TECHNICAL MEMORANDUM

TO: Justin Gove, P.E.
Engineering Division Manager
Water Resource Protection
City of South Portland, Maine

PREPARED BY: Jennifer Glynn, P.E.

REVIEWED BY: Megan McDevitt, P.E. and Jason Kreil, P.E.

DATE: June 28, 2023

RE: Willard Beach Emergency Force Main Project
Trenchless Rehabilitation/Replacement Alternatives

The purpose of this Technical Memorandum (TM) is to provide an evaluation of trenchless rehabilitation/replacement options for the Willard Beach Force Main and provide a recommendation for how to most cost effectively and quickly repair or replace the pipeline. This TM does not address open cut replacement of the pipeline or rerouting of the pipeline into a public right-of-way. Those options will be evaluated by others and are outside the scope of this document.

1. BACKGROUND

The City of South Portland's Willard Beach Force Main is a 12-inch diameter ductile iron pipe located along Willard Beach within established sand dunes that provide erosion protection to the beach adjacent to several homes located along the shoreline. The force main is approximately 1,600 feet long and starts at a pump station located on Fisherman's Lane, travels through the sand dunes along the edge of the beach to Myrtle Avenue, and then travels up Myrtle Avenue where it terminates at a structure located at the intersection of Myrtle Avenue and Fort Road. See **Figure 1**.

There have been three leaks on the force main within the last three years, with the last leak occurring on June 1, 2023. One leak was located close to the pump station and the other two leaks were in the sand dunes just south of Myrtle Avenue. Because of the break history associated with this force main, this project has been declared an emergency and time is of the essence to identify and initiate a rehabilitation or replacement solution. The City would like to initiate a project this summer.

Figure 1: Project Overview Map

2. DESIGN REQUIREMENTS

The trenchless solution for rehabilitation or replacement of the Willard Beach Force Main must be able to accommodate the following design requirements:

- If the force main is rehabilitated, the solution must be fully structural and resilient to tidal influences.
- Rehabilitation solution must be able to accommodate a total of five horizontal bends in the alignment: two 45-degree bends, two 22 ½ degree bends, and one 11 ¼ degree bend.
- Solution should accommodate a maximum operating pressure of 65 psi and a test pressure of 100 psi.

- Solution must handle typical dry weather flows of 150-300 GPM and a Peak Wet Weather Flow of 4500 GPM.
- Desired Force Main Velocity = 3 fps. Minimum velocity = 2 fps. Maximum velocity = 10 fps
- Solution must limit impacts to the established sand dunes along the western edge of the beach (where the existing force main is currently located).
- Solution should minimize environmental impacts and permit acquisition.
- Solution should have a pool of qualified contractors available to complete the work.
- Solution should be implementable in the summer of 2023.
- Construction duration associated with the solution should be minimal.

3. TRENCHLESS OPTIONS

3.1 Horizontal Directional Drilling

One option for this project is to replace the existing force main with a new force main in a new alignment adjacent to the existing alignment using Horizontal Directional Drilling (HDD). HDD is a trenchless pipeline installation method that is conducted in two stages. The first stage consists of directional drilling a small diameter pilot hole with pressurized drilling fluid along the designed drill alignment. The second stage involves enlarging the pilot hole through successive passes with a reaming assembly. During the pilot drilling and reaming operations, the hole is "held open" or stabilized with high density drilling fluid typically consisting of bentonite, water, and polymers in various proportions. Once the hole is reamed to the final size (typically 12 inches larger than the product pipe's outer diameter), the fully assembled product pipe is pulled into the bore hole in one continuous operation. The process is referred to as the pull-back operation, and the pipeline is installed along a gradual circular arc.

The force main would likely be directly installed using HDD as opposed to a casing being installed and the force main pulled through the casing. Pipe installed via HDD must be able to withstand substantial pulling forces, as well as have an allowable bend radius that allows it to be installed and pulled into the subsurface in an arc formation. The most common types of pipes installed via HDD are steel and HDPE. Fusible PVC is also a possibility, although it has a smaller bend radius than steel or HDPE. Pull-back operations require assembly of a section of pipeline on the surface equal to the length of the HDD installation prior to pulling the pipe into the subsurface. When assembling the pipe string, special steps are required to ensure that the pipe is not stressed beyond its allowable bend radius prior to insertion into the subsurface. This pipe assembly and string layout must be at least equal to the length of the drill and can take up a substantial amount of space on the surface along the pipe alignment. In addition, a work/staging area of approximately 20,000 square feet must be available at the launch site location for the HDD drill rig and appurtenant equipment necessary for pipe installation.

HDD is applicable in a wide range of soils and is appropriate for use in areas of high groundwater. However, HDD is considered very challenging in sands like those that will likely be encountered in the dunes along Willard Beach. In sand, the contractor is dealing with a very porous substrate. As such, drilling fluid loss is a major concern when drilling within sands. If the Contractor does not have experience with mixing drilling fluid so that it has enough viscosity and strength to seal the drilled bore path, fluid loss can weaken the sand formation and cause collapse of the tunnel. In addition, pumping high pressure drilling fluid into sandy formations can wash out the bore, either creating void areas above the new pipeline which will likely later collapse or migrating to the surface as a frac out. Frac out during an HDD is considered a reportable incident as it can have environmental implications. While the drilling fluid itself is not toxic, fine particles in the mix can smother plants and animals. In addition, pools of slurry will not be viewed favorably by the adjacent property owners.

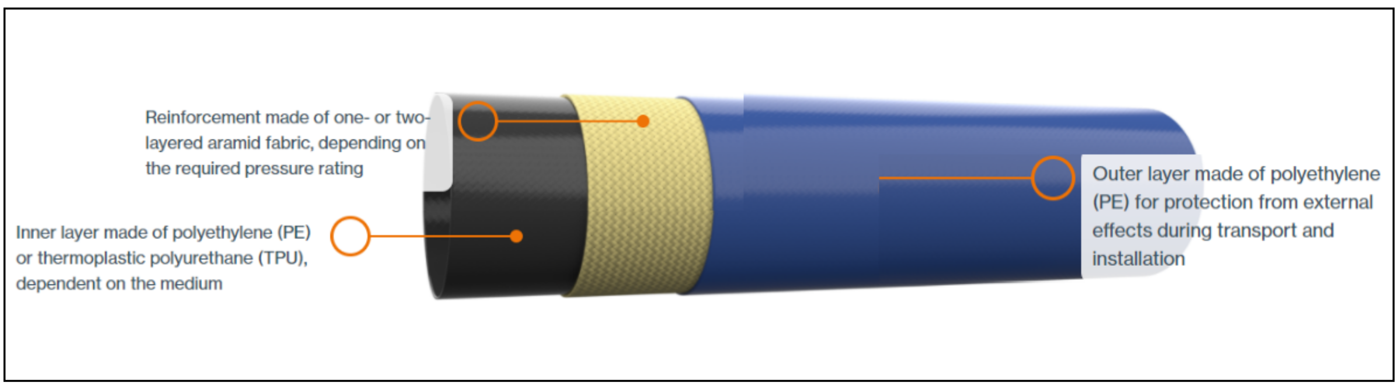
Because HDD in sands is very difficult, the City would be well served to find a contractor who has extensive experience in HDD installation through sands. Because of the limited pool of local contractors with the required experience, the size of required work area and the construction equipment's likely impacts on the sand dunes, and the risk associated with drilling in sands, we do not recommend the use of HDD for installation of a new force main on the Willard Beach project.

3.2 Primus Liner

Instead of replacing the existing force main, the City could potentially rehabilitate the existing pipeline with Flexible Fabric-Reinforced Pipe (FFRP) liner manufactured by Primus Line (Primus). Primus is a trenchless technology for the rehabilitation of pressure pipelines in the water and gas industry and is composed of a flexible high-pressure liner with specially developed pressure connections.

Primus liner is comprised of three layers; a polyethylene (PE) inner layer, a single aramid intermediate layer and PE outer layer. A cross section of the liner is presented in **Figure** .

Figure 2: Primus Liner Section



Source: primusline.com

3.2.1 Hydraulics

Depending on the specific liner product chosen, Primus liner is capable of working pressures of up to 1000 psi. Because the liner is essentially a reinforced flexible hose, it can also successfully be pulled through bends up to 90 degrees. To meet pressure requirements for this project, the manufacturer has recommended their 12" diameter low pressure liner which has the following pressure capabilities at 45-degree bends (where the liner's pressure rating would be most impacted):

12" low pressure liner at 80°F:

- Liner DN 300/12" ND water in bend 45-degree, pipe DN 300/12" radius 1,5xD MOP = 88.73 psi
- Liner DN 300/12" ND water in bend 45-degree, pipe DN 300/12" radius 1,5xD TP = 110.81 psi

A hydraulic analysis of the selected low pressure Primus rehabilitation liner is provided in **Table 1**. See Appendix A for additional product information provided by the manufacturer.

Table 1. Hydraulic Analysis

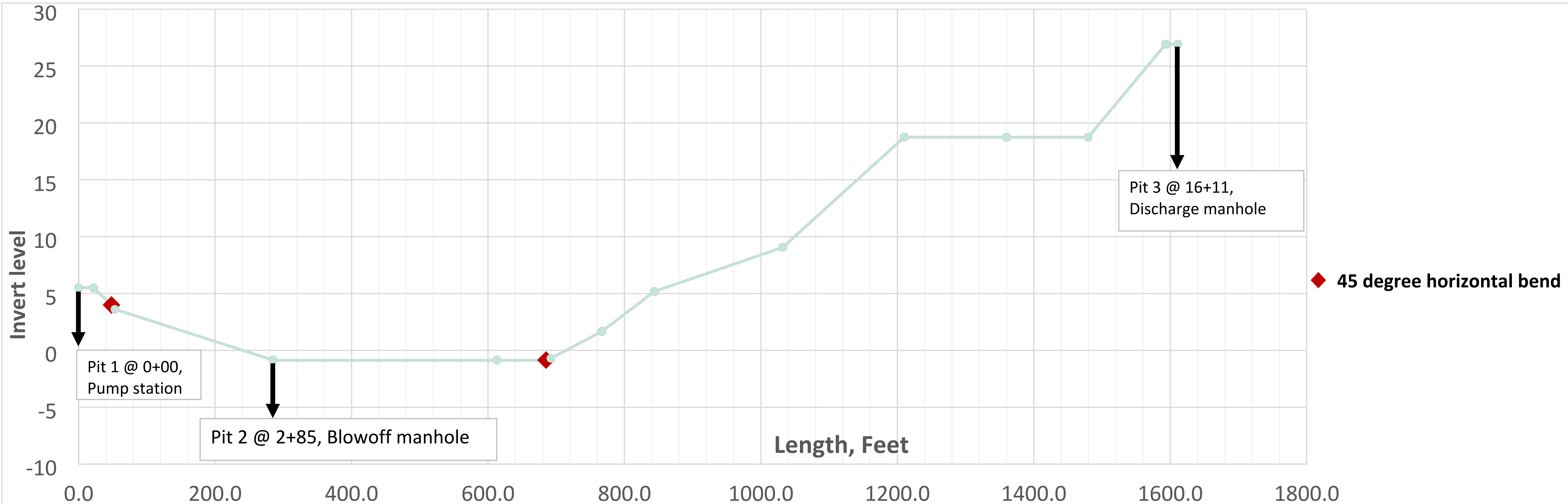
			Pre rehabilitation 12" DI pipe	Post rehabilitation DN300/12"-ND-W
Hazen-Williams factor	**C**		110	150
Flow rate	**Q**	GPM	4500	4500
Pipe length	*L*	ft	1611	1611
Pipe diameter	*D*	in	12.46	10.71
Pipe length	*L*	m	491.033	491.033
Pipe diameter	*D*	m	0.316	0.272
Flow rate calculation				
Flow velocity	*v*	m/s	3.609	4.885
Flow Velocity	*v*	ft/s	11.839	16.024
Flow rate	**Q**	m^3/s	0.284	0.284
Flow rate	**Q**	m^3/h	1022.061	1022.061
Flow rate	**Q**	m^3/d	24529.468	24529.468
Head loss	**ΔPLINER**	**m**	22.876	26.918
		bar	2.288	2.692
		ft	75.053	88.314
		psi	33.179	39.041
Local pressures losses	**ΔP_{Local}**	**Pa**	2340.195	49397.229
		bar	0.023	0.494
		psi	0.339	7.164
		ft	0.784	16.550
Total Pressure loss Main + Local losses		**psi**	33.518	46.206

The pressure drop associated with the friction inside the liner pumping the anticipated peak wet weather flow of 4,500 GPM will be around 46.2 psi, 13 psi higher than what was calculated for the DI 12" pre rehabilitation pipe. For an average dry weather flow rate of 300 GPM, the pressure drop is negligible (0.29 psi) for the liner. In addition, pumping a peak wet weather flow of 4,500 GPM inside the lined force main will result in a flow velocity of 16.02 ft/sec, higher than the maximum recommended velocity. However, the existing system was already pumping at velocities of up to almost 12 ft/sec and high velocities will not harm the liner in any way. Therefore, if these temporary seasonal higher velocities can be accommodated in other parts of the City's system (i.e., pumps, thrust blocks, etc.) then peak wet weather velocities in the system should not be a limiting factor in installing the liner.

3.2.2 Construction Footprint

Primus liner is capable of being installed in lengths of up to 7,500 feet. However, the presence of a blow-off manhole located at Station 2+84 will add some complications to the lining procedure. See **Figure 3**.

Figure 3. Willard Beach Force Main Profile



The project's total length is approximately 1,600 feet and can be completed by excavating three pits:

- Pit 1, Station 0+00, outside of pump station
- Pit 2, Station 2+84, blow-off manhole
- Pit 3, Station 16+11, at discharge manhole

The force main can either be lined from the pump station (Pit 1, Station 0+00) in one pull to the discharge manhole (Pit 3, Station 16+11) or from the blow-off manhole (Pit 2, Station 2+84) in two pulls towards the pump station (Pit 1) and then the discharge manhole (Pit 3). With either option, the contractor will require an access pit at the blow off manhole location to remove and reconnect the blow off to the lined system.

Following the guidance of the example design document provided in Appendix A, the dimension of the pits for both options as described above are as follows:

- **One pull**
  - Pit 1 and Pit 3: 9.68' x 4.94'
  - Pit 2: 15' x 4.94'
- **Two pulls**
  - Pit 1 and Pit 3: 9.68' x 4.94'
  - Pit 2: 10.5' x 4.94'

The depth of the pits will need to be at least 1.5 feet below the invert of the force main.

If the City chooses to install the line in a single pull from Pit 1 to Pit 3, then Pit 2 will need to be larger than Pits 1 and 3 to accommodate demolition of the blow off manhole and installation of a new blowoff on the newly installed liner. If the liner is installed in two pulls, it may not be necessary to demolish the blow-off manhole as the contractor may be able to use the existing manhole to feed the liner and, if its dimensions are adequate, to install the liner connectors at this location. This will have to be confirmed with direct measurements of the existing manhole.

A staging area for cleaning equipment, winches, and the liner will also be required for this project. If there is room, the staging area could be located next to the pump station. Lining equipment would likely be positioned at the access pit where the liner spool would be set up and fed into the existing pipe. This would be either at Pit 1 or Pit 2 depending on whether one or two pulls will be completed. A smaller installation winch would be set up at the installation access pit and a larger winch is needed at the receiving pit. The smaller winch is needed as a contingency in case the CCTV vehicle cannot make it to the receiving pit. It is also needed to move the scraper and pull-through pigs through the pipe. A YouTube video of a typical Primus rehabilitation installation can be found at https://www.youtube.com/watch?v=I68YTQ4AZHY. The installation winch could be positioned off the beach near the pump station.

3.2.3 Installation Pull Forces

To do the job in one pull, the contractor would likely require a 10" pulling head for the low-pressure liner. For two pulls, the contractor would likely use a steel rope. See **Table 2**.

Table 2. Liner Pull Force

Liner Pull	Start pit	End pit	Length [ft]	Comments	Pulling force [ton]	Pulling Force [lbs.]	Puling device
1	Pit 1, Pump Station (0+00)	Pit 3, Discharge manhole (16+11)	1,611.00	2x11.25° hor bends 3x22.5° hor bends 2x45° hor bends	3.16	6,962.61	Pulling head
		Total	1,611.00				

Liner Pull	Start pit	End pit	Length [ft]	Comments	Pulling force [ton]	Pulling Force [lbs.]	Puling device
1	Pit 2 Blowoff manhole (2+85)	Pit 1, Pump station (0+00)	285.00	1x22.5° hor bend 1x45° hor bend	1.09	2,399.70	Steel rope
2	Pit 2 Blowoff manhole (2+85)	Pit 3, Discharge manhole (16+11)	1,326.00	2x11.25° hor bends 2x22.5° hor bends 1x45° hor bends	2.33	5,136.12	Steel rope
		Total	1,611.00				

3.2.4 Other Design Considerations

Primus liner is a flexible pipe liner, therefore, to prevent the liner from contracting, the pipe will need to remain full, even while it is conveying lows flows or is not in operation. To ensure that the pipe always remains full:

1. A check valve (or non-return valve) will have to be installed downstream of the pumps at the pump station (if it does not already exist), and
2. Measures will have to be taken at the location where the force main directly discharges into the manhole at the transition to gravity. In order to avoid having a free outlet and keep the force main full of water, the City should plan to include one of the three following modifications to their system.
    a. Install a camelback after the final connector and before the manhole (**Figure 4**)
    b. Elevate the connection point of the pipe to the manhole (**Figure 5**)
    c. Install an elbow inside the manhole after the final connector (**Figure 6**)

Figure 4: Camelback Installed Before the Discharge Manhole

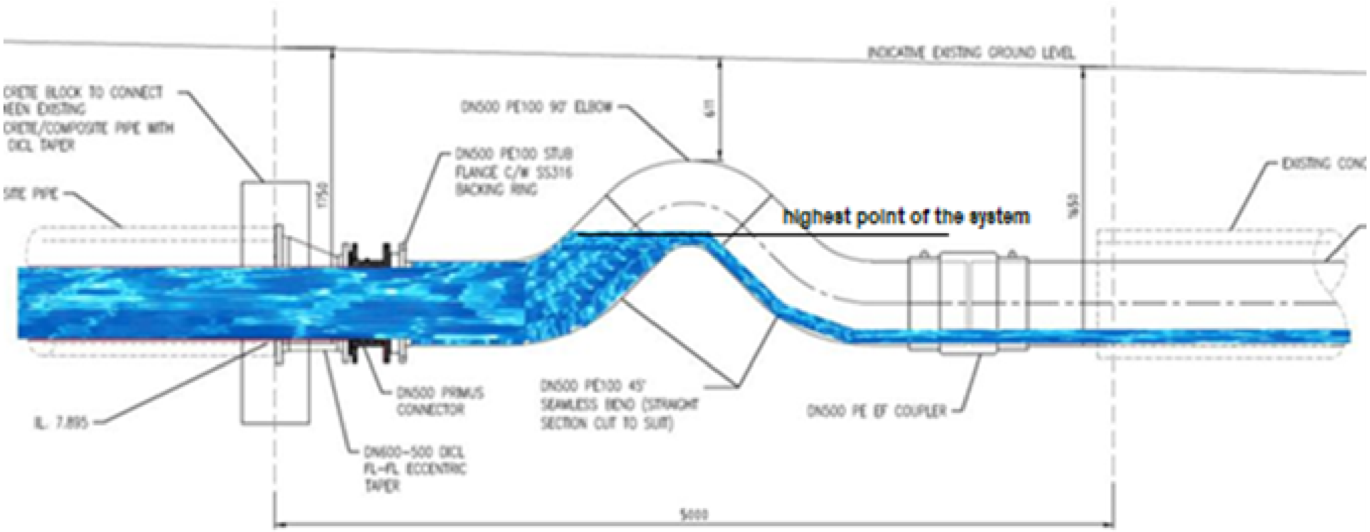


Figure 5: Modification to the Connection Point at the Manhole

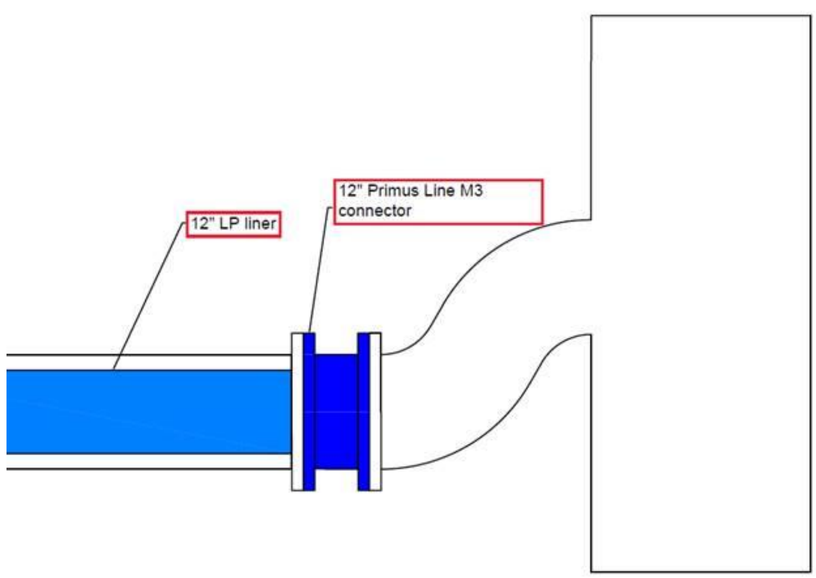
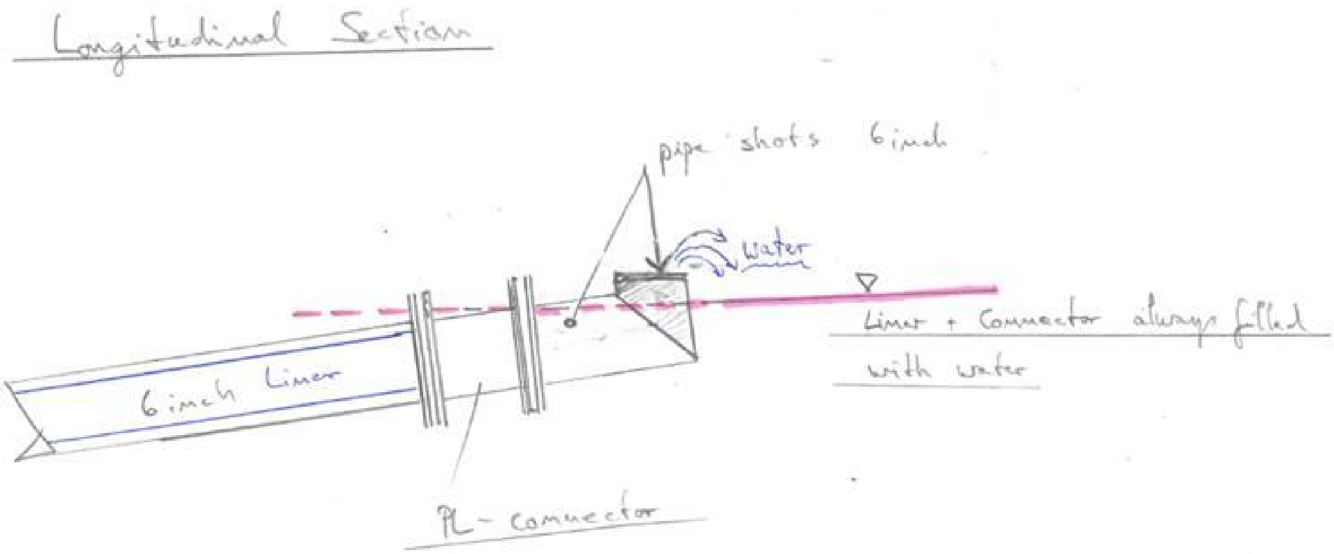


Figure 6: Extra Piece of Pipe With a Bend Inside the Manhole Located After the Connector



3.2.5 Permitting

When comparing lining options to open cut replacement of the force main, impacts to the existing sand dunes and associated permits required for construction will be greatly minimized. For lining, it appears that the only location where sand dunes may be impacted is at Pit 2 where the blow off manhole is currently located. From the information available at the time of writing this TM, it is unclear if the blow off manhole is located within the protected dunes.

3.2.6 Available Contractors

Primus Liner has several installers that are trained and certified covering the project area. These include National Water Main (office in MA), Insituform (office in MA), Michels Corporation (office in CT), Spiniello (office in NJ), and JF Cramer & Sons (office in NJ).

3.2.7 Construction Sequence and Scheduling

The existing force main is located in an area that is within a public beach and the City wishes to minimize the duration of beach shutdown required to complete the work. It will take just over three weeks to install Primus Liner from mobilization to project completion. However, because excavation within the beach would be minimized by lining the existing pipe, the beach may not have to be completely closed during lining construction. Time of completion for one liner pull versus two liner pulls are within one to two days of each other; see **Figures 7 and 8**.

Figure 7: Estimated Construction Schedule – 1 Liner Pull

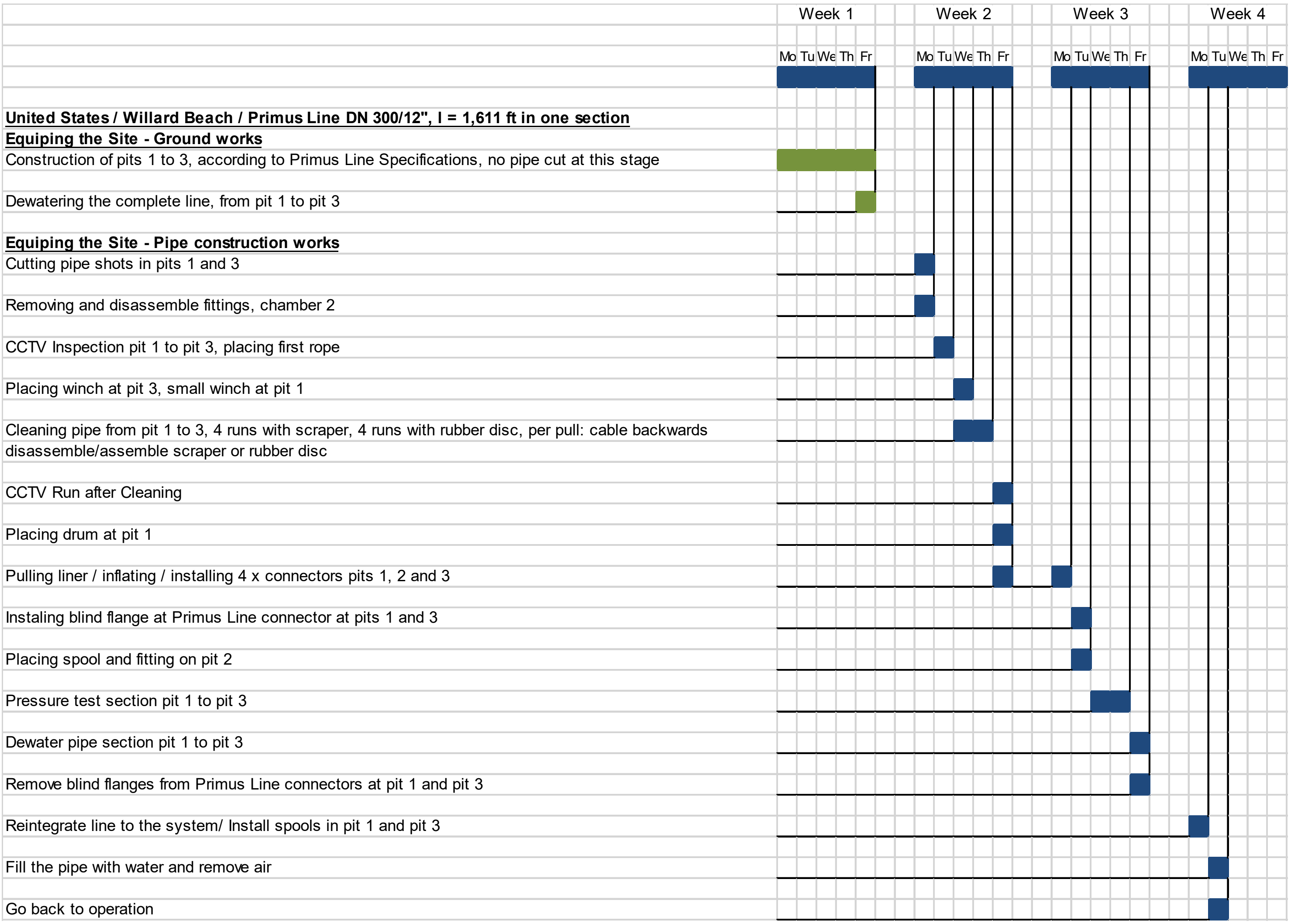
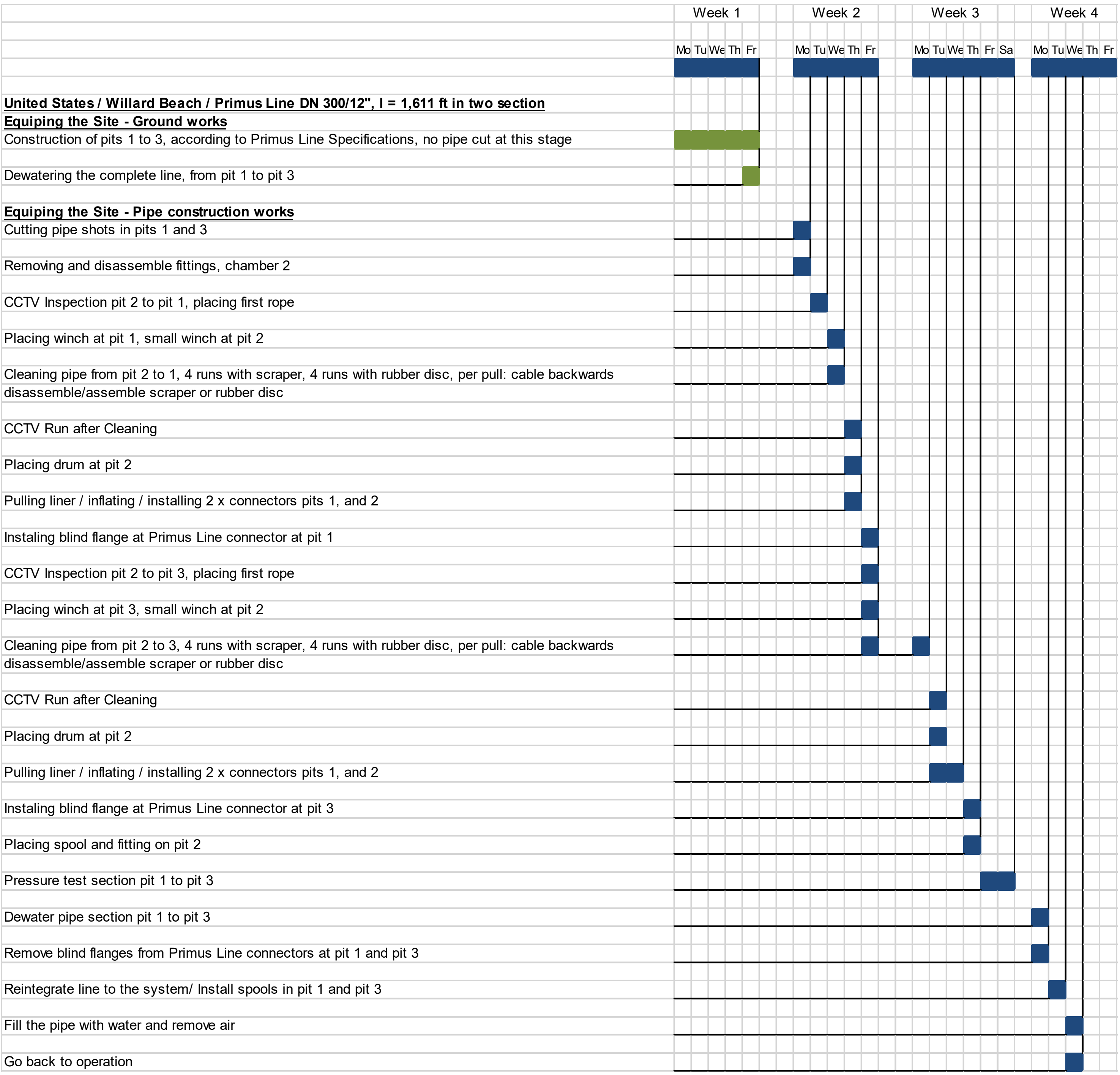


Figure 8: Estimated Construction Schedule – 2 Liner Pulls



According to the Primus Liner manufacturer's representative, the 12" low pressure liner material is currently in stock in the US and is sold on a first come, first served basis. There are several pending projects for 12" material. If this product is purchased for another project, the liner delivery time is currently 8 to 12 weeks which would likely put the project outside of the City's desired Summer 2023 timeline. To secure this material, the manufacturer requires a PO to reserve the liner and connectors.

3.2.8 Preliminary Construction Cost

See **Table 3** for a summary of planning level construction costs for rehabilitating the entire force main between the Pump Station and the transition manhole at the intersection of Myrtle and Fort with Primus Liner.

Table 3: Planning Level Construction Cost

ITEM #	DESCRIPTION	UNIT COST	UNITS	QTY	TOTAL
1	Mobilization and Demobilization	7%	LS	1 lump sum	$ 30,000
2	Traffic Control and General Safety Measures	$ 5,000	LS	1 lump sum	$ 5,000
3	Bypass Pumping	$ 250,000	LS	1 lump sum	$ 250,000
4	12" Primus Liner	$ 234	LF	1,611 ft	$ 377,000
5	Surface Restoration	$ 50,000	LS	1 lump sum	$ 50,000
	Subtotal Construction Cost Est. (w/o contingency)				*$ 712,000*
	Contingency	30%			$ 213,000
	Total Construction Cost Estimate				**$ 925,000**
	Engineering, Permitting, Construction Administration Services	15%			$ 138,000
	Project Cost Estimate				**$ 1,063,000**

Assumptions:

- Costs provided in June 2023 dollars and rounded to the nearest thousand.
- A 30% planning level contingency was added to the construction cost subtotal.
- This is a planning level cost estimate with some unit costs provided by the manufacturer. If moving forward with this alternative, it is recommended that estimates be solicited directly from the contractor who will be completing the work.
- Unit cost for Primus Liner installation includes standard cleaning of host pipe, CCTV inspection of the force main before lining, excavation of three access pits (upstream, downstream, and at the blow-off manhole), and installation of the liner with 4 connectors to the host pipe.
- Heavy cleaning will not be required.

- Three pits will be excavated for the work. Each pit will cost approximately $15,000 and is included in the unit price of the lining.
- Worker rates are $65-$70 per hour.
- Civil work not listed above will be done by others and is not included in this estimate.

4. RECOMMENDATION

If the City decides to rehabilitate the force main with a trenchless option in lieu of the open cut alternatives that they are reviewing independent of this trenchless evaluation, and the City's system can accommodate temporary seasonal higher velocities during peak wet weather events, then Primus Liner is the recommended trenchless rehabilitation method. Primus Liner provides a fully structural solution that can be installed at a relatively reasonable cost within the City's preferred repair timeline. In addition, it has a lower disturbance footprint when compared to an open cut alternative and will have fewer short and long-term impacts on the established sand dunes in the project vicinity. Another benefit of Primus Liner versus an open cut solution is that installation of a liner provides a rehabilitation solution for the entire 1,611 feet of force main versus an open cut repair which would only address the section of the force main located within the beach right-of-way.

APPENDIX A

INFORMATION PROVIDED BY PRIMUS LINING MANUFACTURER

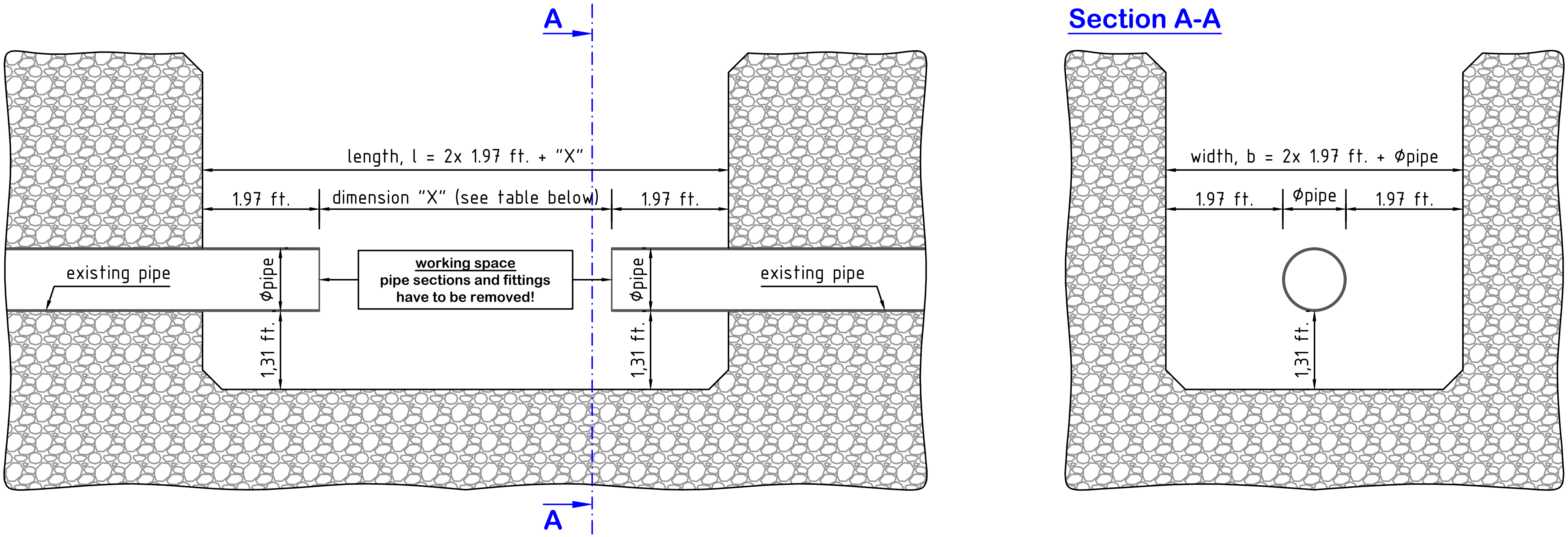


TABLE DIMENSION "X"

minimum required working space to install the Primus Line connector		Diameter Primus Line 6" – 8"	Diameter Primus Line 10" – 20"
Low Pressure System	*one* connector in a start- or endpit	4.10 ft.	5.74 ft.
Connector with Flange	*two* connectors in an intermediate- pit	4.92 ft.	6.56 ft.
Medium and High Pressure System	*one* connector in a start- or endpit	4.10 ft.	5.74 ft.
Connector with Flange	*two* connectors in an intermediate- pit	4.92 ft.	6.56 ft.
Medium and High Pressure System	*one* connector in a start- or endpit	4.92 ft.	6.56 ft.
Connector with Welding End	*two* connectors in an intermediate- pit	7,38 ft.	9,02 ft.

PRIMUS LINE

System drawing

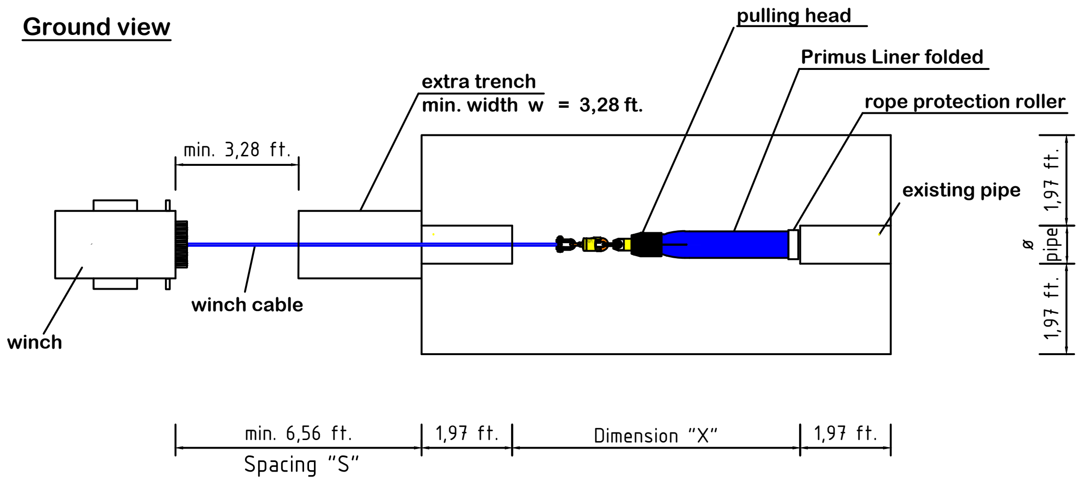
	Datum	Name
Constr.	19.08.2021	Bauer M.
Checked		

dimensions construction pit

Rädlinger primus line GmbH
Kammerdorfer Straße 16, D-93413 Cham
Telefon +49 9971 - 8088 - 0 / Fax +49 9971 - 8088 - 9999
info@primusline.com / www.primusline.com

Drawing CAD No.	Sheet
GB-01 / Water	**001**

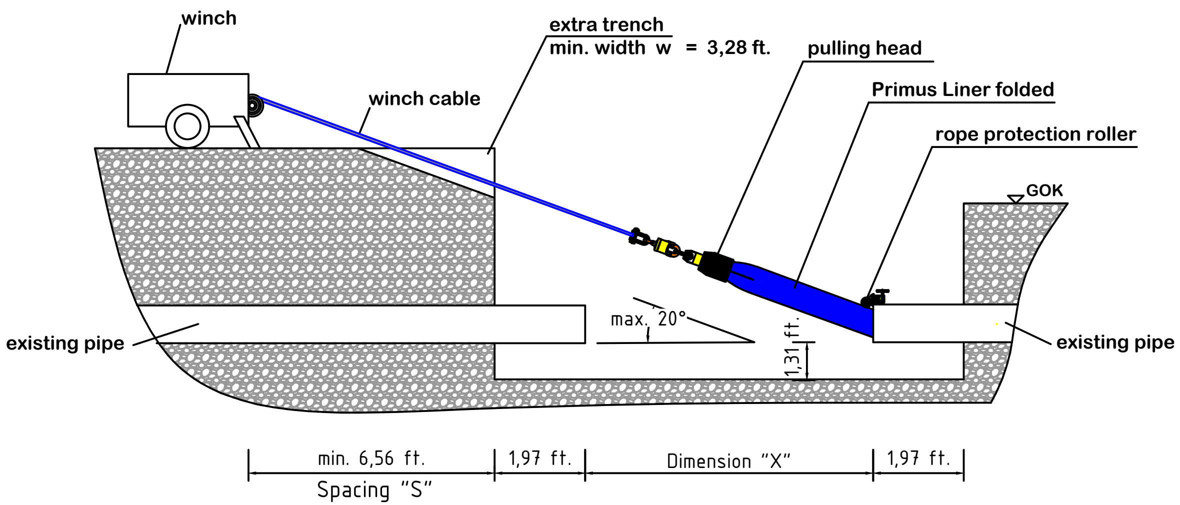
Ground view



When determining the distance "S" in the field, the recognised and currently valid rules of construction technology regarding the safety distances as per country of installation for the unbuilt trenches and slopes must also be observed.

installation length	min. Spacing "S"
up to 100 m	6,56 ft.
up to 200 m	9,84 ft.
up to 300 m	9,84 ft.
up to 400 m	19,68 ft.
up to 800 m	19,68 ft.
up to 1000 m	19,68 ft.
> 1000 m	26,25 ft.

Longitudinal section

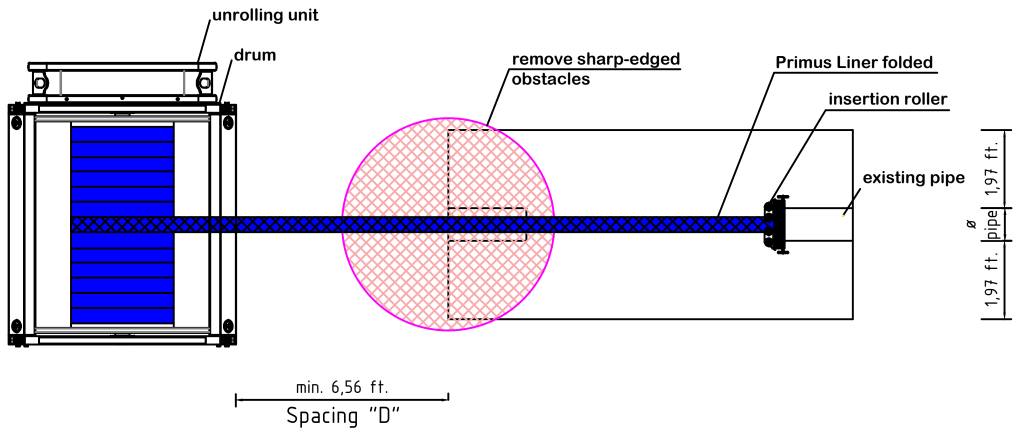


the winch should be placed and centered in a straight extension of the pipe axis

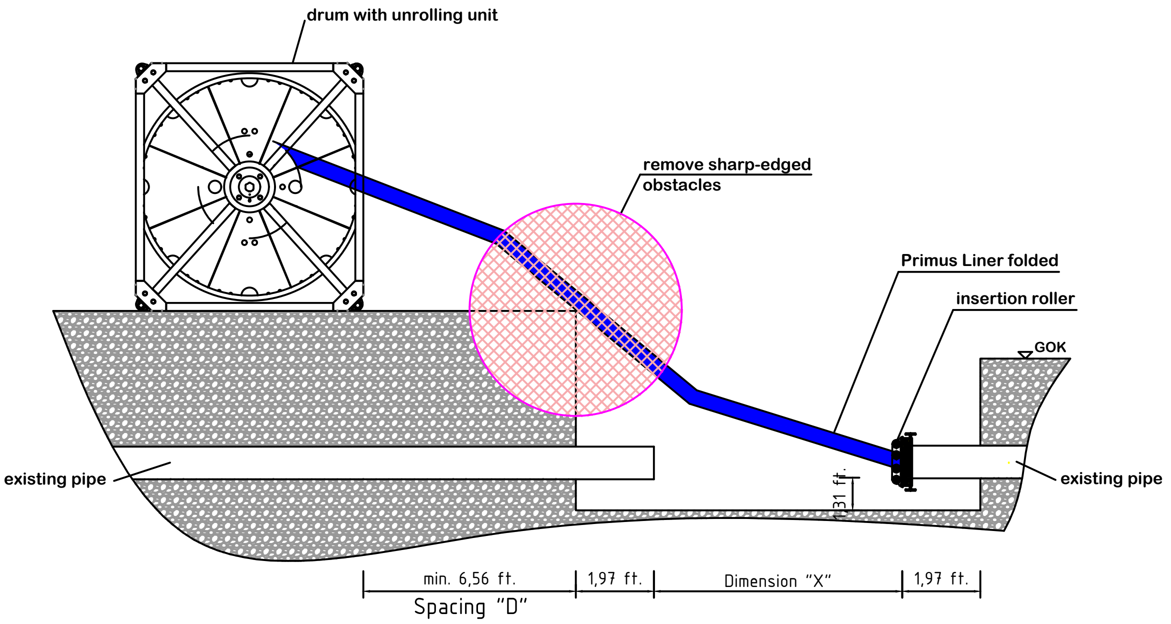
the pulling out of the Primus Liner with an angle less than or equal to 20 degree should be observed

PRIMUS LINE			System drawing	
	Datum	Name	positioning of a winch at the construction pit	
Constr.	23.08.2021	Bauer M		
Checked				
Rädlinger primus line GmbH Kammerdorfer Straße 16, D-93413 Cham Telefon +49 9971 - 8088 - 0 / Fax +49 9971 - 8088 - 9999 info@primusline.com / www.primusline.com			Drawing CAD No. GB-02 / Water	Sheet 001

Ground view



Longitudinal section



When determining the spacing "D" in the field, the recognised and currently valid rules of construction technology regarding the safety distances for the unbuilt trenches and slopes must also be observed.

drum/unrolling unit	min. Spacing "D"
T-140	6,56 ft.
T-210 / TE-210	6,56 ft.
T-300	9,84 ft.
TE-400	13,12 ft.
TE-500	16,40 ft.
TE-600	19,68 ft.
TE-800	26,25 ft.

the drum should be placed in a straight extension of the pipeline axis

System drawing

positioning of a drum at the construction pit

	Datum	Name
Constr.	23.08.2021	Bauer M
Checked		

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Telefon +49 9971 - 8088 - 0 / Fax +49 9971 - 8088 - 9999
info@primusline.com / www.primusline.com

Drawing CAD No.: GB-03 / Water

Sheet: 001

Submittal Support Document

Table of content

1. Company Profile

1.1 Manufacturer of a Unique System for Trenchless Pipe Rehabilitation

A single idea was the spark which stimulated the successful development of Primus Line® – the unique system for the trenchless rehabilitation of pressure pipelines. After intensive development work, the Rädlinger primus line GmbH was founded in 2001 and is part of the Werner Rädlinger Group. The family-owned group with over 400 employees is located in Bavaria, Germany.

Embedded in this traditional group of companies with great financial strength, Primus Line acts worldwide in the area of trenchless pipe rehabilitation with its unique product for pressurised pipelines. Since its foundation in 2001, the company's network of installation partners for the flexible relining system has grown considerably, as a great number of successfully completed projects around the world show. Today the company, with its headquarters in Germany and subsidiaries in the USA, Australia, Canada, and China, has numerous employees who are specialised in the areas of technology and development, production and international sales. Primus Line is also an active member of several industry associations like NASTT, AWWA, CATT, German Water Partnership and AWA.

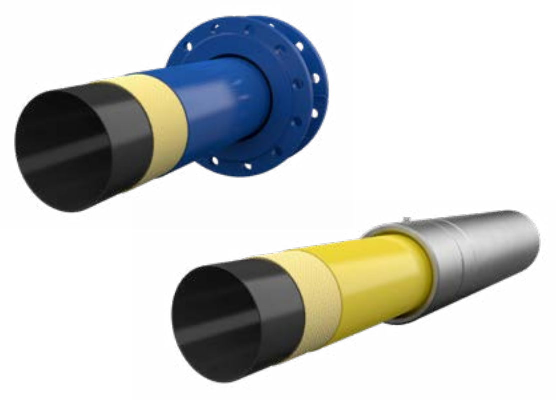
From the Initial Idea to Success

Primus Line® was developed to react to the recurring, time-consuming and expensive problem of run down pipelines in existing buildings.

Josef Rädlinger already had the idea for using a flexible hose for civil engineering in the 1980s. The hose was to be characterised by flexibility, mobility, light weight and low wall thickness while having the material strength of a steel pipe.

Ten years later, the know-how from the fields of construction, mechanical engineering and weaving technology were combined to find a creative and efficient solution. Together with research and industry partners, Rädlinger experts developed the Primus Line® technology. This technology now sets new standards in the transportation of gases and liquids via pipeline.

The system is based on a woven flexible high-pressure composite pipe and a specially developed connection technique.



Primus Line® products enable the cost-effective trenchless rehabilitation of pressure pipelines for different media such as water, oil and gas. The company's growing international success is based on a clearly defined strategy and excellent products providing cost-saving solutions to a multitude of challenges.

1988	Foundation of Rädlinger Maschinen- und Anlagenbau GmbH Start of the production of circular looms for fabric hoses
1996	Development of a high-pressure liner for pipe rehabilitation
2001	Foundation of Rädlinger primus line GmbH and market introduction of Primus Line® Pilot project gas for Verbundnetz Gas AG, Germany
2002	Pilot project gas for Ruhrgas AG, Germany
2003	First Primus Line gas installation for Municipal Utilities Leipzig, Germany
2004	First Primus Line water installation for BASF, Germany Creation of the test specification VP643 in collaboration with DVGW (German Association for Gas and Water)
2005	First Primus Line oil installation for Exxon Mobil, Germany
2008	New building for the Primus Line® production facilities in Weiding, Germany
2013	Foundation of Raedlinger Primus Line, Inc. in the United States
2016	Foundation of Raedlinger Primus Line Pty Ltd. in Australia
2018	Foundation of Raedlinger Primus Line CA Inc. in Canada
2019	Foundation of Primus Line (China) Ltd. in China Foundation of the Werner Rädlinger Holding GmbH & Co. KG
2020	Official market introduction of Primus Line® Overland Piping

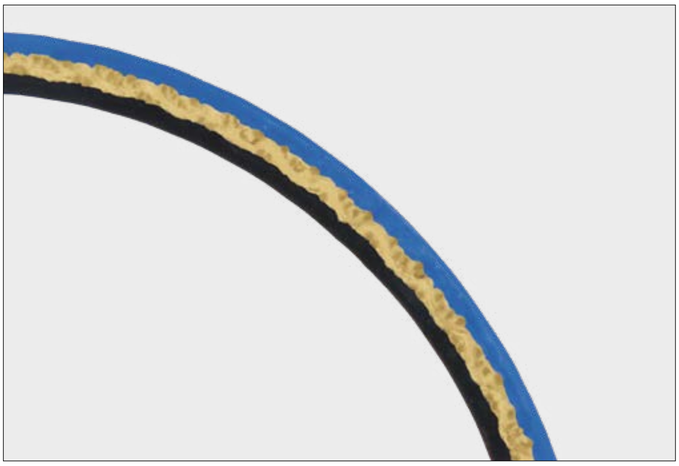
2. The Primus Line® System

Primus Line® is a flexible sliplining solution for the trenchless rehabilitation of pressure pipelines.

The system consists of a flexible aramid-reinforced liner and specially developed end fittings. The liner is self-supporting and not attached to the host pipe – an annular space remains. Developed by experienced engineers, the system is suitable for different media as well as various other applications and has already proven itself in numerous projects: besides the rehabilitation of damaged pipelines, it can also be used to increase the pressure within existing systems, protect them from corrosion and build bypass systems or stand-alone solutions. The Primus Line® system is certified in many countries – for example Australia, the USA, Germany, Canada, France and China – and meets the highly demanding standards for the transportation of drinking water worldwide. Primus Line® is available in nominal diameters ranging from DN 150 to DN 500 (6 inches to 20 inches).

2.1 Primus Liner

The liner is one of two parts of the Primus Line® system and consists of three different layers, as shown in Figure 1. The outer layer protects the internal load-bearing core structure during the installation process. Regardless of the type of fluid transported, this layer is made of an abrasion-resistant polyethylene (PE). Depending on the required pressure rating, the core structure is made of either one or two layers of seamless woven aramid fabric. The aramid fabric absorbs the pulling force during the insertion of the Primus Liner as well as the operating pressure. Its inner layer varies corresponding to the medium transported.



For drinking water applications, the liner is based on polyethylene (PE) while for its use in the oil and gas industry thermoplastic polyurethane (TPU) is the preferred solution because of the often higher requirements concerning chemical resistance. Due to its composition of multiple layers and a low wall thickness, the Primus Liner unites both flexibility and ultra-high material strength.

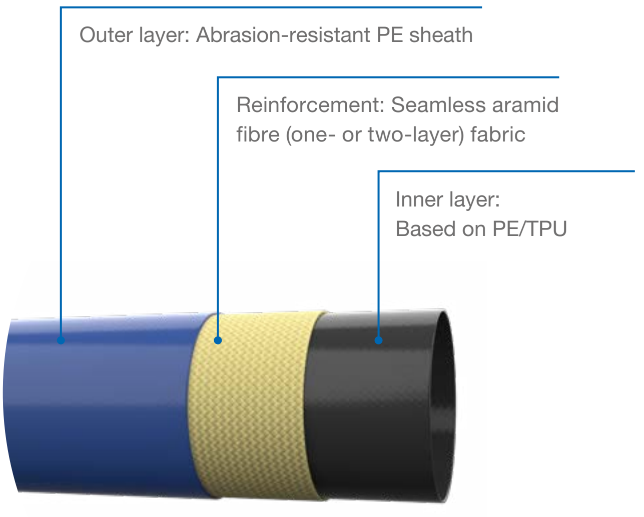


Figure 1: Schematic view of the Primus Liner

2.1.1 Fields of Application

Water

Primus Line® provides loss-free and secure conveyance of potable water as well as contaminated or polluted liquids. The composite liner protects the inside of the host pipe against corrosion and abrasive particles situated in the transported media.

Primus Line® is suitable for the transport of the following liquids in the water sector:

- potable water
- firefighting water
- industrial water
- sea water
- waste water

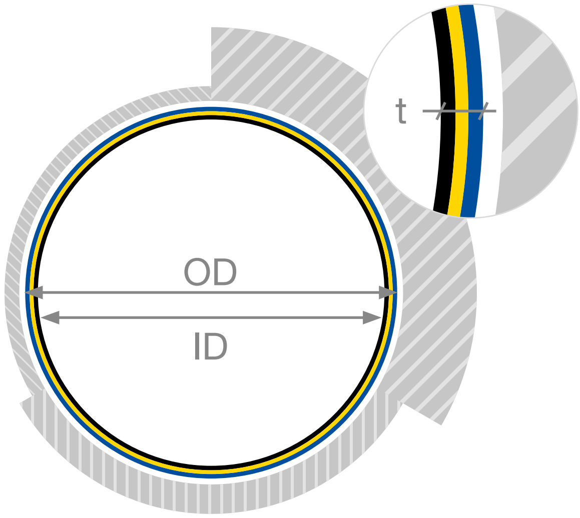
Gas

Gaseous media present a special challenge to trenchless pipe rehabilitation. However, an inner layer made of low permeation plastics and the seamless production of up to 4,500 m (approx. 14,700 feet) of the Primus Liner have made it possible for gas pipelines to be renovated with Primus Line®. A monitoring pipe with a fitted valve which is attached to the host pipe allows the observation of the system-specific annular space after the renovation process. The conveyed gas covers media from categories such as natural gases, liquid gases, coke gases and mixed gases (for detailed information please see our attached Chemical Resistance Sheet).

Oil

The oil industry is facing new challenges as a result of increasing damage to steel pipelines caused by internal corrosion. Possible leakages can cause significant environmental problems. They also lead to higher costs or even loss of reputation for network operators. Primus Line® is suitable for the renovation of oil pipelines due to its medium-specific inner layer and acts as a corrosion barrier between the transported fluid and the host pipe. The conveyed fluid covers media from categories such as crude oils, fuel oils, oil slag and other refined products (for detailed information please request our Chemical Resistance Sheet).

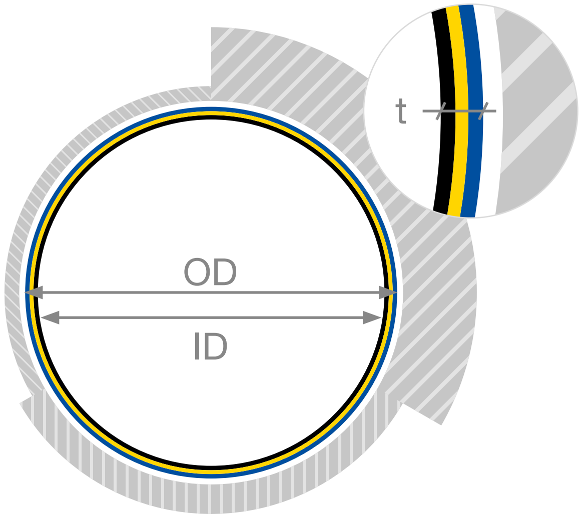
2.1.2 Product Portfolio



Metric

	ND						MD								HD							
	single-layer hybrid design						single-layer aramid design								double-layer aramid design							
	OD mm	t mm	ID mm	burst bar	MOP bar	weight kg/m	OD mm	t mm	ID mm	burst bar	MOP water bar	weight water kg/m	MOP oil/gas bar	weight oil/gas kg/m	OD mm	t mm	ID mm	burst bar	MOP water bar	weight water kg/m	MOP oil/gas bar	weight oil/gas kg/m
Primus Line® DN 150	134	6,0	122	63	25	2,1	134	6,0	122	140	56	2,2	35	2,4	-	-	-	-	-	-	-	-
Primus Line® SD 150	150	6,0	138	54	20	2,4	150	6,0	138	120	48	2,4	30	2,7	155	8,0	139	206	82	3,3	51	3,6
Primus Line® DN 200	183	6,0	171	47	18	2,9	183	6,0	171	100	40	3,0	25	3,3	187	8,0	171	173	69	4,0	43	4,4
Primus Line® SD 203	205	6,0	193	42	16	3,3	205	6,0	193	84	33	3,4	21	3,8	-	-	-	-	-	-	-	-
Primus Line® DN 250	237	6,0	225	38	15	3,8	237	6,0	225	75	30	4,0	18	4,4	241	8,0	225	128	51	5,3	32	5,8
Primus Line® SD 261	261	6,0	249	30	12	4,2	261	6,0	249	64	25	4,4	16	4,9	-	-	-	-	-	-	-	-
Primus Line® DN 300	284	6,0	272	30	12	4,6	284	6,0	272	64	25	4,8	16	5,3	288	8,0	272	110	44	6,4	27	6,9
Primus Line® DN 350	-	-	-	-	-	-	312	6,0	300	50	20	5,2	12	5,9	-	-	-	-	-	-	-	-
Primus Line® DN 400	-	-	-	-	-	-	354	6,0	342	46	18	6,0	11	6,7	357	8,0	341	82	32	8,1	20	8,8
Primus Line® DN 450	-	-	-	-	-	-	408	6,0	396	40	16	7,0	10	7,8	-	-	-	-	-	-	-	-
Primus Line® DN 500	-	-	-	-	-	-	454	6,0	442	40	16	7,7	10	8,6	-	-	-	-	-	-	-	-

The information in this document is based on our current knowledge and experience. Unless specified through a standard, the tests were carried out using internal methods on in-house testing equipment. Tests using other methods or other test equipment might produce different results. As a result of our ongoing development work, we reserve the right to modify products and change the features of the products. The information provided in this document cannot be used to derive any legally binding assurance or warranty for certain properties or the suitability of the product for a specific application.
Primus Liner ND 150, ND 200, ND 250, ND 300 (water) on stock. Primus Liner MD 150, MD 150 SD, MD 200, MD 203 SD, MD 250, MD 300, MD 350, MD 400, MD 450, MD 500 (water) on stock.
Remark: The indicated maximum operating pressure (MOP) includes safety factors and is valid for a straight course of the pipe without bends. Maximum operating pressure (MOP) in bends according to specification of the technical department of Rädlinger primus line GmbH.



Imperial

	ND						MD								HD							
	single-layer hybrid design						single-layer aramid design								double-layer aramid design							
	OD	t	ID	burst	MOP	weight	OD	t	ID	burst	MOP water	weight water	MOP oil/gas	weight oil/gas	OD	t	ID	burst	MOP water	weight water	MOP oil/gas	weight oil/gas
	inch	inch	inch	psi	psi	lbs/ft	inch	inch	inch	psi	psi	lbs/ft	psi	lbs/ft	inch	inch	inch	psi	psi	lbs/ft	psi	lbs/ft
Primus Line® DN 150/6“	5.28	0.24	4.80	914	363	1.4	5.28	0.24	4.80	2030	812	1.5	508	1.6	-	-	-	-	-	-	-	-
Primus Line® SD 150/6“SD	5.91	0.24	5.43	783	290	1.6	5.91	0.24	5.43	1740	696	1.6	435	1.8	6.10	0.31	5.47	2987	1189	2.2	740	2.4
Primus Line® DN 200/8“	7.20	0.24	6.73	682	261	1.9	7.20	0.24	6.73	1450	580	2.0	363	2.2	7.36	0.31	6.73	2509	1001	2.7	624	3.0
Primus Line® SD 203/8“SD	8.07	0.24	7.60	609	232	2.2	8.07	0.24	7.60	1218	479	2.3	305	2.5	-	-	-	-	-	-	-	-
Primus Line® DN 250/10“	9.33	0.24	8.86	551	218	2.6	9.33	0.24	8.86	1088	435	2.7	261	3.0	9.49	0.31	8.86	1856	740	3.6	464	3.9
Primus Line® SD 261/10“SD	10.28	0.24	9.80	435	174	2.8	10.28	0.24	9.80	928	363	2.9	232	3.3	-	-	-	-	-	-	-	-
Primus Line® DN 300/12“	11.18	0.24	10.71	435	174	3.1	11.18	0.24	10.71	928	363	3.2	232	3.6	11.34	0.31	10.71	1595	638	4.3	392	4.6
Primus Line® DN 350/14“	-	-	-	-	-	-	12.28	0.24	11.81	725	290	3.5	174	3.9	-	-	-	-	-	-	-	-
Primus Line® DN 400/16“	-	-	-	-	-	-	13.94	0.24	13.46	667	261	4.0	160	4.5	14.06	0.31	13.43	1189	464	5.4	290	5.9
Primus Line® DN 450/18“	-	-	-	-	-	-	16.06	0.24	15.59	580	232	4.7	145	5.2	-	-	-	-	-	-	-	-
Primus Line® DN 500/20“	-	-	-	-	-	-	17.87	0.24	17.40	580	232	5.2	145	5.8	-	-	-	-	-	-	-	-

The information in this document is based on our current knowledge and experience. Unless specified through a standard, the tests were carried out using internal methods on in-house testing equipment. Tests using other methods or other test equipment might produce different results. As a result of our ongoing development work, we reserve the right to modify products and change the features of the products. The information provided in this document cannot be used to derive any legally binding assurance or warranty for certain properties or the suitability of the product for a specific application.
Primus Liner ND 150/6“, ND 200/8“, ND 250/10“, ND 300/12“ (water) on stock. Primus Liner MD 150/6“, MD 150/6“SD, MD 200/8“, MD 203/8“SD, MD 250/10“, MD 300/12“, MD 350/14“, MD 400/16“, MD 450/18“, MD 500/20“ (water) on stock.
Remark: The indicated maximum operating pressure (MOP) includes safety factors and is valid for a straight course of the pipe without bends. Maximum operating pressure (MOP) in bends according to specification of the technical department of Rädlinger primus line GmbH.

2.1.3 Pressure Rating in Bends

Nominal diameter in nominal diameter

Computed values for max. operating pressure and max. test pressure are based on „percentage (%) of burst pressure of used Primus Line system“.

Primus Line water liner

	max. operating pressure [%] bend radii			max. test pressure [%] bend radii		
α [°]	1.5D	3D	5D	1.5D	3D	5D
0	40.0%	40.0%	40.0%	50.0%	50.0%	50.0%
5	37.5%	37.5%	38.4%	46.9%	46.9%	48.0%
10	35.8%	35.9%	37.3%	44.8%	44.9%	46.7%
15	33.8%	33.9%	36.0%	42.2%	42.4%	45.0%
20	31.5%	31.7%	34.5%	39.4%	39.6%	43.1%
25	29.0%	29.3%	32.7%	36.3%	36.7%	40.9%
30	26.7%	27.1%	30.6%	33.4%	33.9%	38.2%
35	24.7%	25.1%	28.5%	30.8%	31.4%	35.6%
40	23.0%	23.4%	26.6%	28.8%	29.3%	33.3%
45	21.7%	22.1%	25.1%	27.1%	27.6%	31.4%

Primus Line water liners are tested by using potable water.

Primus Line gas liner

	max. operating pressure [%] bend radii			max. test pressure [%] bend radii		
α [°]	1.5D	3D	5D	1.5D	3D	5D
0	25.0%	25.0%	25.0%	31.3%	31.3%	31.3%
5	23.4%	23.5%	24.0%	29.3%	29.3%	30.0%
10	22.4%	22.4%	23.3%	28.0%	28.0%	29.2%
15	21.1%	21.2%	22.5%	26.4%	26.5%	28.1%
20	19.7%	19.8%	21.6%	24.6%	24.7%	27.0%
25	18.2%	18.3%	20.4%	22.7%	22.9%	25.5%
30	16.7%	16.9%	19.1%	20.9%	21.2%	23.9%
35	15.4%	15.7%	17.8%	19.3%	19.6%	22.2%
40	14.4%	14.6%	16.6%	18.0%	18.3%	20.8%
45	13.6%	13.8%	15.7%	16.9%	17.3%	19.6%

Primus Line gas liners are tested by using compressed air.

Primus Line oil liner

	max. operating pressure [%] bend radii			max. test pressure [%] bend radii		
α [°]	1.5D	3D	5D	1.5D	3D	5D
0	25.0%	25.0%	25.0%	50.0%	50.0%	50.0%
5	23.4%	23.5%	24.0%	46.9%	46.9%	48.0%
10	22.4%	22.4%	23.3%	44.8%	44.9%	46.7%
15	21.1%	21.2%	22.5%	42.2%	42.4%	45.0%
20	19.7%	19.8%	21.6%	39.4%	39.6%	43.1%
25	18.2%	18.3%	20.4%	36.3%	36.7%	40.9%
30	16.7%	16.9%	19.1%	33.4%	33.9%	38.2%
35	15.4%	15.7%	17.8%	30.8%	31.4%	35.6%
40	14.4%	14.6%	16.6%	28.8%	29.3%	33.3%
45	13.6%	13.8%	15.7%	27.1%	27.6%	31.4%

Primus Line oil liners are tested by using potable water.

2.1.4 Material of the Primus Liner

The Primus Liner is manufactured out of up to three different materials: aramid fabric, polyethylene and – depending on the application – thermoplastic polymer.

The aramid fabric produced from aramid fibres has a seamless, continuous twill. While the polyethylene material used in the inner layer of the Primus Liner is black in appearance, its outer layer is individual and identifies its application. The Primus Liner has sufficient UV resistance to protect its barrier layer from deleterious UV exposure effects during unprotected outdoor shipping and storage.

Primus Line only uses virgin material in a form such as granules that has not been subjected to use or processing other than that required for its manufacture and to which no rework or recyclable materials have been added.

The Primus Liner is clearly marked with the following information:

- the nominal composite liner diameter
- the fluid and MOP (Maximum Operating Pressure) for the transported fluid
- the trade name/trademark
- the day, month and year of manufacture in the format DDMMYYYY
- Primus Line batch number
- the continuous production run length in metres

For shipment all Primus Liners are spooled onto transport reels. All Primus Liners must be handled in accordance to the Primus Line Installation Manual.

2.1.5 Transport reel capacity

folded Liner (all capacity values in meters)											
Drum Type	Nominal Size										
	DN 150	150 SD	DN 200	203 SD	DN 250	261 SD	DN 300	DN 350	DN 400	DN 450	DN 500
T-140	631	554	449	396	338	305	276	247	215	181	161
T-210	1,194	1,048	851	751	642	580	526	470	410	345	308
T-300	1,448	1,276	1,043	925	796	723	659	593	522	445	401
T-400	2,046	1,803	1,474	1,307	1,125	1,021	931	838	738	629	567
T-500	2,579	2,278	1,872	1,665	1,440	1,312	1,200	1,085	962	827	751
T-600	3,112	2,749	2,258	2,009	1,738	1,583	1,448	1,309	1,161	998	906
T-800	4,156	3,671	3,016	2,684	2,321	2,114	1,934	1,748	1,550	1,333	1,210
T-1100	5,754	5,083	4,176	3,716	3,214	2,927	2,678	2,421	2,147	1,846	1,675

folded Liner (all capacity values in feet)											
Drum Type	Nominal Size										
	6 inch	6 inch SD	8 inch	8 inch SD	10 inch	10 inch SD	12 inch	14 inch	16 inch	18 inch	20 inch
T-140	2,070	1,816	1,473	1,299	1,110	1,001	907	810	706	592	528
T-210	3,918	3,439	2,793	2,465	2,107	1,902	1,725	1,542	1,346	1,132	1,010
T-300	4,750	4,185	3,422	3,035	2,612	2,370	2,161	1,945	1,714	1,460	1,317
T-400	6,713	5,914	4,836	4,288	3,692	3,350	3,054	2,748	2,422	2,064	1,861
T-500	8,461	7,474	6,141	5,464	4,726	4,303	3,938	3,559	3,156	2,714	2,463
T-600	10,209	9,018	7,409	6,593	5,702	5,192	4,751	4,295	3,808	3,274	2,972
T-800	13,635	12,044	9,896	8,805	7,616	6,935	6,346	5,736	5,086	4,373	3,969
T-1100	18,879	16,677	13,702	12,192	10,545	9,602	8,786	7,943	7,043	6,055	5,496

- lists valid for medium and low pressure liner
- for high pressure liner length must be multiplied by a factor of 0.85
- lists valid for oil, gas and water liner
- drum suitable for transportation in ISO container

2.2 Primus Line Connectors

The second part of the Primus Line® system are specially developed termination fittings which are divided into two categories:

connectors with resin injection and connectors with mechanical connetion.

Primus Line connectors are manufactured from either cast iron, carbon steel or stainless steel. They meet the requirements of following specifications:

	EN	ASTM
cast iron	EN GJS-500-7	A395 60-40-18
carbon steel	S355	
stainless steel	1.4462	A182 F51

Connectors are both available with flanges or welded ends. While models with welded ends are not coated, models with flanges have a full-surface, high quality powder coating, which provides corrosion protection on all sides. Flanges used by Primus Line comply with either EN 1092, ANSI B16.5 or AS 4087. All connectors preserve the overall integrity and function of the liner.

Primus Line recommends the installation of the system in accordance to its comprehensive installation manual.

M-Connector

M-Connector with wall plate

R-Connector with flange

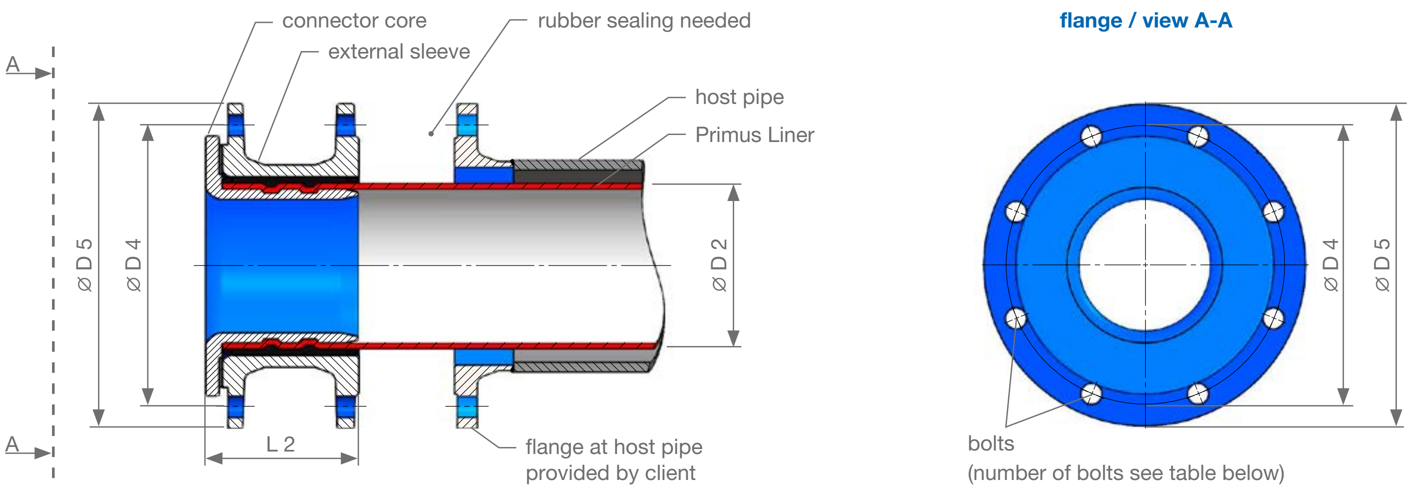
R-Connector with wall plate

R-Connector with welded end

2.2.1 M-Connector

The M-Connector is a purely mechanical fitting which uses a sleeve with corresponding contours and can be disassembled for reuse. It is installed with mechanical force to achieve a durable and pull-proof connection. Since no curing process is necessary for the M-Connector, its installation is quick and a leak test can be performed right afterwards. As a result, considerable time savings are possible. The M-Connectors are available for liners ranging from DN 150 to DN 300 (6 inches to 12 inches).

Primus Line® M-Connector



mm/bar Dimensions (EN)

	ø liner	length of connector	ø flange of connector				number of bolts			
	ND/MD	M	PN10	PN16	PN10	PN16	PN10	PN16	PN10	PN16
	D 2 (mm)	L 2 (mm)	D 4 (mm)		D 5 (mm)		pieces		screw thread	
Primus Line® DN 150/6''	134	162	240	240	285	285	8	8	M20	M20
Primus Line® SD 150/6''SD	150	162	295	295	340	340	8	12	M20	M20
Primus Line® DN 200/8''	183	162	295	295	340	340	8	12	M20	M20
Primus Line® SD 203/8''SD	205	162	350	355	395	405	12	12	M20	M24
Primus Line® DN 250/10''	237	162	350	355	395	405	12	12	M20	M24
Primus Line® SD 261/10''SD	261	162	400	410	445	460	12	12	M20	M24
Primus Line® DN 300/12''	284	162	400	410	460	460	12	12	M20	M24

Exploded and general assembly drawing of the M-Connector

mm/#150 Dimensions (ANSI)

	ø liner	length of connector	ø flange of connector		number of bolts	
	ND/MD	M	#150	#150	pieces	screw thread
	D 2 (mm)	L 2 (mm)	D 4 (mm)	D 5 (mm)		
Primus Line® DN 150/6''	134	162	241.3	280.0	8	3/4''
Primus Line® SD 150/6''SD	150	162	298.4	342.9	8	3/4''
Primus Line® DN 200/8''	183	162	298.4	345.0	8	3/4''
Primus Line® SD 203/8''SD	205	162	361.9	406.4	12	7/8''
Primus Line® DN 250/10''	237	162	361.9	405.0	12	7/8''
Primus Line® SD 261/10''SD	261	162	431.8	482.6	12	7/8''
Primus Line® DN 300/12''	284	162	431.8	485.0	12	7/8''

inch/#150 Dimensions (ANSI)

	ø liner	length of connector	ø flange of connector		number of bolts	
	ND/MD	M	#150	#150	pieces	screw thread
	D 2 (inch)	L 2 (inch)	D 4 (inch)	D 5 (inch)		
Primus Line® DN 150/6''	5.28	6.38	9.50	11.02	8	3/4''
Primus Line® SD 150/6''SD	5.91	6.38	11.75	13.50	8	3/4''
Primus Line® DN 200/8''	7.20	6.38	11.75	13.58	8	3/4''
Primus Line® SD 203/8''SD	8.07	6.38	14.25	16.00	12	7/8''
Primus Line® DN 250/10''	9.33	6.38	14.25	15.94	12	7/8''
Primus Line® SD 261/10''SD	10.28	6.38	17.00	19.00	12	7/8''
Primus Line® DN 300/12''	11.18	6.38	17.00	19.09	12	7/8''

mm/bar Dimensions (AS)

	ø liner	length of connector	ø flange of connector		number of bolts	
	ND/MD	M	PN16	PN16	PN16	PN16
	D 2 (mm)	L 2 (mm)	D 4 (mm)	D 5 (mm)	pieces	screw thread
Primus Line® DN 150/6''	134	162	235	285	8	M16
Primus Line® SD 150/6''SD	150	162	292	340	8	M16
Primus Line® DN 200/8''	183	162	292	340	8	M16
Primus Line® SD 203/8''SD	205	162	356	405	8	M20
Primus Line® DN 250/10''	237	162	356	405	8	M20
Primus Line® SD 261/10''SD	261	162	406	460	12	M20
Primus Line® DN 300/12''	284	162	406	460	12	M20

2.2.2 R-Connector

The R-Connector consists of a dimensionally stable profiled connector core and an external sleeve with a deformable metal jacket, as shown in Figure 3. During the installation, a two-component resin injected through a valve on the external sleeve, forces the metal jacket and consequently the liner into the contours of the connector core. After a curing time of at least 6 hours at 20 °C (68 °F), the connection is permanent and has a high tensile strength as shown in Figure 4. The R-Connector is available for all liners from DN 150 to DN 500 (6 inches to 20 inches).

Each end of the Primus Line connectors can be equipped with either a standard flange or a welded end in order to connect it to the host pipe or to enable the integration of a hydrant, service connection or valve. Additionally, it is always possible to provide customised solutions for special applications. More information about this topic is available in chapter 4.10.

Figure 3: R-Connector prior to the injection of the two-component resin

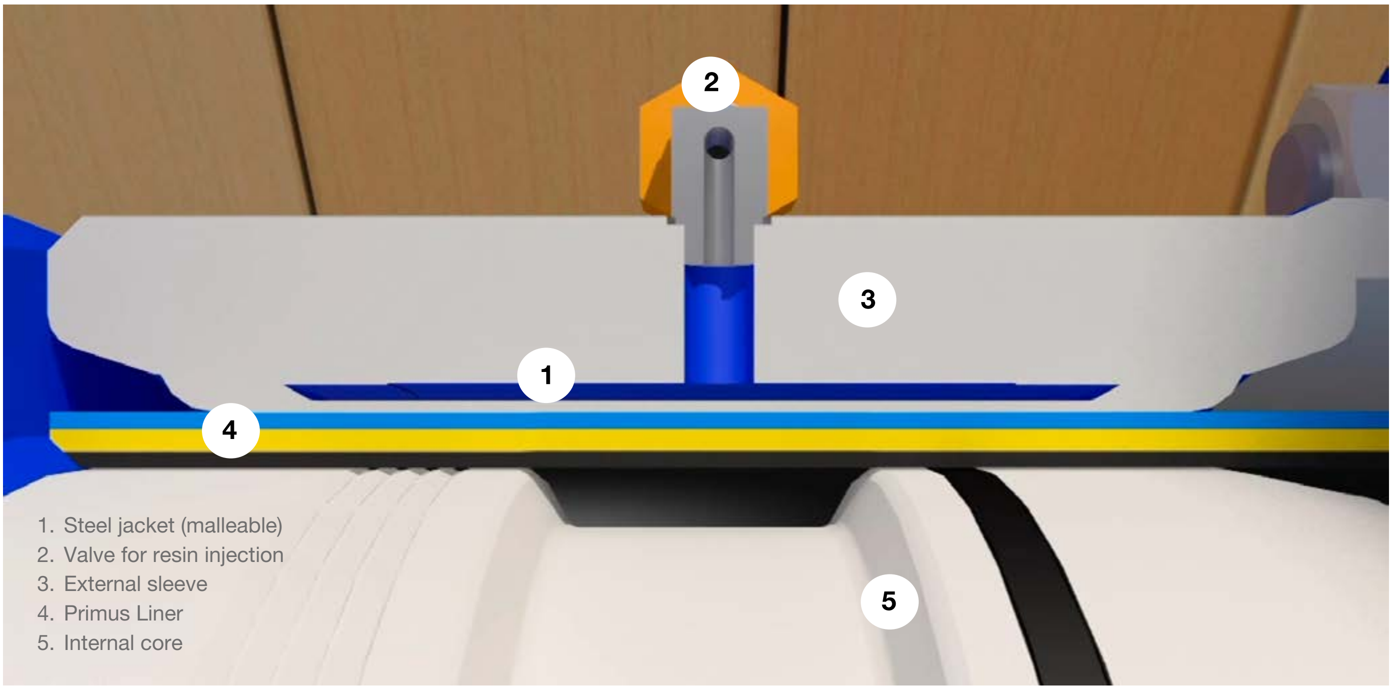
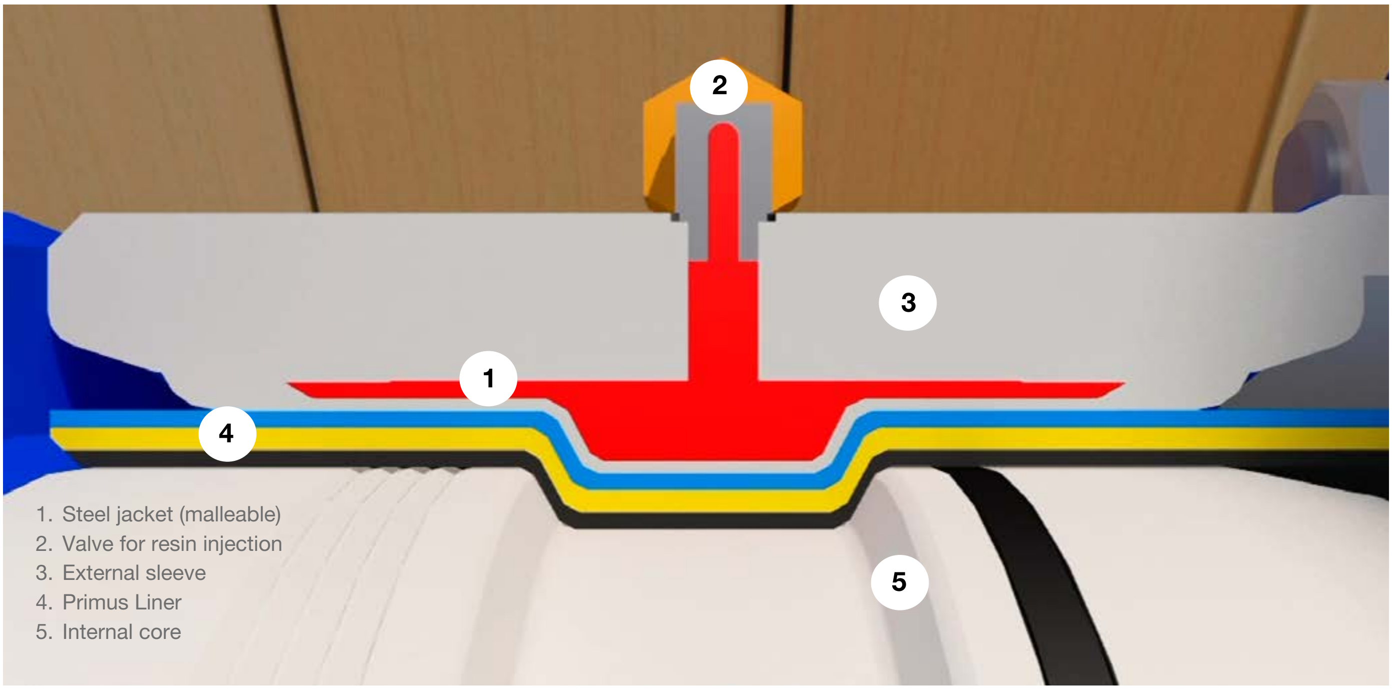
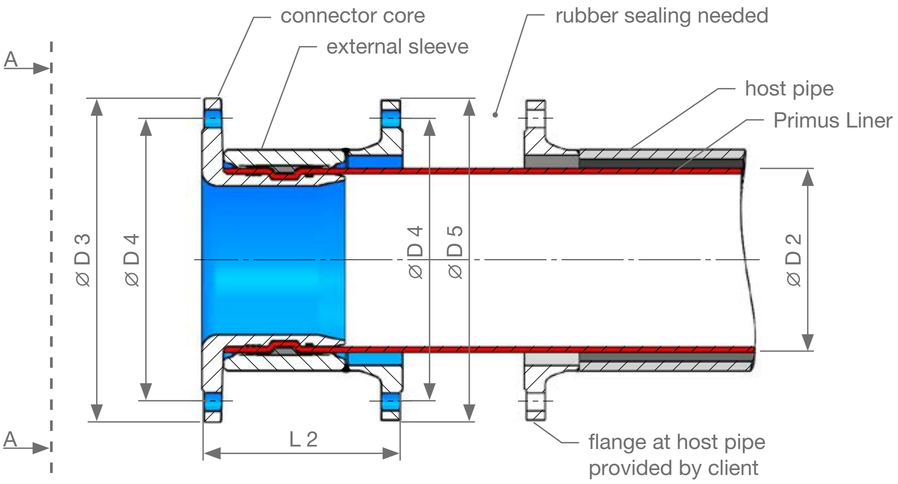
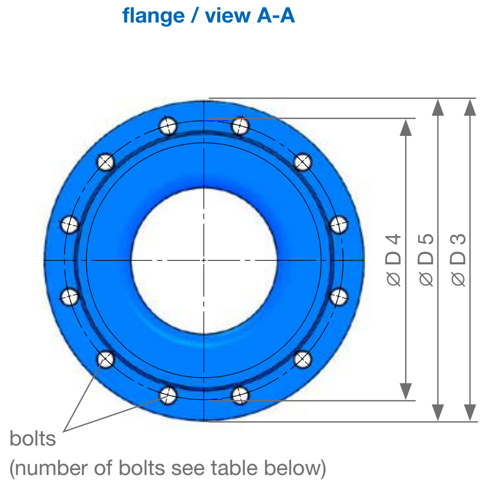


Figure 4: R-Connector connector after the injection of the two-component resin



Primus Line® R1-Connector





mm/bar Dimensions (EN)

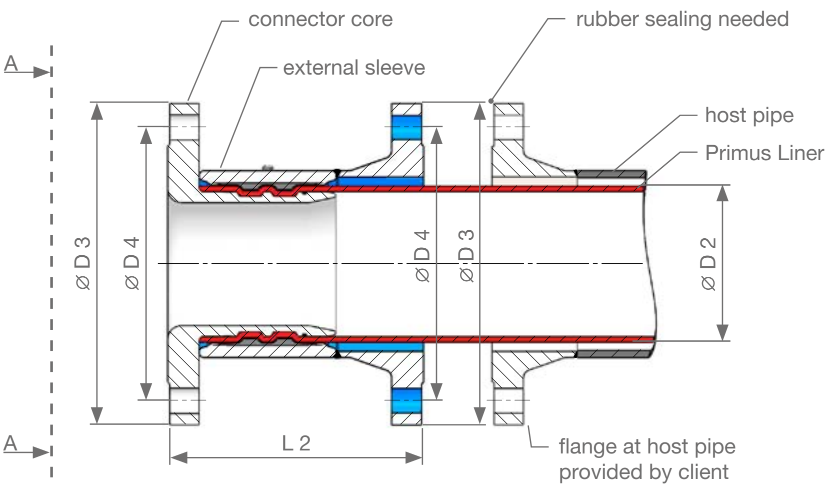
	ø liner	length of connector		ø flange of core		ø bolt circle		ø flange at external sleeve		number of bolts			
	ND/MD	PN10	PN16	PN10	PN16	PN10	PN16	PN10	PN16	PN10	PN16	PN10	PN16
	D 2 (mm)	L 2 (mm)		D 3 (mm)		D 4 (mm)		D 5 (mm)		pieces		screw thread	
Primus Line® DN 150	134	233	233	285	285	240	240	285	285	8	8	M20	M20
Primus Line® SD 150	150	176	176	340	340	295	295	340	340	8	12	M20	M20
Primus Line® DN 200	183	241	241	340	340	295	295	340	340	8	12	M20	M20
Primus Line® SD 203	205	178	178	400	400	350	355	395	405	12	12	M20	M24
Primus Line® DN 250	237	250	252	400	400	350	355	395	405	12	12	M20	M24
Primus Line® SD 261	261	180	180	455	455	400	410	445	460	12	12	M20	M24
Primus Line® DN 300	284	252	262	455	455	400	410	445	460	12	12	M20	M24
Primus Line® DN 350	312	253	267	520	520	460	470	505	520	16	16	M20	M24
Primus Line® DN 400	354	311	324	580	580	515	525	565	580	16	16	M24	M27
Primus Line® DN 450	408	312	323	640	640	565	585	615	640	20	20	M24	M27
Primus Line® DN 500	454	317	326	715	715	620	650	670	715	20	20	M24	M30

mm/#150 or #300 Dimensions (ANSI)	ø liner	length of connector		ø flange of core		ø bolt circle		ø flange at external sleeve		number of bolts			
	ND/MD	#150	#300	#150	#300	#150	#300	#150	#300	#150	#300	#150	#300
	D 2 (mm)	L 2 (mm)		D 3 (mm)		D 4 (mm)		D 5 (mm)		pieces		screw thread	
Primus Line® DN 150/6''	134	269	289	279.4	317.5	241.3	269.9	279.4	317.5	8	12	3/4''	3/4''
Primus Line® SD 150/6''SD	150	180	192	342.9	381.0	298.4	330.2	342.9	381.0	8	12	3/4''	7/8''
Primus Line® DN 200/8''	183	285	307	342.9	381.0	298.4	330.2	342.9	381.0	8	12	3/4''	7/8''
Primus Line® SD 203/8''SD	205	182	198	406.4	444.5	361.9	287.3	406.4	444.5	12	16	7/8''	1''
Primus Line® DN 250/10''	237	286	318	406.4	444.5	361.9	287.3	406.4	444.5	12	16	7/8''	1''
Primus Line® SD 261/10''SD	261	183	201	482.6	520.7	431.8	450.8	482.6	520.7	12	16	7/8''	1 1/8''
Primus Line® DN 300/12''	284	301	334	482.6	520.7	431.8	450.8	482.6	520.7	12	16	7/8''	1 1/8''
Primus Line® DN 350/14''	312	316	350	533.4	584.2	476.2	514.3	533.4	584.2	12	20	1''	1 1/8''
Primus Line® DN 400/16''	354	368	408	596.9	647.7	539.7	571.5	596.9	647.7	16	20	1''	1 1/4''
Primus Line® DN 450/18''	408	384	422	635.0	711.2	577.8	628.8	635.0	711.2	16	24	1 1/8''	1 1/4''
Primus Line® DN 500/20''	454	392	427	698.5	774.7	635.0	658.8	698.5	774.7	20	24	1 1/8''	1 1/4''

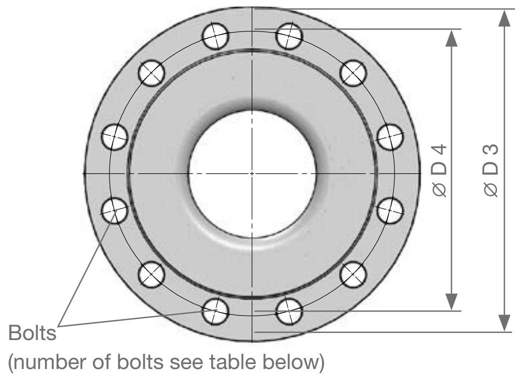
inch/#150 or #300 Dimensions (ANSI)	ø liner	length of connector		ø flange of core		ø bolt circle		ø flange at external sleeve		number of bolts			
	ND/MD	#150	#300	#150	#300	#150	#300	#150	#300	#150	#300	#150	#300
	D 2 (inch)	L 2 (inch)		D 3 (inch)		D 4 (inch)		D 5 (inch)		pieces		screw thread	
Primus Line® DN 150/6''	5.28	10.59	11.38	11.00	12.50	9.50	10.63	11.00	12.50	8	12	3/4''	3/4''
Primus Line® SD 150/6''SD	5.91	7.09	7.56	13.50	15.00	11.75	13.00	13.50	15.00	8	12	3/4''	7/8''
Primus Line® DN 200/8''	7.20	11.22	12.09	13.50	15.00	11.75	13.00	13.50	15.00	8	12	3/4''	7/8''
Primus Line® SD 203/8''SD	8.07	7.16	7.80	16.00	17.50	14.25	11.31	16.00	17.50	12	16	7/8''	1''
Primus Line® DN 250/10''	9.33	11.26	12.52	16.00	17.50	14.25	11.31	16.00	17.50	12	16	7/8''	1''
Primus Line® SD 261/10''SD	10.28	7.20	7.91	19.00	20.50	17.00	17.75	19.00	20.50	12	16	7/8''	1 1/8''
Primus Line® DN 300/12''	11.18	11.85	13.15	19.00	20.50	17.00	17.75	19.00	20.50	12	16	7/8''	1 1/8''
Primus Line® DN 350/14''	12.28	12.44	13.78	21.00	23.00	18.75	20.25	21.00	23.00	12	20	1''	1 1/8''
Primus Line® DN 400/16''	13.94	14.49	16.06	23.50	25.50	21.25	22.50	23.50	25.50	16	20	1''	1 1/4''
Primus Line® DN 450/18''	16.06	15.12	16.61	25.00	28.00	22.75	27.76	25.00	28.00	16	24	1 1/8''	1 1/4''
Primus Line® DN 500/20''	17.87	15.43	16.81	27.50	30.50	25.00	25.94	27.50	30.50	20	24	1 1/8''	1 1/4''

mm/bar Dimensions (AS)	ø liner	length of connector	ø flange of core	ø bolt circle	ø flange at external sleeve	number of bolts	
	ND/MD	PN16	PN16	PN16	PN16	PN16	PN16
	D 2 (mm)	L 2 (mm)	D 3 (mm)	D 4 (mm)	D 5 (mm)	pieces	screw thread
Primus Line® DN 150	134	175	285	235	280	8	M16
Primus Line® SD 150	150	176	335	292	336	8	M16
Primus Line® DN 200	183	176	340	292	335	8	M16
Primus Line® SD 203	205	178	405	356	405	8	M20
Primus Line® DN 250	237	179	400	356	405	8	M20
Primus Line® SD 261	261	180	455	406	455	12	M20
Primus Line® DN 300	284	181	455	406	455	12	M20
Primus Line® DN 350	312	182	520	470	520	12	M24
Primus Line® DN 400	354	236	580	521	580	12	M24
Primus Line® DN 450	408	237	640	584	640	12	M24
Primus Line® DN 500	454	239	715	641	705	16	M24

Primus Line® R2-Connector



flange / view A-A



mm/bar Dimensions (EN)	**ø liner**	**length of connector**				**ø flange**				**ø bolt circle**				**number of bolts**							
	HD	PN25	PN40	PN63	PN100	PN25	PN40	PN63	PN100	PN25	PN40	PN63	PN100	PN25	PN40	PN63	PN100	PN25	PN40	PN63	PN100
	D 2 (mm)	L 2 (mm)				D 3 (mm)				D 4 (mm)				pieces				screw thread			
Primus Line® SD 150	155	231	235	243	253	360	375	415	430	310	320	345	360	12	12	12	12	M24	M27	M33	M33
Primus Line® DN 200	187	314	326	356	386	360	375	415	430	310	320	345	360	12	12	12	12	M24	M27	M33	M33
Primus Line® DN 250	241	324	347	375	-	425	450	470	-	370	385	400	-	12	12	12	-	M27	M30	M33	-
Primus Line® DN 300	288	330	361	396	-	485	515	530	-	430	450	460	-	16	16	16	-	M27	M30	M33	-
Primus Line® DN 400	357	354	389	-	-	620	660	-	-	550	585	-	-	16	16	-	-	M33	M36	-	-

mm/#150
Dimensions (ANSI)

	ø liner	length of connector		ø flange		ø bolt circle		number of bolts			
	HD	#150	#300	#150	#300	#150	#300	#150	#300	#150	#300
	D 2 (mm)	L 2 (mm)		D 3 (mm)		D 4 (mm)		pieces		screw thread	
Primus Line® SD 150/6'' SD	155	230	242	342.9	381.0	298.4	330.2	8	12	3/4''	7/8''
Primus Line® DN 200/8''	187	334	356	342.9	381.0	298.4	330.2	8	12	3/4''	7/8''
Primus Line® DN 250/10''	241	336	369	406.4	444.5	361.9	387.3	12	16	7/8''	1''
Primus Line® DN 300/12''	288	350	385	482.6	520.7	431.8	450.8	12	16	7/8''	1 1/8''
Primus Line® DN 400/16''	357	367	407	596.9	647.7	539.7	571.5	16	20	1''	1 1/4''

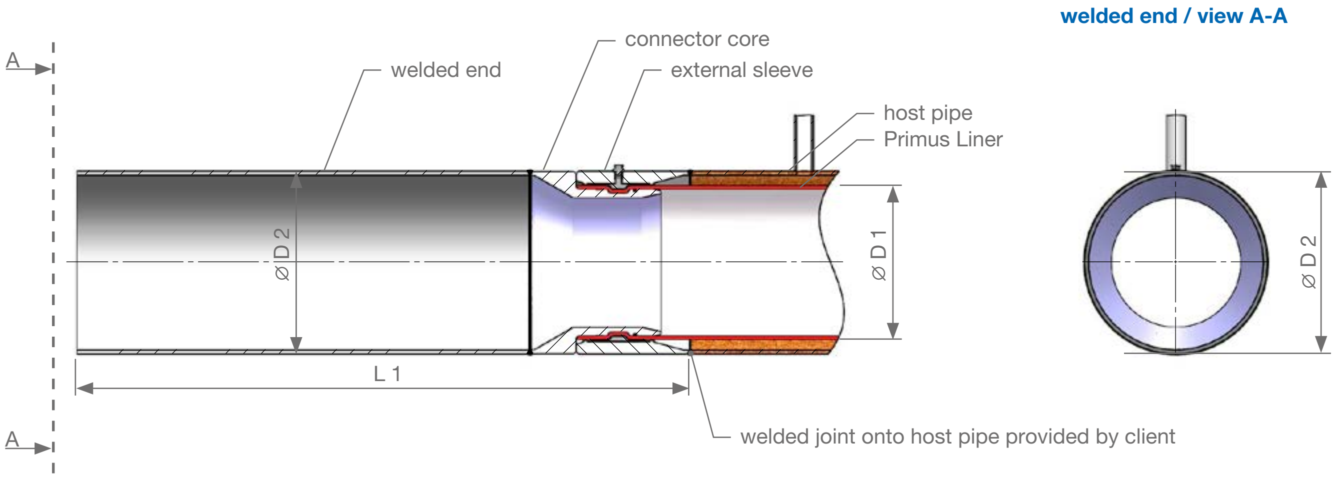
inch/#150
Dimensions (ANSI)

	ø liner	length of connector		ø flange		ø bolt circle		number of bolts			
	HD	#150	#300	#150	#300	#150	#300	#150	#300	#150	#300
	D 2 (inch)	L 2 (inch)		D 3 (inch)		D 4 (inch)		pieces		screw thread	
Primus Line® SD 150/6'' SD	6.10	9.04	9.53	13.50	15.00	11.75	13.00	8	12	3/4''	7/8''
Primus Line® DN 200/8''	7.36	13.15	14.02	13.50	15.00	11.75	13.00	8	12	3/4''	7/8''
Primus Line® DN 250/10''	9.49	13.22	14.53	16.00	17.50	14.25	15.25	12	16	7/8''	1''
Primus Line® DN 300/12''	11.34	13.78	15.16	19.00	20.50	17.00	17.75	12	16	7/8''	1 1/8''
Primus Line® DN 400/16''	14.06	14.46	16.03	23.50	25.50	21.25	22.50	16	20	1''	1 1/4''

mm/bar
Dimensions (AS)

	ø liner	length of connector	ø flange	ø bolt circle	number of bolts	
	HD	PN16	PN16	PN16	PN16	PN16
	D 2 (mm)	L 2 (mm)	D 3 (mm)	D 4 (mm)	pieces	screw thread
Primus Line® SD 150	155	225	335	292	8	M16
Primus Line® DN 200	187	225	335	292	8	M16
Primus Line® DN 250	241	227	405	356	8	M20
Primus Line® DN 300	288	229	455	406	12	M20
Primus Line® DN 400	357	233	580	521	12	M24

Connector with welded end



mm/bar Dimensions	ø liner		length of connector		ø welded end	
	MD	HD	R1	R2	R1	R2
	D 1 (mm)		L 1 (mm)		D 2 (mm)	
Primus Line® DN 150	134	-	1078	-	168	-
Primus Line® DN 200	183	187	1083	1135	219	219
Primus Line® DN 250	237	241	1083	1138	273	273
Primus Line® DN 300	284	288	1083	1138	324	324
Primus Line® DN 350	312	-	1083	-	356	-
Primus Line® DN 400	354	357	1153	1153	406	406
Primus Line® DN 450	408	-	1153	-	457	-
Primus Line® DN 500	454	-	1153	-	508	-

inch/psi Dimensions	ø liner		length of connector		ø welded end	
	MD	HD	R1	R2	R1	R2
	D 1 (inch)		L 1 (inch)		D 2 (inch)	
Primus Line® DN 150	5.28	-	42.44	-	6.61	-
Primus Line® DN 200	7.20	7.36	42.63	44.68	8.62	8.62
Primus Line® DN 250	9.33	9.49	42.63	44.80	10.75	10.75
Primus Line® DN 300	11.18	11.34	42.63	44.80	12.76	12.76
Primus Line® DN 350	12.28	-	42.63	-	14.02	-
Primus Line® DN 400	13.94	14.06	45.39	45.39	15.98	15.98
Primus Line® DN 450	16.06	-	45.39	-	18.00	-
Primus Line® DN 500	17.87	-	45.39	-	20.00	-

2.3 Performance and Testing

In collaboration with DVGW (German Association for Gas and Water) Primus Line developed the test specification VP 643, which is complemented by a separate factory standard established over the past 10 years. This is the basis for Primus Line's quality measures. Primus Line® is subject to a continuous quality control with opto-electronic measurement tools during the entire manufacturing process. An external test lab strictly monitors the adherence to the guidelines of VP 643 required for obtaining the DVGW type approval certificate in half-yearly inspections.

Primus Line employs various test methods after each production batch to achieve highest quality standards. The data from short-term burst pressure tests allows for a reliable calculation of the maximum allowable operating pressure.

Combined with results from longterm hydrostatic verification Primus Line extrapolates the stress on the liner over a time span of 50 years and verifies its durability.

3. The Primus Line® Advantage

3.1 Suitability of Primus Line®

Currently Primus Line® is more suitable to rehabilitate damaged pressure pipes between DN 150 - DN 500 (6 inches - 20 inches) in diameter with several bends and for installation sections between 300 m and 2,500 m (approx. 1,000 feet - 8,200 feet) in a sensitive or difficult environment quickly and reliably than any other existing system in the world.

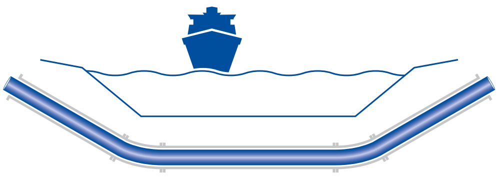
Bend-Traversing Capability

Pipelines often do not run in a straight line. In ailing pipelines this presents an unsolvable task for most pipe rehabilitation systems. With its flexible, multi-layered structure the Primus Liner masters multiple bends of up to 45° with ease. 90° bends can be mastered as well. However any 90° bend has to be evaluated and approved from the technical department.

High-Performance Connectors

Primus Line® connectors are specially developed for the unique system and significantly contribute to its fast installation. They offer an absolutely leak-free and pull-proof connection, a firm assembly onto the host pipe and an easy integration of junctions.

Simple Solution for Inverted Siphons and Difficult Special Projects



A special construction design and/or routing with at least four bends between 0° and 45° and a fast restart of operation are only some of the additional requirements which appear in case of culvert rehabilitation.

In such cases, Primus Line® offers an optimal solution with its characteristics of flexibility, bend traversing capability and simple installation. Other special projects it can be used for are:

- inverted siphons
- bypasses
- pipelines at airports
- chemical plant & refinery pipelines
- pipelines at military bases

Large Lengths Guarantee Cost-Effectiveness in Case of Installation and Transport

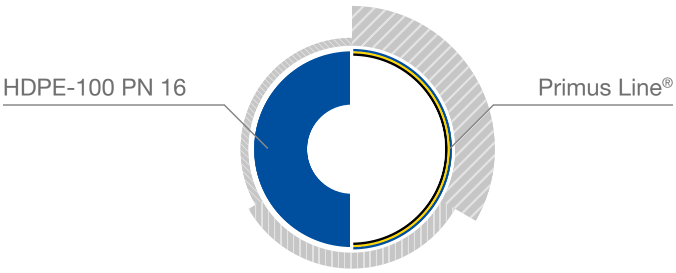
In regard to the installation of the liner and its transport, Primus Line® offers an important characteristic which has significant influence on the cost-effectiveness: the length.

The system allows for unusually large installation lengths of up to 2,500 m (approx. 8,200 feet) which reduce the necessity of construction pits to a minimum and guarantee the lowest possible impact on the environment.

Furthermore, Primus Line® scores with large liner lengths available in one piece on a transport reel (up to 11 m (approx. 36 feet) wide), which enable the transport of up to 5,300 m (approx. 17,300 feet). Together with a reel design that is especially adapted for international shipping by sea and air freight, minimum logistics costs can be achieved.

Hydraulic Capacities for a High Level of Performance on a Long-Term Basis

High-performance pipes and optimum flow-through characteristics are determining factors for the efficiency of line networks and their ability to transport different media rapidly and reliably.



Many rehabilitation methods considerably reduce the inner diameter of a pipeline, which results in a significant loss of hydraulic capacity.

Primus Line® is different: Its small wall thickness of 6 mm to 8 mm (approx. 0.24 inches to 0.31 inches), minimizes the cross-sectional loss and so the capacity of the pipe remains nearly constant. In addition, Primus Line® guarantees improved flow-through characteristics in the pipeline due to the use of optimal materials and ensures the long-term supply by extending the service life of the pipes by at least 50 years.

Protecting Sensitive and Living Environments

Small construction pits, short rehabilitation times and the low level of environmental intervention make Primus Line® the ideal technology for the rehabilitation of defective lines in sensitive areas.

Regardless of whether highly-frequented streets, nature reserves or sites difficult to access are involved, Primus Line® is exactly the right solution. Pipelines can be renovated easily, rapidly and securely and put into operation again within a very short time.

For both residents and nature, the system offers considerable economic and ecologic advantages:

- no disturbance in street, railroad or shipping traffic
- avoidance of traffic jams
- decrease in noise and pollution by emission
- decrease in road-digging work
- low level of impairment to existing structural fabric
- sustainability through use of existing infrastructure (old piping)
- low impact on landscapes and protected areas
- protection of plants and species

The particular suitability for sensitive environments results from the special installation method of Primus Line® and its simple handling. Installation is possible in the most confined spaces and with a low level of machine employment.

3.2 Benefits of the System

1. Safe & Reliable

a. 100% quality control during the manufacturing process and before shipping

b. no curing, steaming or adhesion process

c. independent of weather conditions during the installation

d. 50+ year lifetime

2. Environmentally Friendly

a. small installation footprint

b. small pits and reduction of road work

c. reduced use of machinery

d. reduced impact on traffic

3. Cost-Effective

a. installation speeds of up to 10 m/min (33 feet/min)

b. up to 2,500 m (approx. 8,200 feet) per pull

c. low pre-investment for installers

d. quick recommissioning for minimal time of service interruption

4. Highly Flexible

a. installation through multiple bends of up to 45° (up to 90° after technical clearance)

b. withstands thermal expansion of the host pipe and seismic movement

c. fully flexible seamless woven aramid fabric

d. installation in difficult to access areas

3.3 Most Suited Environments

Pipelines often run through environments that are hard to access. Obstacles to an easy and fast rehabilitation of ageing pipes can be of geographical, economical, architectural or environmental nature.

Primus Line® is the trenchless rehabilitation system of choice to easily overcome those obstacles and is uniquely suited for projects in the following areas:

- airports
- river crossings (inverted siphons)
- military bases
- refineries
- bridge crossings
- railway crossings
- environmentally sensitive areas
- congested cities
- high-traffic areas
- chemical plants
- nature parks

Primus Line is most suitable for…

High-traffic Areas

Airports

Chemical Plants & Refineries

Nature Parks

Military Bases

Siphons

4. Design Guidelines

4.1 General Design

The Primus Line® system can be deployed for pressurized applications only and is not suitable for gravity pipes. The system is installed into an existing host pipe with an annular space. It is operated with a constant, static and homogenous pressure. The Primus Line® system is considered a self-supporting system that accommodates the entire operating pressure independently from the host pipe, however requires the host pipe for external loading. The Primus Line® system is referenced in EN ISO 11295:2017 - Classification and information on design and applications of plastic piping systems used for renovation and replacement. In addition, the Primus Line® system is referenced in EN ISO 11298-1:2018 - Plastic piping systems for renovation of underground water supply networks. Primus Line falls under the product family “lining with inserted hoses”.

4.2 Fluid Compatibility and Chemical Resistance

The Primus Line® system is suitable for the transport of different fluids including, but not limited to, potable water, raw water, brine, natural gas, diesel, and residential waste water. The inner layer of the liner that is in contact with the transported fluid has to be selected according to the attached Chemical Resistance Sheet. Further applications and their suitability have to be reviewed by the manufacturer. The following hygienic certifications and many more are available:


DVGW
CERT
DVGW type examination certificate
DVGW-Baumusterprüfzertifikat
DG-8955BP0476
Field of Application: products of gas supply
Owner of Certificate: Rädlinger primus line GmbH, Kammerdorfer Straße 16, D-93413 Cham
Distributor: Rädlinger primus line GmbH, Kammerdorfer Straße 16, D-93413 Cham
Product Category: tube inside coating procedure: sealing and hose relining procedures for supply pipes (8955)
Product Description: flexible textil-reinforced plastic inliner for pipe-relining of gas high pressure pipes
Model: Primus Line®
Test Reports: type testing: B 20/12/3358 from 17.12.2020 (DBI)
Test Basis: DVGW VP 643 (01.06.2004)
Date of Expiry / File No.: 29.09.2022 / 19-0363-GNV
01.02.2021 Rie A-1/2


CSA Group
Certificate of Compliance
Certificate: 2588210 Master Contract: 257316 (257316)
Project: 70163845 Date Issued: 2017-12-21
Issued to: Raedlinger Primus Line GmbH, Kammerdorfer Str. 16, Cham, Bayern 93413, GERMANY
Attention: Andreas Muehlbauer
The products listed below are eligible to bear the CSA Mark shown with adjacent indicators 'C' and 'US'
Drinking Water NSF/ANSI 61
Issued by: Brook Hatton
PRODUCTS
CLASS - C686105 - BARRIER MATERIALS - NSF/ANSI 61 SECTION 5-Certified to NSF/ANSI 61
Material for use in contact with drinking water only (Cold 23°C).
Primus Line Water Low Pressure System:
DN150-LP
DN150SD-LP
DN200-LP
DN203SD-LP
DN250-LP
DN261SD-LP
DN300-LP
DN350-LP
DN400-LP
DN450-LP
DN500-LP
Primus Line Water Medium Pressure System:
DN150-MP
DQD 507 Rev. 2016-02-18 Page 1


Hygiene-Institut des Ruhrgebiets
Rädlinger Primus Line GmbH, Kammerdorfer Straße 16, 93413 CHAM
TEST CERTIFICATE according to the KTW-Guideline
Product: Primus Line Type G
Test specimen: Pipe segments made of inner hose, intermediate layer and outer hose

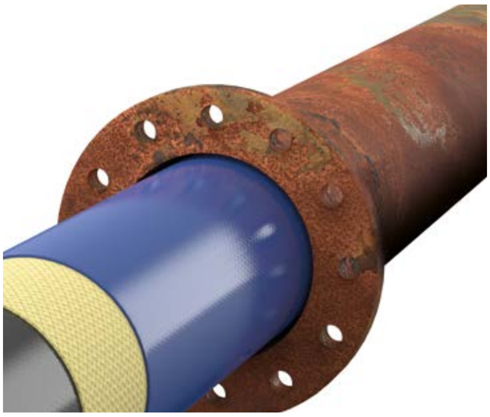

Hygiene-Institut des Ruhrgebiets
Rädlinger Primus Line GmbH, Kammerdorfer Straße 16, 93413 Cham
TEST CERTIFICATE
Enhancement of Microbial Growth on Materials to Come into Contact with Drinking water
Test pursuant to DVGW Technical Standard W 270, November 2007
Client: Rädlinger Primus Line GmbH, Kammerdorfer Straße 16, 93413 Cham
Test material: Primus Line Type G
Test method: Material test

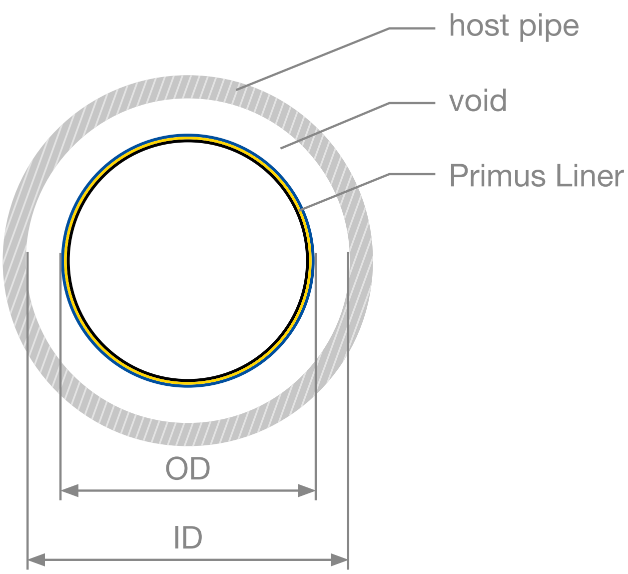

BESTÄTIGUNG - CONFIRMATION
Rädlinger primus line GmbH
Kamerdorfer Str. 16 – 93413 Cham - Deutschland
Primus Line Typ G

4.3 Host Pipe Material

The Primus Line® system can be installed regardless of the host pipe material and is suitable for, including, but not limited to, asbestos cement, concrete, ductile iron, cast iron, PVC, HDPE, and steel. The host pipe has to be able to accommodate all external loading. Internal pressures are completely accommodated by the Primus Line® system. Since the liner works independently from the host pipe with respect to the internal pressure, it can bridge pinholes and gaps. In case of protruding soil, it is recommended to close these areas, for example with patch liners. Protruding ground water will accumulate in the annular space and does not get in contact with the transported fluid since the liner is terminated with the end fittings.

4.4 Annular Space





4.4.1 Host Pipe laid straight

The annular space defined as the void between the inner diameter (ID) of the host pipe and the outer diameter (OD) of the Primus Liner has to be equal to or larger than 1 mm (approx. 0.04 inches) when verifying the continuously free inner diameter of the host pipe with the Primus Line product portfolio.

4.4.2 Host Pipe laid with bends

The annular space defined as the void between the inner diameter (ID) of the host pipe and the outer diameter (OD) of the Primus Liner has to be equal to or larger than 8 mm (approx. 0.31 inches) when verifying the continuously free inner diameter of the host pipe with the Primus Line product portfolio.

A reduction of the hydraulic capacity with the Primus Line® system is also feasible by installing a smaller diameter into an existing larger diameter host pipe.

4.5 Operating Conditions

4.5.1 Operating Pressure

The Primus Line® system requires a minimum operating pressure of 0.5 bar (approx. 7.3 psi) to achieve its full round shape. The system can be designed to accommodate lower sectional operating pressures by installing, for example a siphon so that the liner is continuously filled with the transported fluid. The pressure rating of the Primus Line® system according to the **Product Portfolio** is based on the burst pressure of the system. Long term tests according to ISO 9080 have derived a fabric factor of 2.0 to realise a minimum life span of 50 years. An additional safety factor of 1.25 for water applications and 2.0 for oil and gas applications has been considered.

4.5.2 Different Load Types

Cyclic Loads

The Gas Technology Institute (GTI) based in Des Plaines, IL, United States performed tests on behalf of the US Department of Transportation (DOT) to assess the performance of the Primus Line® system under cyclic pressures.

For the long-term pressure rating, the American Petroleum Institute (API) Recommended Practice 15S for the qualification of spoolable reinforced plastic pipes determines the pressure rating of composite products from a series of stress rupture tests under constant pressures at room temperature and elevated temperature respectively. Based on ASTM D2992 creep failure points are determined from samples failing at durations ranging from 100 hours to 10,000 hours when subject to various constant hydrostatic pressures.

The report shows the effect of cyclic loads on the longevity of the Primus Line® system. The report concludes that the long-term cyclic pressure of the system was about 50% (de-rating factor of 2.0) of the short-term burst strength at about 315,000 cycles at room temperature.

The detailed test report can be accessed via the following link:

Test Report

https://primis.phmsa.dot.gov/matrix/FilGet.rdm?fil=10312&s=EEE58739AE38478EB-118D958E1C3C537&c=1

Collapse Resistance

Primus Line® is considered a flexible liner and has only minimal inherent ring stiffness. The lining material will not fold onto itself, if it is without pressure as per the picture below. In case of external pressure due to a water column, the internal operating pressure needs to be greater to maintain the liner's round shape. If the internal pressure is lower than the external pressure and is not filled with the transported fluid, the liner can be flattened by an external water column. Once the liner is repressurized and exceeds the external pressure, it is returned into its round shape. Water in the annular space can be evacuated through monitoring pipes at the host pipe or by loosening the connector from the flange at the host pipe.

Negative Pressure

The Primus Liner is considered a flexible liner that is installed loose-fit and does not adhere to the host pipe material. The liner is flexible and has only minimal inherent ring stiffness. In case of negative pressure, the liner will be contracted, however turns back into its full round shape with the application of pressure. A test was conducted comparing a virgin sample to a treated sample. (Test Report on page 37) The treated sample was exposed to -0.8 bar (approx. -11.6 psi) of negative pressure for ten minutes and subsequently a positive pressure of 10 bar (approx. 145 psi) was applied for another ten minutes. This cycle was repeated for six times. A subsequent burst pressure was conducted on the virgin sample and treated sample. There was no significant difference in the burst pressure.

In general, frequent exposure to negative pressure shall be avoided. In case of sewer rising mains which work intermittently, back flow prevention valves can be installed so that negative pressure is avoided and the liner is continuously filled with the transported fluid.

4.6 Electrostatics

Electrostatics in pipelines that are transporting gaseous fluids can pose a hazard. GICON, an independent engineering firm was tasked by a natural gas network operator to review the explosion hazard during the operation of a flexible high-pressure liner in natural gas networks.

The report concludes that there is no risk for any hazardous discharge as there is the possibility for charge compensation in the host pipe.

4.7 Operating Temperature

The maximum operating temperature for the Primus Line® system must not exceed 50 °C (122 °F).

4.8 Flow Characteristics

- the recommended flow velocity should not exceed 3 m/s (approx. 9.8 feet/s)
- a free intake or free outflow has to be avoided
- the roughness of the Primus Line® system has been determined by an external institute with k = 0.028 mm (approx. 0.0011 inch)
- the c-Factor of the Primus Line® system has been internally calculated and has a value of 145 - 150 in the permitted area of application

4.9 Permeation

The physical phenomenon of permeation does occur for all existing plastic types; only the degree of permeation is different. Therefore the Primus Line® is applied with the TPU inner layer. Its outstanding permeability resistance is superior in contrast to many other plastic types.

The limited value for the TPU inner layer, based on realistic and achievable values, was fixed in tests with Primus Line® by the DVGW. Furthermore the testing basis VP643 orders, that the permeation of the outer layer has to be at least the decuple of the inner layer. The outer layer has to be more permeable than the inner layer to avoid an accumulation in the reinforcement, which leads to a separation of the outer layer. The limited values are determined in annual tests in compliance with DIN 53536, which regulates the standard conditions with methane as test gas as follows:

determined average permeability coefficient of methane gas inner layer of Primus Line®	0.03 $cm^3 \times m^{-2} \times h^{-1} \times bar^{-1}$
superior acceptance criteria	0.5 $cm^3 \times m^{-2} \times h^{-1} \times bar^{-1}$
determined permeability coefficient of methane gas outer layer of Primus Line®	20.62 $cm^3 \times m^{-2} \times h^{-1} \times bar^{-1}$
lower acceptance criteria	5.0 $cm^3 \times m^{-2} \times h^{-1} \times bar^{-1}$

Example:

The permeability coefficient of methane gas for Primus Line® is specified with 0.03 $cm^3 \times m^{-2} \times h^{-1} \times bar^{-1}$. Consequently the permeability is 0.032 ml/h for 1 meter Primus Line DN 400 (lateral surface of 1.05 m^2) with an operating pressure of 1 bar. Thus the permeability will be 0.8 ml/h if you work with an operating pressure of 25 bar.

4.10 Special Applications

Multiple Liner Solutions

The Primus Line® system can be used to install multiple liners into an existing host pipe. The existing host pipe functions as a conduit and the installed liners can be used to transport different fluids. The liners can accommodate the entire internal pressures independently from the host pipe. Special connectors can be designed for this type of application by the manufacturer.

Reduction of the Hydraulic Capacity

The Primus Line® system can be used to improve the flow properties and quality of the transported fluid by installing a smaller diameter Primus Liner into an existing host pipe. Rededication of existing infrastructure abandoned pipes can be revitalised by installing a Primus Line® system since the system is independent from the host pipe material. Hygienic certifications are available to turn existing pipework into potable water lines.

Double Containment

In case of hazardous liquids or pipelines with a high consequence of failure, the Primus Line® system can be used to provide a second barrier. The pipe-in-pipe approach provides additional safety for the transport of hazardous fluids and the integrity of the installed Primus Line® system can be monitored.

Upgrading Existing Pipework

With increasing demand, higher pressure ratings on existing pipework might be required. Since the Primus Line® system accommodates the pressure rating independently from the host pipe material, a liner with a corresponding pressure rating can be installed to increase the pressure on existing infrastructure.

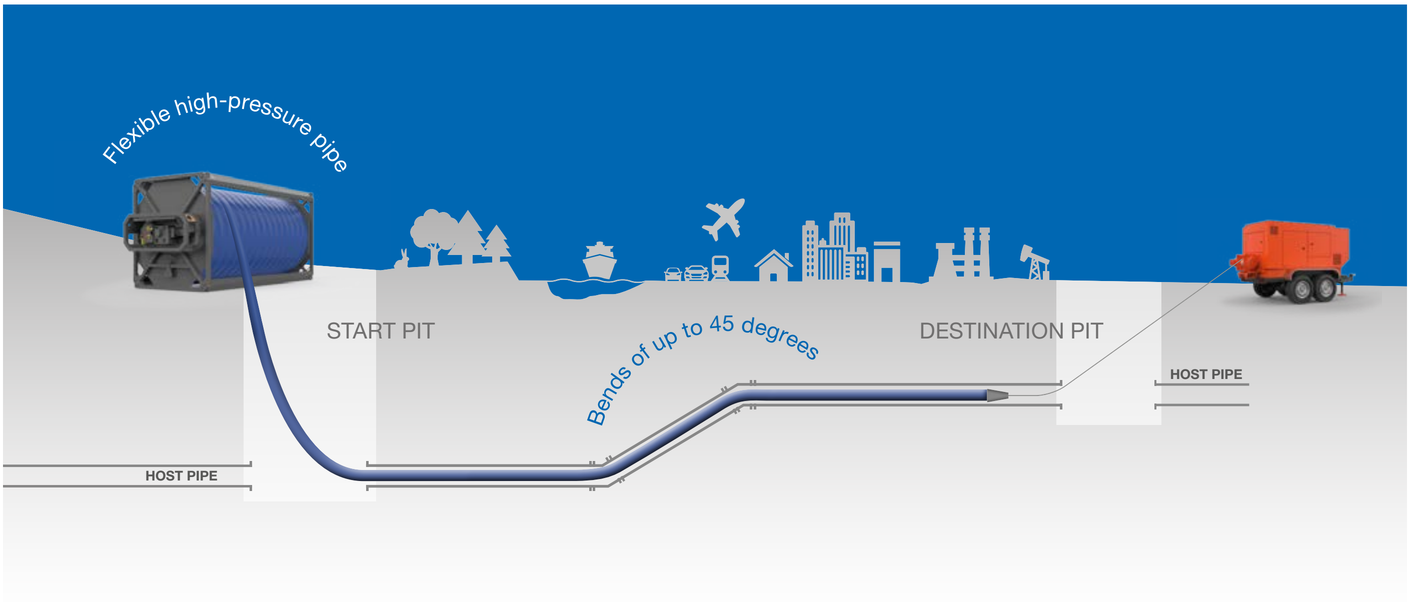
Installation through Bends

The Primus Liner can be inserted through multiple bends of up to 45° with a radius equal or greater than 1.5xD. The maximum continuous operating pressure is reduced in the most significant bend. The pressure reduction for certain projects can be determined with the table in chapter 2.1.3.

Emergency Bypass

In case of a breakdown of critical pipe infrastructure, the Primus Line® system can be deployed as an emergency bypass to continue the supply of potable water to affected residents. The liner can be placed on the ground and the damaged pipe network can be bridged. Due to the reinforcement, the complete operating pressure is accommodated.

5. Installation Process



5.1 Access to the Host Pipe

5.1.1 Pits

Pits are required at the beginning and the end of each rehabilitation section. Pits in between have to be established with the same dimensions.

Key pit details:

- clear workspace of 40 cm (approx. 15.8 inches) underneath the pipe.
- clear workspace of 60 cm (approx. 23.6 inches) on either side of the pipe.
- pipe to be rehabilitated to protrude from the pit wall by not less than 60 cm (approx. 23.6 inches)

The pipe section to be removed inside the pit has to be at least 1.25 m (approx. 4.1 feet) and up to max. 2.75 m (approx. 9 feet) (required workspace) long. The length varies with the system diameter and the number of connectors to be installed (one connector in each pit at starting and end pits, two connectors in intermediate pits). The pits have to be built in compliance with the generally acknowledged and valid codes of technical practice. It is subject to the mandatory industrial accident prevention codes and regulations of construction associations as well as the local standards and safety codes.

5.1.2 Distribution and Valve Pits

The manhole represents either the starting point (inserting the liner) or an intermediate point (pulling the liner through). A manhole at the end pit (pulling the liner out) is generally inconvenient. The liner should be pulled out with the lowest possible angle. The manhole should be replaced with a pit. Additional civil works like core holes or breaking down some of the manhole may be used to prepare the manhole at the end for pulling out the liner. Access to the manhole must be large enough to feed-through the connector flange.

Key details for working inside the manhole:

- clear workspace of 40 cm (approx. 15.8 inches) underneath the pipe.
- clear workspace of 60 cm (approx. 23.6 inches) on either side of the pipe.
- pipe to be rehabilitated to protrude from the manhole wall by not less than 60 cm (approx. 23.6 inches)

In order to create workspace, the host pipe can also be cut off directly at the manhole wall. In that case, the connector will be attached to a plate on the outer sleeve and screwed to the manhole wall.

The pipe section to be removed inside the manhole has to be at least 1.25 m (approx. 4.1 feet) and up to max. 2.75 m (approx. 9 feet) (required workspace) long. The length varies with the system diameter and the number of connectors to be installed (one connector in each manhole at starting and end points, two connectors in intermediate manholes).

Working in the manholes must comply with the generally acknowledged and valid codes of technical practice. All work is subject to the mandatory industrial accident prevention codes and regulations of construction associations as well as the local standards and safety codes.

5.1.3 Pump Rooms

The procedure for pump rooms is equivalent to that of section 6.1.2.

5.2 Cutting the Pipe

The pipes in pits, manholes and rooms are to be cut to a length of at least 1.25 m (approx. 4.1 feet) and not more than 2.75 m (approx. 9 feet) (required workspace). The length varies with the system diameter and the number of connectors to be installed (one connector in each manhole at starting and end points, two connectors in intermediate manholes).

Each pipe cut must be made perpendicular to the pipe axis. It has to be deburred and chamfered at the inner diameter of the host pipe. At each of the cut-off points, both the inner and outer diameter of the pipe have to be measured and documented. The pipe material must be described and documented as well.

5.3 Camera Inspection of Host Pipe Prior to Cleaning

The entire pipe length has to be inspected prior to cleaning the host pipe and inserting the liner. The camera inspection will be recorded and the recording submitted to the customer at the end of the project.

At each of the cut-off points, both the inner and outer diameter of the pipe have to be measured and documented. The pipe material must be described and documented. Both camera inspection and recording/validation will focus on the following points:

- reductions in cross sections caused by incrustations and obstacles protruding into the cross section (sagging weld seam roots, protruding flanges, screws, pins, plugs, fittings or sacrificial anodes).
- sudden changes in cross section (steps)
- direction changes (bends)

Camera inspection results will be taken as the basis of planning how to clean the pipe. Ideally, the project setup includes a camera inspection of the pipe section to be handled already. Apart from inspecting the pipe, the camera will be used to establish a rope connection between the pits.

5.4 Cleaning the Pipe

The goal of the rough cleaning is to provide a free inner diameter of the pipe. Therefor high water pressure cleaning techniques are used. Spring steel scrapers and rubber discs have also shown their support in the rough cleaning process. Pigs can also be sufficient to clean non-metal pipes and pipes with a non-metal internal coating (not including subsequent cement mortar coatings). Stationary obstacles (casting defects, sagging weld seam roots, protruding flanges, screws, pins, plugs, fittings or sacrificial anodes, etc.) protruding from the pipe wall will be removed by removing the pipe section containing the obstacle or by using a milling robot equipped with diamond tools. Weld seams have to be machined until they are perfectly uniform and flat all the way around.

5.5 Camera Inspection of Host Pipe After Cleaning

The entire pipe length has to be reinspected after cleaning and before inserting the liner. The camera inspection will be recorded and the recording submitted to the customer at the end of the project. Both camera inspection and recording/validation will focus on the following points:

- cross section after cleaning: free from reductions in cross section caused by incrustations and obstacles protruding into the cross section (sagging weld seam roots, protruding flanges, screws, pins, plugs, fittings or sacrificial anodes).

- maximum cross-sectional jumps or maximum mismatch of pipe joints: At and near a cross-sectional jump, the minimum width to be obtained is the outside diameter of the fitted liner.
- direction changes (bends): detection of the bend radius; the bend to negotiate must have a minimum radius of not less than 1.5xD. Liner installation and subsequent application of operating pressure supports a maximum of 45° bends.

5.6 Inserting of the Liner

The liner is folded by the manufacturer and its U-shape is maintained by adhesive tape. The U-shaped and folded liner is spooled onto transport reels (max. outside diameter: 2.5 m (approx. 8.2 feet), drum shaft diameter: 1 m (approx. 3.3 feet) and placed at the starting pit of the section. Depending on the reel weight and length, either unwinding rails or unwinding stations are used to unwind the liner from the reels.

A winch is placed at the destination pit of the pipe section. From there, the rope of the winch is pulled through the pipe to the pit at the starting point. Depending on the liner diameter, the length of liner to be inserted and the bends in the section, either a rope or a pulling head is attached to insert the liner. The rope or pulling head is connected to the rope of the winch.

To prevent the liner from twisting while being inserted, an anti-twist device is installed between the rope (or pulling head) and the rope of the winch. On straight sections, the liner can be inserted with speeds of up to 10 m (approx. 32.8 feet) per minute. When going through bends, the insertion speed is to be reduced to not more than 5 m (approx. 16.4 feet) per minute. Inserting the liner is complete when at least 3 m (approx. 9.8 feet) of tensionless liner after the rope or pulling head come to rest in the destination pit.

5.7 Inflating the Liner by Means of Compressed Air

In order to inflate the liner or to give it its final round shape, sealing balloons are used to close the beginning (pit 1) and end (pit 2) of the liner. One of the sealing balloons features a bypass. Oil-free compressed air has to be blown into the bypass and from there into the liner. At an internal pressure of 0.5 bar (approx. 7.3 psi) or higher, the adhesive tapes (maintaining the U-shape) begin to break. All of the tapes will have opened at a maximum internal liner pressure of 1 bar (approx. 14.5 psi). After inflating the liner, the liner can be cut to a length of 1 m (approx. 3.3 feet) projecting the host pipe in both the starting and destination pits. The 1 m (approx. 3.3 feet) of projecting end of liner is required to install the connectors.

5.8 Installing the Connectors

A two-piece design of connector is used. The liner is mechanically jammed-in between an outer sleeve and a connector core. The outer sleeve is fitted with a flange and is screwed to the flange of the host pipe. The outer sleeve may also be welded to the host pipe if the host pipe is made of weldable steel. After attaching the outer sleeve, the liner is cut directly at the edge of the sleeve. Either a flange or a welded end is attached to the connector core which is inserted in the liner or the outer sleeve. Like this, the adapter (i.e. the link between the rehabilitated section and the adjoining pipe) can be screwed or welded to the connector core. The connectors provide a permanently sealed connection between the rehabilitated pipe section and the adjoining pipe section.

5.9 Pressure or Leak Test

To perform the pressure or leak test, a blind flange is used to close the flange at the connector core. Another option is to use a dished boiler end to close the welded end of the connector core. The connectors need to be safeguarded with reference to the horizontal forces resulting from the test pressure that the sample was exposed to. Any known method of leak-testing metal and non-metal pipes may be used to test the liner.

Water liners and oil liners are tested by using potable water.
Gas liners are tested by using compressed air.

6. References

Primus Line has grown tremendously since its foundation. Several hundred kilometres/miles of liner have been installed for satisfied customers in more than 50 countries around the globe. Several of these rehabilitated pipes have been renewed with the Primus Line® system more than 15 years ago and are still going strong for at least another 40 years of service.

At its core Primus Line® is a technology for the rehabilitation of host pipes carrying varied types of water, gas or oil. But as a result of its unique properties the system is capable of a much wider variety of applications.

In Lismore, Australia Primus Line® not only renewed a failing water main but at the same time upgraded its pressure rating from 9 bar to 16 bar (approx. 131 psi to 232 psi). The strong, self-supporting structure of the Primus Liner does not just allow for such upgrades but also for its use outside of a host pipe. In Messina an emergency bypass with three DN 300 (12 inches) liners – laid above-ground along a hillside – restored the city's water supply in just a few days after a landslide had damaged a DN 1000 (40 inches) steel water pipeline. The compact Primus Line transport reels help immensely in bringing liners to such hard to access places. While in Messina a chain dredger brought the reels up the steep climb, in Spain they actually were flown to a mountain by helicopter. These reels are available in different sizes up to a length of 11 m (approx. 36 feet) and can hold 5,300 m (approx. 17,300 feet) of liner at once, significantly reducing transport costs.

In some cases not the location but the pipeline itself is hard to access or runs in a particularly complex way. The Primus Liner is very flexible and can easily negotiate bends of up to 45° within a pipe as well as obstacles outside a pipe. For projects in Norway, Spain and the USA the liner was first inserted through existing inspection pits before being pulled through the host pipe, completely foregoing any earth-works. In a majority of cases earthworks are still unavoidable even for trenchless technologies. Primus Line® requires only few construction pits with a very small footprint, minimising the environmental impact of a pipeline rehabilitation. Traffic in densely packed urban areas like Brussels went on unhindered, and protected, decade-old olive groves in Turkey were preserved while ageing pipelines got an extended service life.

Conducive to the overall small footprint is a reduced machine employ-ment. Combined with insertion lengths of 2,500 m (approx. 8,200 feet) in one pull makes Primus Line® an excellent solution for rehabilitating underwater pipelines. After the renewal with the system, a diesel pipeline in the southern Mediterranean Sea is now well protected both from salt water on the outside and the diesel flowing through due to the Primus Liner's high resistance to various types of corrosion.

Primus Line® is a highly versatile system for a wide range of appli-cations that keeps growing constantly – not least due to customised designs developed for specific customer needs.

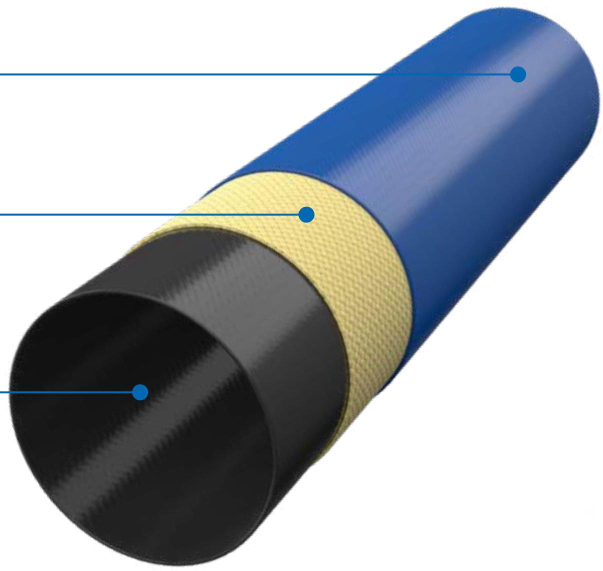
For additional references, please refer to our website:
https://www.primusline.com/en/applications/references

Chemical Resistance - Primus Line® system

The system Primus Line® consists of liner and connector. The inner layer of the liner as well as the connector coating are the layers which are in direct contact with the transported media.

Primus Liner

Type: ND, MD, HD



Outer Layer:

- made of polyethylene (PE) for protection from external effects during transport and installation

Reinforcement :

- made of one- or two-layered aramid fabric, depending on the required pressure rating

Inner Layer:

- made of polyethylene (PE) or thermoplastic polyurethane (TPU), dependent on the medium
- PE Water
- TPU Gas
- TPU Oil
  (applicable for aliphatic hydrocarbons and aqueous solutions)

Primus Line Connector

Type: M-Connector, R-Connector

Type 1: M-Connector with two flanges

field of application	water
connector+flange	made from cast iron or carbon steel
flange compatible with	EN 1092
coating	Resicoat

Type 2: R1-Connector with two flanges

field of application	water / oil
connector+flange	made from cast iron or carbon steel
flange compatible with	EN 1092
coating	Resicoat

Type 3: R2-Connector

field of application	water / oil
connector+flange	made from carbon steel and stainless steel (1.4462)
flange compatible with	EN 1092
coating (external sleeve)	Resicoat

Type 4: R-Connector with welded end

field of application	gas
connector+flange	made from carbon steel
coating	without

The information given in the following tables 1-3 is based on immersion tests without mechanical stress and corresponds to the current level of knowledge and experience.

Additional parameters like higher concentrations and temperatures and in particular the mixture of different media, leads to new assessment criteria.

As a result of our ongoing development work, we reserve the right to modify products and change the features of the products.
The information, recommendations and suggestions provided in this document cannot be used to derive any legally binding assurance or warranty for certain properties or the suitability of the product for a specific application.

The information regarding the chemical resistance refers to an operation temperature of 20°C.

Media not listed in the tables below can be reviewed by Primus Line's technical department upon request.

Status 05/2021

Table 1	
field of application: water	Inner layer PE
Medium	
Drinking water	resistant
Supply water	resistant
Process water	resistant
Treated waste water	resistant
Residential Waste Water	resistant
Industrial waste water	examination technical department
Seawater	resistant
Saturated brine	resistant
Chlorine water (2.5ppm chlorine)	resistant

Table 3	
field of application: gas	Inner layer TPU
Medium	
Natural gas	resistant
Coke oven gas	resistant
Methane	resistant
Propane	resistant
Butane	resistant
Hydrogen	examination technical department
Nitrogen	resistant
Carbon dioxide	resistant
Carbon monoxide	resistant
Oxygen	resistant
Hydrogen sulphide	not resistant
Biogas	not resistant

Table 2	
field of application: oil	Inner layer TPU
Medium	
Diesel	resistant
Kerosine/ Jet A-1	resistant
Heavy oil	resistant
Avgas	resistant
Hydraulic oil	resistant
Crude oil	examination technical department
Heating oil	examination technical department
Mogas	not resistant
Biodiesel	not resistant
Wide Light Hydrocarbon Fraction	examination technical department
Gasoil	examination technical department
Pygas	not resistant
Chlorine water (1.5ppm chlorine)	resistant

Including also media analogous table 1

Including also media analogous table 3

Expertise

Resistance of the flexible sliplining system Primus Line® against temporary vacuum

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Provided by:

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Leipzig, 08.03.2017

This expertise consists of 3 pages.

selle consult

1 References

[1] EN 11295. (August 2010). Classification and information on design of plastics piping systems used for renovation (ISO 11295:2010)

[2] EN 805. (September 2000). Water supply - Requirements for systems and components outside buildings

[3] EN 1990. (July 2002). Eurocode - Basis of structural design

[4] Test report of Rädlinger primus line GmbH, vacuum tests, 15.09.2011

[5] Inspection report of Bureau Veritas with regard to test report [4] of September, 19th 2011

2 Expertise

Rädlinger primus line GmbH is successfully engaged in renovating pressure pipes for various media since about 20 years.

Basis for the renovation technique is the Primus Line® system, a flexible fabric tube with specially developed end fittings being slip-lined into host pipes. The reinforced liner consists of a flexible Kevlar® fabric, or a mixed polyester and Kevlar® fabric, respectively, to which an inner and outer layer made of polyethylene or polyurethane is added during production. Fittings are made of cast iron or steel. Applications cover a range from nominal diameters of DN 150 to DN 500.

Within current editing of EN 11295: 2010 [1] this renovation technique will be included in the standard named as “slip-lining with flexible hoses”.

One application of Primus Line® is renovating water pipes based on EN 805:2000 [2]. This standard specifically includes renovation measures. In the chapter about structural design, the following requirement for structural integrity is given: pipes shall be designed in a way that they can withstand a temporary vacuum on 80 kPa.

Interpretation of this requirement is to be based on EN 1990:2010 [3]. For given loads in certain applications, construction products shall not be transformed into a state, where they can no longer fulfill its design requirements. Thus, the requirement of EN 805:2000 [2] is not to be understood in the way that a liner should retain its circular shape also under vacuum, as this shape is present in service state under pressure. That is, because Primus Line® is designed in the fashion, that the liner loses its circular shape without pressure since it has no ring stiffness. It will directly go back into circular shape under pressure.

The remaining question is, whether a temporary vacuum will transform the liner into a state, where it will no longer fulfill its design requirements, i. e. primarily a long term resistance against pressure.

Against this background, Rädlinger primus line GmbH conducted vacuum tests with liners, in order to investigate a possible influence of repeated vacuum of 80 kPa on the burst pressure behavior of the system [4], [5]. As a result of the tests no reduction to mechanical properties could be observed.

With regard to the technology aspect, during installation of the system adequate measures have to assure that no external pressure is hindering the expansion of the liner due to internal pressure up to the circular shape. This external pressure can be relevant for example in renovations with leaky host pipes under the groundwater table. In these cases Rädlinger primus line GmbH has two specific installation methods which are described in the installation manual.

On one hand all systems will be designed to a service pressure being higher than a potential external pressure. On the other hand specific measures are implemented in leaky host pipes to guarantee streaming out of water from the annulus space while the liner is expanding. Such a measure could be for example installing release valves in the host pipes.

As a conclusion the statement can be made, that the system Primus Line® is designed in the fashion, that it withstands a temporary vacuum of 80 kPa. Structural integrity is compliant with requirements of EN 805:2000 [2].

Notes

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