

DEP SPECIFICATION

THERMOPLASTIC LINED PIPELINES FOR ONSHORE USE

DEP 31.40.30.34-Gen.

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DESIGN AND ENGINEERING PRACTICE



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the materials selection, design, and manufacture of thermoplastic liners as applied to onshore carbon steel pipelines and flowlines.

In the context of this DEP, a liner consists of a number of thermoplastic pipe lengths, which are fused together into sections of up to approximately 1 km (0.6 mi). After pressure testing, the section of liner is inserted into a pre-welded carbon steel pipeline or flowline section. The carbon steel pipe provides the pressure containment and the liner, the internal corrosion protection. At the ends of the section the liner is terminated in a thermoplastic flange or other (usually mechanical) connection system, to enable sections to be joined together.

This DEP covers both buried and above-ground applications. Within certain limitations, thermoplastic lined pipelines and flowlines may be used in oil, gas or water service.

Specific services addressed in this DEP are:

- a. Natural gas with hydrocarbon condensates, including multiphase (The presence of hydrogen sulphide in the gas heavily influences the type of annular gas management that can be used);
- b. Gas without hydrocarbons (a rare situation);
- c. Liquid systems with greater than 0.5 % hydrocarbons and without free gas;
- d. Liquids with less than 0.5 % hydrocarbons and without free gas (This is primarily fresh water service).

The liners covered in this DEP are based both on currently applied thermoplastic materials and on those materials that have the potential to be applied in future, more demanding applications. It applies to both smooth wall liners and liners with manufactured external grooves.

This DEP addresses only the thermoplastic liner. The carbon steel pipeline or flowline into which the liner is to be inserted is covered in DEP 31.40.00.10-Gen.

Factory-applied liners inside steel pipe and fittings are covered by DEP 31.38.01.11-Gen.

The following topics are not covered in this DEP:

- Hose lining techniques, using polyester materials with fibre tubes and epoxy to bond these to the pipe wall.
- Pipelines lined with thermoset materials such as GRE (glass fibre reinforced epoxy)

This is a revision of the DEP of the same number dated December 1999; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorisation to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in onshore facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing.. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the

requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

NOTE: The project may involve both a primary Contractor and a liner Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
Acceptance criteria	Defined limits placed on characteristics of materials, products or services.
Annulus	Liner annulus means the interstitial space that exists between the liner outside surface and the steel carrier pipe internal surface.
Bell hole	Excavated area allowing access to a buried carbon steel pipeline, e.g., for insertion of a section of thermoplastic liner.
Butt fusion welding	A process of fusing thermoplastic materials that entails squaring and aligning the pipe materials, heating the pipe ends, bringing the two aligned pipe ends together under pressure and a predetermined cooling time resulting in a fused joint having a hydrostatic strength equal to the parent pipe.
Hydrocarbon service	Fluids containing hydrocarbons (crude oil). Note that water with small amounts of hydrocarbons shall also be designed equal to hydro carbon service.
Flanges	Face flanges with a bolt circle according to ASME B 16.5 or ASME B16.47, including thermoplastic flanges with metallic backup rings.
Groove	An external groove that is manufactured at the liner pipe Manufacturer plant, on the liner pipe external surface.
HDPE	High Density Polyethylene liner pipe material
Inspector	Individual designated by the Principal to act on behalf of the Principal for monitoring Contractor's quality control testing and technical acceptance.
Liner Contractor	Liner Contractor (see 1.3.1) means a Principal approved contractor who is responsible for the liner installation in accordance with this specification that includes as a minimum the design, supply, assembly, installation and quality assurance of the non-metallic liner.
Modulus	Elastic modulus: proportionality constant between applied stress and strain.

Term	Definition
Ovality	This is a measurement of the deflected set in a cross-section of pipe and is expressed as a percentage. It is measured by taking the maximum measured diameter minus the minimum measured diameter (the out-of-roundness value) and dividing that sum by the average measured diameter and multiplying that result by 100.
PA liner	Liner based on Polyamide in combination with fillers and plasticisers.
PA-11	Polyamide 11 pipe material
PA-12	Polyamide 12 pipe material
PE liner	Liner based on Polyethylene in combination with fillers and plasticisers.
PE	High-density polyethylene liner pipe material. Often used as generic name for MDPE, HDPE, XLPE/XPE/PEX, PE-63, PE-80, and PE-100.
Primary Contractor	A contractor, other than the liner Contractor, who has been designated by the Principal as responsible for certain aspects of the overall liner project including activities such as excavations, steel flange installations, steel pipeline cleaning, preparation for lining, installation of vent station piping, pressure test implementation, etc. (See 1.3.1)
Permeation	Gradual diffusion of liquid and gas through a thermoplastic layer under the influence of pressure.
PEX	PEX (also indicated as XPE or XLPE) is a cross-linked high-density polyethylene pipe material.
Records	Retrievable information.
Standard Dimension Ratio (SDR)	A specific ratio of the average specified outside diameter to the minimum specified wall thickness (OD/t) for outside diameter-controlled plastic pipe. The SDR is sometimes referred to as DR ratio.
Thermoplastic materials	Plastic materials, which retain their mechanical properties after heating and cooling.
Vent	A vent in a lined pipeline system is a hole that is drilled through the steel pipe to allow passage of any permeated gases or liquids or to monitor pressure build-up in the liner annulus. The liner integrity is determined by monitoring of any pressure accumulations at the vent holes.
Vent connection or point	Hole in the carbon steel outer pipe to allow the release of gas accumulated in the annulus between the liner and the carbon steel pipe.
Venting	The release of gas accumulated in the annulus between the thermoplastic liner and the carbon steel pipeline.
Water service	Water containing no hydrocarbons. Water containing even low hydrocarbon concentrations shall be treated as hydrocarbon service.
XLPE	XLPE (also indicated as XPE or PEX) is a cross-linked high-density polyethylene pipe material.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets (). Other documents referenced by this DEP are listed in (7).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated December 1999. The following are the main, non-editorial changes.

Section	Change
All	Full integration of the previous DEP 31.40.30.34-Gen. and the following Canadian engineering documents: • “Selection and design of thermoplastic liners for pipelines”, Material and equipment standard 3.1.24. • “Polyethylene pipeline liners - Manufacturing”, Material and equipment standard 3.2.24. • “Polyethylene pipeline liners – Installation”, Material and equipment standard 3.3.24. HDPE liner qualification adopted from DEP 31.40.20.39-Gen.
All	Split into DEP Specification and Informative

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the “Give feedback” link, fill in the online form and submit.
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DEP Standard Form (Other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com.

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

2. SELECTION PROCESS

2.1 DECISION TO USE A LINER

The decision to design and install a thermoplastic liner in a new pipeline shall be based on the evaluation of numerous factors including:

- a. Comparison of the lifecycle operating costs of the pipeline with and without a liner. This includes any maintenance, inspection and corrosion management costs.
- b. Cost of the liner installation, which is determined by the type of liner chosen. This includes any facilities required for dealing with gases vented from the annulus.
- c. Cost of maintaining the liner system.
- d. Regulatory requirements with respect to activities on the pipeline right-of-way, flaring or venting activities, allowable pipeline damage, etc.

Installing a thermoplastic liner in an existing pipeline normally means that the existing corrosion mitigation procedures used in maintaining the integrity of that pipeline were inadequate or uneconomic. For retrofitting, the same factors listed above for the new pipelines are valid. An additional consideration is the cost of replacing the existing pipeline prematurely.

The following sections describe various scenarios and liner designs. that lead the liner designer through a stepped process to select the liner material and appropriate liner design basis that will enable an initial liner design.

2.2 LINER MATERIAL SELECTION

This DEP covers liner systems commonly used for oil, gas and water service. For these specific applications, the most common liner material is polyethylene.

For other polymer liner materials, refer to DEP 30.10.02.13-Gen., which provides detailed material information, temperature limits for different operating services, chemical compatibility with service fluids and mechanical and physical properties.

2.2.1 Polyethylene liners – Operating experience envelope

Operating experience with HDPE has been build up within Shell for many years, and shall be selected as the base case material for liner applications.

The use of alternative polymers may be considered, but a materials specialist of the Principal shall be consulted for feasibility.

All pipe and fittings supplied shall be manufactured from high density polyethylene material compounds with one of the following designation codes; see DEP 31.40.20.39-Gen:

- a. PE 3608;
- b. PE 4710;
- c. PE 80, or;
- d. PE 100.

XPE/XLPE has a maximum temperature limit, but has not been tested as extensively as HDPE. To date, XPE/XLPE has not been used within Shell for liner applications.

The use of XPE/XLPE may be considered, if higher operating temperatures or increased collapse resistance is required. A materials specialist of the Principal shall be consulted for feasibility or other options. Classification and qualification of XPE/XLPE is not covered in DEP 31.40.20.39-Gen.

The current temperature experience envelope for HDPE is provided in Table 2.1. The data for XPE/XLPE if provided for information purposes only.

Table 2.1 Liner selection based on maximum temperature

	Maximum Operating Temperature ²⁾ , C			
	Gas	Multiphase	Liquid HC	Liquid H ₂ O
		With free gas	No free gas	No free gas
HDPE	50 °C (120 °F)	50 °C (120 °F)	60 °C (140 °F)	60 °C (140 °F)
XLPE	60 °C (140 °F)	60 °C (140 °F)	80 ¹⁾ °C (175 °F)	80 ¹⁾ °C (175 °F)

- NOTES:
1. For greater than 60 °C (140 °F), the Principal's materials specialist shall be consulted to verify compatibility.
 2. Recent research within Shell showed that the use of HDPE (PE 100) at higher temperatures is feasible from a collapse design point of view. If the operating temperature of the pipeline is above that listed in Table 2. 1, a materials specialist of the Principal shall be consulted for options.

3. DESIGN OF THE LINER SYSTEM

3.1 RESPONSIBILITIES

The final design of the liner shall be the responsibility of the liner Contractor.

If annular gas management requires venting, flaring or scrubbing of annular fluids, the design of the necessary facilities shall be the responsibility of the primary Contractor.

3.2 CONCEPTUAL DESIGN

There are three (3) basic types of liner design that shall be considered for installation:

Type I	Inherently collapse resistant liner
Type II	Limited collapse resistant liner with an operational pressure control
Type III	Grooved liner with (active) venting

The design philosophy is described in (3.2.1), (3.2.2) and (3.2.3).

3.2.1 Type I: Inherently collapse resistant liner

Type I is a smooth, thick, liner that withstands a full depressurization of the pipeline system from line pressure without radial or axial collapse of the liner. This liner system is designed to operate with full line pressure in the annulus with temporary line pressure fluctuations and therefore requires no periodic annulus venting for maintenance of annulus pressure, even during a temporary full pipeline depressurization.

Venting is required if the pressure drop exceeds 40 % of the line pressure for more than one (1) day. Further, venting is required for periodic checks of liner integrity to ensure no liner leaks or breaches. The frequency of these checks will depend on the severity of potential corrosion but should be done on an annual basis as a minimum.

Gas free liquid lines shall be a type 1 design and shall be designed against full vacuum collapse with a safety factor $SF = 1.5$.

$$P_{crit,rad} \geq 1.5 \times P_{vacuum} \quad \geq 1.5 \times 0.1 \text{ MPa} \quad \geq 0.15 \text{ MPa (22 psi)}.$$

Where:

P_{crit} is the critical radial or axial critical collapse pressure whichever is the smallest.

P_{vacuum} full vacuum condition (max surge condition) set at 0.1 MPa (15 psi).

For (associated) gas service, the liner shall be designed to be able to withstand a differential pressure equal to the bore pressure conditions, equal to the sum of the partial gas pressures (multiphase service), or full bore gas pressure (gas service) with a safety factor $SF = 1.5$.

$$P_{crit} \geq 1.5 (P_{differential})$$

Where:

$P_{differential}$ is the differential pressure between annulus and bore.

For gas service, this is the full bore pressure.

Note: If surge conditions can occur, this need to be added to the differential pressure $P_{differential}$.

For multiphase service, this is the sum of the partial pressures of the gasses present in the fluid.

NOTE: If surge conditions can occur, this need to be added to the differential pressure $P_{differential}$.

The equations for the critical collapse pressure P_{crit} are discussed in (3.3).

NOTE: Besides the radial collapse, the liner needs to be designed against axial collapse as described in (3.3.2).

Where a Type I system is not practical, then a Type II system shall be considered (but not recommended for liquid service).

3.2.2 Type II: Limited collapse resistant liner with an operational pressure control

A Type II liner is a smooth, thick liner that withstands a planned and temporary maximum line pressure fluctuation without radial or axial collapse of the liner for multiphase or gas systems. The pressure fluctuation is some fraction of the total line pressure. Although this liner system is designed to operate with full line pressure in the annulus, an operational control of pressure fluctuation is required. Within these controlled temporary pressure fluctuations of less than 40 % of the maximum allowable fluctuation, no periodic annulus venting for maintenance of annulus pressure is necessary. Venting is necessary if the temporary pressure fluctuation exceeds 40 % of the maximum allowable fluctuation for more than one day.

$$P_{\text{crit,rad}} \geq SF \times P_{\text{max fluctuation}}$$

Where:

$P_{\text{crit,rad}}$ = critical radial liner collapse pressure

$P_{\text{max fluctuation}}$ = maximum allowable pressure fluctuation

SF = safety factor (default = 1.5)

Example:

Assume a design pressure of 4 MPa (40 bar)

By design (as an example):

Maximum allowable fluctuation = 1 MPa (10 bar)

Venting required at fluctuation of $0.4 \times 1 \text{ MPa} = 0.4 \text{ MPa}$ (4 bar)

Vacuum collapse pressure = 0.1 MPa (if applicable)

Liner shall have a minimum collapse resistance of:

$$P_{\text{crit}} \geq SF \times (1 + 0.1) \text{ MPa} = SF \times 1.1 \text{ MPa}.$$

NOTES: a) If applicable, the liner also needs to be designed against vacuum collapse, i.e., in case of a surge condition (liquid service) a negative pressure of – 0.1 MPa could occur. The 0.1 MPa needs to be added to the maximum pressure fluctuation, as indicated in the example above.

b) Besides the radial collapse, the liner need to be designed against axial collapse as described in (3.3.2).

NOTE: If the line pressure in a system is expected to decline with time, it is possible to move operational requirements of a higher type liner system to a lower one. For example, if the maximum line pressure in a Type II system drops to the maximum allowable fluctuation, then the system essentially has become a Type I system and Type I operational procedures can be used.

3.2.3 Type III: Grooved liner with active venting

A Type III liner is an externally (grooved), thick, tight liner that is periodically or continuously vented for multiphase or gas systems. Without venting this system cannot withstand the normal operational pressure fluctuations if a high pressure is allowed to develop in the annulus. The annulus pressure expected in the grooves is dependent on the line pressure. This design can withstand a full line depressurization with an annulus pressure below a critical annulus pressure for collapse or the maximum allowable annulus pressure. The annulus in this liner system shall be periodically or continuously depressurized to maintain the annulus pressure below the allowable annulus pressure at all times. For line pressure drops to below 60 % of the maximum allowable annulus pressure, venting is required for periodically vented systems. Since there is frequent depressurization of the annulus, the resulting annulus gases shall be managed.

Although there are various possible schemes (such as reinjection or flaring), the current practicable option is to vent the annular gases. For sour pipelines, the annular vent gases shall be scrubbed for H₂S with a scrubber system.