked up to the table 11:

Table 12: Maximum operating pressures in different applications

<table>
<thead>
<tr>
<th>Pipe characteristics</th>
<th>PE type</th>
<th>SDR</th>
<th>Max. operating pressure (bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water/Industrial Gas</td>
</tr>
<tr>
<td></td>
<td>PE 80 (MRS 8)</td>
<td>26</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17.6</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>PE 100 (MRS10)</td>
<td>26</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17</td>
<td>10</td>
</tr>
</tbody>
</table>

* minimum values in EN standards

In cases where the pipe material is exposed to temperatures other than 20 °C, the allowable pressures may have to be derated. In table 12 de-rating factors for higher temperature applications, as presented in EN 12201 for PE 80 and PE 100, are listed.

Table 13: Temperature influence on allowable pressure

<table>
<thead>
<tr>
<th>Temperature</th>
<th>De-rating factor*</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>1.00</td>
</tr>
<tr>
<td>30°C</td>
<td>0.87</td>
</tr>
<tr>
<td>40°C</td>
<td>0.74</td>
</tr>
</tbody>
</table>

* For other temperatures between each step interpolation is allowed.

Note: when temperatures are lower than 20°C, up-rating of the allowable pressures would be applicable, but this is usually not done, implying that then an even higher factor of safety on the allowable pressure is present.
Risk of buckling
The risk of buckling due to external loads, in particular ground water pressure, is extremely low with pressure pipe applications. The same as presented with non-pressure applications (see previous pages) applies here, but the pipes are in general at least of the SDR class 26 and have an even better fit than in non-pressure applications (higher amount of support of the host pipe). Very important here is the fact that a pressure pipe is under inside pressure for most of its life time, which gives an extra counter force against a possible buckling. Any risk of buckling due to internal negative pressures is extremely low as well, as is demonstrated in Chapter 5.4., where the issue ‘water hammer’ is dealt with.

Gap and hole spanning
As mentioned in the beginning of this chapter, interactive pressure pipeliners, such as Compact SlimLiner and Neofit, rely on the strength of the host pipe and pass on the internal pressures to this host pipe. The design on internal pressure with interactive liners is only relevant if substantial gaps (e.g. in open joints) or holes (e.g. corrosion pits) have to be bridged. Design graphs for gap and hole spanning have been set up from a series of experiments and FEM analyses, from which the allowable pressure can be derived as a function of SDR with gap spanning, and hole size/wall thickness with hole spanning, respectively. Note: in figures 48 and 49 possibilities with 24 bar pressure are shown.

The graphs in figures 48 and 49 are valid for all kinds of close-fit linings where the liner pipe is not extremely over-expanded. If over-expansion is the case, it is recommended for extra security to de-rate the pressure capability of the lining against bridging gaps or holes.

Table 14: De-rating factors for gap and hole spanning at over-expanded close-fit linings

<table>
<thead>
<tr>
<th>Expansion [%]</th>
<th>De-rating factor [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 3</td>
<td>1.0</td>
</tr>
<tr>
<td>3 – 10</td>
<td>2.0</td>
</tr>
</tbody>
</table>

**Notes:**
- In figures 48 and 49 possibilities with 24 bar pressure are shown.
- The graphs in figures 48 and 49 are valid for all kinds of close-fit linings where the liner pipe is not extremely over-expanded. If over-expansion is the case, it is recommended for extra security to de-rate the pressure capability of the lining against bridging gaps or holes.

**References:**
- Fig. 48: Long term (50 years) gap-spanning capability for PE 80 interactive liners.
- Fig. 49: Long term (50 years) hole-spanning capability for PE 80 interactive liners.

**Images:**
- Image: Relining truck from ‘us’ Utility Services.
5.4. Hydraulic aspects

If a pipeline is rehabilitated, of course leaks are sealed and tightness is restored. Apart from that it shall be ensured that adequate hydraulic capacity is provided.

Hydraulic capacity

To choose the most economic renovation technique it is necessary to determine the required hydraulic capacity.

The following formulae apply for calculating the flow in pipelines:

Continuity equation:

\[ Q = \frac{v \cdot \pi \cdot D_i^2}{4} \]  

where:  
- \( Q \) = flow capacity or discharge (m\(^3\)/s)  
- \( v \) = flow velocity (m/s)  
- \( D_i \) = internal pipe diameter (m)

Reynold's Number:

\[ Re = \frac{v \cdot D_i}{\mu} \]  

where:  
- \( m \) = kinematic viscosity of the fluid (m\(^2\)/s)

Darcy / Weisbach:

\[ i = \frac{\lambda}{2g} \cdot \frac{v^2}{D_i} \]  

where:  
- \( \lambda \) = friction coefficient (-)  
- \( g \) = gravitational constant (m/s\(^2\))

Colebrook / White:

\[ \frac{1}{\sqrt{\lambda}} = -2 \log \left[ \left( \frac{2.51}{Re \sqrt{\lambda}} \right) + \left( \frac{k}{3.71 \cdot D_i} \right) \right] \]  

where:  
- \( k \) = pipe wall roughness (m)

The material-dependent k-values are presented in table 14.

<table>
<thead>
<tr>
<th>Pipe condition</th>
<th>k [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>thermoplastics pipe</td>
<td>0.01</td>
</tr>
<tr>
<td>smooth asbestos-cement pipe</td>
<td>0.02</td>
</tr>
<tr>
<td>new steel pipe, new pre-stressed concrete pipe.</td>
<td>0.05</td>
</tr>
<tr>
<td>asbestos-cement pipe, new zinc coated steel pipe.</td>
<td>0.10</td>
</tr>
<tr>
<td>slightly corroded steel pipe, clay pipe</td>
<td>0.20</td>
</tr>
<tr>
<td>corroded steel pipe, cement coated pipe.</td>
<td>0.50</td>
</tr>
<tr>
<td>new iron pipe, smooth concrete pipe.</td>
<td></td>
</tr>
<tr>
<td>concrete pipe, considerably corroded steel pipe, iron pipes with small blares</td>
<td>1.00</td>
</tr>
<tr>
<td>heavily corroded steel pipe, deteriorated concrete pipe, heavily corroded iron pipe.</td>
<td>2.00</td>
</tr>
<tr>
<td>extremely corroded steel pipe, iron pipe with extreme blares</td>
<td>5.00</td>
</tr>
</tbody>
</table>

Any additional benefits of hydraulic smoothness and continuity of invert provided by the lining system should be taken into account with the design.

The change in flow capacity as a result of lining with a close-fit PE pipe (2% gap and \( k = 0.01 \) mm assumed) is presented in the following graph for different SDR values in relation to the roughness of the host pipe.

From this graph the following can be deducted:

- lining a heavily corroded cast-iron pipeline (\( k = 2 \) mm) with a thick-walled Compact Pipe SDR 17 gives a flow improvement of 10%
- lining a concrete sewer (\( k = 1 \) mm) with a Compact Pipe SDR 26 gives also a flow improvement of 10%
- lining a cement-coated pipeline (\( k = 0.5 \) mm) with a Compact SlimLiner SDR 51 gives a flow improvement of 14%
- for Compact SlimLiner (SDR 51) it is shown that the flow improves already when the roughness of the host pipe is only 0.25 mm.

It appears that in most cases the loss in internal diameter (2 x wall thickness + gap) is easily compensated by the smoother bore, and improvement in flow is most likely.

The values in fig. 50 apply for a pipe, excluding joints etc. Pipelines with joints will exhibit considerable higher k-values than shown above. When such pipelines are lined with a continuous plastic liner without joints, the difference between the old system k-value and the new system k-value becomes even more significant.
Water hammer
An effect that has to be considered in re-designing pressure pipelines is the possible occurrence of water hammer. This phenomenon arises when a valve is suddenly shut, causing a pressure wave to run through the pipeline, followed by a negative pressure.

The pressure wave itself runs at a very high speed depending on pipe material type: e.g. with PE pipes ~ 300 m/s and with steel ~ 1200 m/s.

The peak of the pressure wave depends on pipe material and pipe stiffness and can have a significant influence on design. Pressure peaks due to water hammer can be calculated as follows:

\[
\Delta p = \frac{1}{\sqrt{\left( \frac{\rho \cdot (s/K + Sp)}{\rho \cdot (s/K + Sp)} \right)}} \cdot \frac{\Delta v}{g}
\]

where:
- \(\Delta p\) = pressure peak (Mpa)
- \(\rho\) = density of water = 1000 (kg/m³)
- \(K\) = stiffness of water = 2000 (Mpa)
- \(Sp\) = pipe stiffness characteristic
- \(\Delta v\) = velocity drop to 0 (m/s)
- \(g\) = gravitational constant (m/s²)

pipe stiffness characteristic:

\[
Sp = \left(1 - \nu^2\right) / \left(\frac{Ep \cdot (D_i / e)}{\rho \cdot g}\right)
\]

where:
- \(\nu\) = Poisson's ratio (-)
- \(Ep\) = mod.of elasticity of pipe (Mpa)
- \(D_i\) = internal pipe diameter (mm)
- \(e\) = pipe wall thickness (mm)

Working out these formulae for different pipe types leads to the following graph:

Fig. 51: Pressure peak [mPa] due to Water Hammer.

This graph demonstrates that, closing a valve instantaneously leads to pressure peaks that may be substantial with relatively thin-walled steel pipes: \(p = 12\) bar. It shows on the other hand that with PE pipes the peaks are not high, e.g. with PE SDR 26 pipes: \(p = 2\) bar, and this only for fractions of seconds. The negative pressure that follows the pressure wave is to be set at –0.8 bar for all. Also here, the extremely short time prevents that the pipe suffers in any way.

Deformation
Particularly in case of renovating an existing sewer, which is cracked, sometimes questions are posed regarding the effect of deformation on the flow quantity discharged from the pipeline. This effect can also be analysed, but here even more complex calculations are required, with the internal perimeter to be calculated with a formula containing a so-called complete elliptic integral of the second kind. In doing this it can be learned that the effect is negligible: with 10% average deflection of the pipe, the reduction in flow capacity is only 2.36% (details available on request).

Filling degree
Improvement in flow capacity for gravity sewers means that the water depth or filling degree will change (will become lower) and hence the storage capacity will increase.

Self-cleansing
The gradient and the roughness of the pipe rule this ability. The k-value of a plastic liner is in any case better than that of a traditional pipe and hence the self-cleansing effect improves.

Abrasion
Abrasion depends obviously on the fluid/slurry transported, but also on the pipe material. Research has shown that plastic pipes, and in particular PE pipes, show remarkable good results in comparison with pipes of traditional materials. Table 15, containing average results from several tests, extracted from Janson's publication (ref. 29) shows the differences and the improved resistance to abrasion/wear that resulting from lining the existing pipeline with a PE pipe.

### Table 16: Abrasion

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific abrasion, (\mu m)</th>
<th>Abrasion, relative to PE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td>0.75</td>
<td>4.4 x</td>
</tr>
<tr>
<td>steel</td>
<td>1.72</td>
<td>10 x</td>
</tr>
<tr>
<td>cast-iron</td>
<td>2.09</td>
<td>12 x</td>
</tr>
<tr>
<td>clay</td>
<td>4.31</td>
<td>25 x</td>
</tr>
<tr>
<td>concrete</td>
<td>15.90</td>
<td>94 x</td>
</tr>
<tr>
<td>asbestos cement</td>
<td>17.28</td>
<td>102 x</td>
</tr>
</tbody>
</table>

Chemical resistance
PE pipes like Compact Pipe, Compact SlimLiner and Wavin TS are resistant to public waste water with a pH between 2 (acid) and 12 (alkaline). In case of industrial waste water the chemical resistance data given on www.wavin.de shall be consulted.
6. Case Histories

6.1. Compact Pipe

Sewer Rising Main in Melbourne, Australia
Total length: 325m, DN150 in Nellie Street.
Problem: Corrosion and past history of spills.
Solution: Compact Pipe PE80 SDR17
Highlights: Service ran at back of properties, under driveways and road.

Water pipeline in Melbourne, Australia
Total length: 400m, DN150 in Corrigan Road.
Problem: Corrosion and leaking connections.
Solution: Compact Pipe PE100 SDR17
Highlights: Fast completion (2 days) in high traffic area.

Fig. 52: Pressure Sewer in Melbourne, Australia.

Fig. 53: Water Pipeline in Melbourne, Australia.

Sewer Rising Main in Melbourne, Australia
Total length: 220m, DN300 in Beach Street.
Problem: History of bursts in different sections.
Solution: Compact Pipe PE80 SDR26
Highlights: Little inconvenience to residents, traffic and businesses.

Fig. 56: Pressure Sewer in Melbourne, Australia.

Fig. 57: Pressure Sewer in Melbourne, Australia.

Sewer Rising Main in Melbourne, Australia
Total length: 200m, DN375 in Governor Road.
Problem: Corrosion and spill into nearby waterway.
Solution: Compact Pipe PE80 SDR26
Highlights: No access into backyards required. Little inconvenience to residents, traffic and businesses.

Fig. 54: Pressure Sewer in Melbourne, Australia.

Fig. 55: Water Pipeline in Melbourne, Australia.
**Sewer Rising Main in Melbourne, Australia.**
*Total length:* 550m, DN 300 in Wise Avenue.
*Problem:* Corrosion and history of bursts in different sections.
*Solution:* Compact Pipe PE 80 SDR 26.
*Highlights:* Sewer runs under freeway, next to properties and public space. Works completed within one week.

![Fig. 58: Compact Pipe under freeway](image)

**Gas pipeline in Padua, Italy**
*Total length:* 8.4 km, DN 200, 300 and 400.
*Problem:* Leaks in the steel and cast-iron pipes. Pipeline situated in historical centre.
*Solution:* Compact Pipe PE 80 SDR 26.
*Highlights:* Successful close-fit lining of a pipeline with very small bends in very narrow circumstances.

![Fig. 59: Compact Pipe in Padua, Italy.](image)

**Industrial pipeline in Budapest, Hungary**
*Total length:* 29.2 km, DN 150, 200, 250, 400.
*Problem:* Corrosion of the fire fighting pipeline of the oil refinery plant. For safety reasons, the pipeline had to be renovated very quickly.
*Solution:* Compact Pipe PE 100 SDR 17.
*Highlights:* Several 90° bends in DN 400.

![Fig. 60: Compact Pipe in Budapest, Hungary.](image)

**Water pipeline in Bærum, Norway**
*Total length:* 5.2 km, DN 150 and 200.
*Problem:* Corrosion of the major water supply line of this suburban village of Oslo.
*Solution:* Compact Pipe PE 100 SDR 17.
*Highlights:* Cold weather conditions during installation with ambient temperatures down to –15°C.

![Fig. 61: Compact Pipe in Bærum, Norway.](image)

**Sewer gravity line in Heerlen, The Netherlands**
*Total length:* 500 m, DN 600/400 and 450/300 egg profile.
*Problem:* Damaged sewer in busy shopping centre.
*Solution:* Compact Pipe PE 80, DN 350 and DN 500; SDR 32.
*Highlights:* First rehabilitation of larger sized egg shaped sewers with PE close-fit pipes.

![Fig. 62: Compact Pipe in Heerlen, The Netherlands.](image)

**Gas pipelines in Madrid, Spain**
*Total length:* 9 km, with sizes ranging from DN 150 to DN 400.
*Problem:* Corrosion, and/or wish to upgrade low to medium pressure lines.
*Solution:* Compact Pipe, PE 80 SDR 26 or PE 100 SDR 17.
*Highlights:* Minimum excavations, long radius bends up to 180° per section, narrow site conditions.

![Fig. 63: Compact Pipe in Madrid, Spain](image)
Gas pipelines in Abu Dhabi, United Arab Emirates
Total length: 600 m, with sizes DN 150, 250 and 400.
Problem: salt ground water infiltration in sewer and irrigation pipeline.
Solution: Compact Pipe, PE 80 SDR 17 or PE 100 SDR 17.
Highlights: extreme high depths of cover, with substantial amount of infiltration.

Fig. 64: Compact Pipe in Abu Dhabi, UAE.

Image: Compact Pipe in Nellie St, Lang Lang, Australia. 150mm sewer rising main.

Sewer in Wildemann, Germany
Problem: untight clay ware sewer DN 200 located 1.5 m deep in a river, causing extreme infiltration: 5 x the normal amount of 'water' had to be led to the purification plant.
Solution: Compact Pipe DN 200, PE 80, SDR 26.
Highlights: During reversion of the Compact Pipe the level of water in the shafts rose to 1.2 m over the crown of the pipe. Even although this water was only 5°C, the Compact Pipe reverted perfectly, sealing the line completely and thus preventing further infiltration.

Fig. 66: Compact Pipe in Wildemann, Germany.

Images: Wise Avenue Rehabilitation, Australia

Water pipeline in Bayonne, France
Total length: 600 m, DN 250.
Problem: Corrosion and leaking connections of a twin cast-iron pipeline for potable water transport in a historical bridge.
Solution: Compact Pipe PE 100 SDR 17.
Highlights: only 3 small pits were required for the whole lining process. Traffic on the bridge was not hindered.

Fig. 65: Compact Pipe in Bayonne, France.
6.2. Neofit

Water service lines in Melun, France
*Problem:* lead contamination of 3/4” potable water from the lead service pipes.
*Solution:* Neofit DN 10.
*Highlights:* very quick installation, at a very low price.

Water service lines in Melbourne, Australia
*Problem:* leaking copper service pipe 20 m and because of corrosion discoulourisation of potable water.
*Solution:* Neofit DN 10.
*Highlights:* minimum excavations, lining through existing fittings that could be reconnected; extreme low-cost, back in service within 1 hour.

Water service lines in Regional Victoria, Australia
*Problem:* leaking or damaged pipes in difficult areas to access, i.e. retaining wall.
*Solution:* Neofit DN 10 + 15.
*Highlights:* reline existing pipes through joints and connections.

Water service lines in Sydney, Australia
*Problem:* leaking bitumen lined galvanised pipes
*Solution:* Neofit DN 10 + 15.
*Highlights:* no drilling through rocks. Reline existing service in less than 2 hours.

Water service lines in Vienna, Austria
*Problem:* lead contamination from 1” lead services.
*Solution:* Neofit DN 15.
*Highlights:* working in busy city centre without obstructing social life.

6.3. Compact SlimLiner

Water pipeline in Esztergom, Hungary
*Problem:* corrosion.
*Solution:* Compact SlimLiner DN 100, PE 80, SDR 36.
*Highlights:* steep road gradients, small access pits.

Water pipeline in Opoloniza, Poland
*Problem:* leaking asbestos-cement pipeline.
*Solution:* Compact SlimLiner, DN 150, PE 80, SDR 51.
*Highlights:* minimum excavations, narrow site conditions.

Water pipeline in Kassel, Germany
*Problem:* corrosion and leakages in cast-iron pipeline.
*Solution:* Compact SlimLiner, DN 250, PE 80, SDR 51.
*Highlights:* pipeline located under 4-lane motorway.

Fig. 64: Neofit in Melun, France.

Fig. 64b: ‘us’ in Sydney.

Fig. 62: Compact SlimLiner in Esztergom, Hungary.

Fig. 62: Compact SlimLiner in Opoloniza, Poland.

Fig. 63: Compact SlimLiner in Kassel, Germany.

Fig. 65: Expanded Neofit liner.
7. References

7.1. Standards, requirements and regulations

1) EN 752-5, Drain and sewer systems outside buildings – Part 5: Rehabilitation.
2) EN 805, Water supply – requirements for systems and components outside buildings.
3) EN 1295-1, Structural design of buried pipelines under various conditions of loading – Part 1: General requirements.
4) prEN 1295-2, Structural design of buried pipelines under various conditions of loading – Part 2: Details about established methods.
5) EN 1555-2, Plastics piping systems for gas supply – Polyethylene (PE) – Part 2: Pipes.
6) EN 12007-4, Gas supply systems - Pipelines for maximum operating pressure up to and including 16 bar - Part 4: Specific functional recommendations for renovation.
7) EN 12889, Trenchless construction and testing of drains and sewers.
8) EN 13380, General requirements for components used for renovation and repair of drain and sewer systems outside buildings.
9) EN 13689, Guidance on the classification and design of plastics piping systems used for renovation.
10) EN 13566-1, Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks – Part 1: General.
11) prEN 13566-2, Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks – Part 2: Lining with continuous pipes.
12) EN 13566-3, Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks – Part 3: Lining with close-fit pipes.
13) EN 13566-4, Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks – Part 4: Lining with cured-in-place pipes.
14) prEN 14409-1, Plastics piping systems for renovation of underground water supply networks – Part 1: General.
15) prEN 14409-3, Plastics piping systems for renovation of underground water supply networks – Part 3: Lining with close-fit pipes.
16) prEN 14408-1, Plastics piping systems for renovation of underground gas supply networks – Part 1: General.
17) prEN 14408-3, Plastics piping systems for renovation of underground gas supply networks – Part 3: Lining with close-fit pipes.
18) ISO/TR 11295, Techniques for rehabilitation of pipeline systems by the use of plastics pipes and fittings.
19) ATV-A127, Statische Berechnung von Abwasserkanälen

7.2. Wavin system specifications

21) Wavinorm 302; Compact Pipe for non-pressure applications.
22) Wavinorm 303; Compact Pipe for pressure applications; part W, water applications; part G, gas applications.
23) Wavinorm 304; Neofit for lining small diameter pipelines.
24) Wavinorm 310; Compact SlimLiner for pressure applications.

7.3. Other publications

Effective piping solutions.

For buildings, utilities and civils.

**BUILDING**

**Hot & Cold Water Systems**  
Wavin Future K1 · Wavin Future K2

**Soil & Waste Systems**  
Wavin AS

**Above-ground Pressure Systems**  
Wavin HT-PE

**Rainwater Management**  
ELWA

**UTILITIES AND CIVILS**

**Inspection Chambers and Manholes**  
Wavin SP 425 · Wavin SX 400  
Wavin Tegra 1000 · Wavin Tegra 600

**Sewer Systems**  
Ultra Hochlastrohr · Ultra Rib 1 · Ultra Rib 2  
Wavin KG · Wavin KG SN8 · KG 2000

**Below-ground Pressure Systems**  
Wavin TS · Wavin PE 100 · Wavin PE 80  
Wavin PE-Fittings · Wavin PVC Pressure Pipe System

**Pipe Rehabilitation Systems**  
Compact Pipe · Compact SlimLiner · Neofit · Wavin TS

**Cable Ducting Systems**  
Wavin KS-R · Wavin MR4 · Wavin KS

**Rainwater Management**  
ELWA