

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, flowlines and piping.

This DEP covers both buried and above-ground applications.

Specific services addressed in this specification are:

- Water service: total hydrocarbon fraction does not exceed 0.5 vol % of total fluids and no gas phase is present.
- Hydrocarbon and multiphase services, including live crude oil and gas applications. For the purpose of this specification hydrocarbon service is defined the total hydrocarbon fraction exceeding 0.5 vol % of total fluids.
- Natural gas with hydrocarbon condensates, including multiphase; gas without hydrocarbons.

The liners covered in this DEP are based on:

- Currently applied thermoplastic materials.
- Smooth wall liners.
- 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.

This is a revision of the DEP of the same number dated February 2013; see (1.5) regarding the changes.

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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.

In this DEP, the Contractor is also referred to as the **Primary Contractor** to differentiate from the Liner Contractor as defined in (1.3.2).

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.

The word **may** indicates a permitted option.

1.3.2 Specific definitions

Term	Definition
Acceptance criteria	Defined limits placed on characteristics of materials, products or services.
Annulus	Liner annulus is the 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.
Elastic Modulus	Proportionality constant between applied stress and strain.
Groove	An external groove that is manufactured at the liner pipe Manufacturer/Supplier plant, on the liner pipe external surface.
HDPE	High Density Polyethylene; used for liner pipe material.
Hydrocarbon service	Fluids containing hydrocarbons or water with hydrocarbons.
Hydrostatic Design Basis (HDB)	The categorized long-term hydrostatic strength (LTHS) in the circumferential or hoop direction, for a given set of end use conditions, as established by ASTM Test Method D 2837. The HDB is one of a series of established stress values (specified in Test Method D 2837) for a plastic compound.

Term	Definition
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 refer (1.3.1) is a Principal approved Contractor responsible for the liner installation in accordance with this specification, deemed to be competent in the design, supply, assembly, installation and quality assurance of the non-metallic liner.
LTHS	Long Term Hydrostatic Strength
Multiphase	Fluid containing a mix of different phases or fluid components. In this DEP Multiphase will mean that at least one of the components is a gas.
Ovality	This is a measurement of the dimensions 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	Generic group name of polyethylenes that come in different grades like MDPE, HDPE, XLPE/XPE/PEX, or strength classes like: PE-63, PE-80, and PE-100.
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.
5% Secant Modulus	Ratio of stress to strain at the 5% strain point on curve in a stress-strain diagram.
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 within certain limits.
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 any pressure accumulations at the vent holes.

Term Definition

Water service A pipeline may be considered in water service for the purpose of this specification if the total hydrocarbon fraction does not exceed 0.5 vol.% of total fluids and no gas phase is present.

XLPE XLPE (also indicated as XPE or PEX) is a cross-linked high-density polyethylene grade.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause 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 full revision of the DEP of the same number dated February 2013. The following are the main, non-editorial changes.

Section/Clause	Change
2	Rewritten and changed temperature limits.
3	Extensive rewrite and added requirements for approval.
4	Extensive rewrite and added tables.
5	Extensive rewrite.
6	Rewritten – removed operational instructions and focus on project handover to operations.

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.

1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

2. SELECTION PROCESS

2.1 DECISION TO USE A LINER

1. The decision to design and install a thermoplastic liner in a new pipeline should be based on the evaluation of numerous factors including the following:
 - a. Comparison of the total lifecycle costs of the pipeline with and without a liner.
This includes design- installation- procurement- maintenance-, inspection- and corrosion management costs.
 - b. Cost of the liner installation.
This depends on the type of liner chosen. This includes any facilities required for dealing with gases vented from the annulus.
 - c. Regulatory requirements with respect to activities on the pipeline right-of-way, such as flaring or venting activities, allowable pipeline damage.
 - d. Competency of the liner contractor.
2. For retrofitting of a thermoplastic liner, the evaluation listed in (2.1, item 1) should be carried out in addition to an evaluation of the cost of premature pipeline replacement.
 - a. In case of permeation of highly corrosive fluids such as H₂S or CO₂, a corrosion assessment of the annulus should be carried out, see (3.5).
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. An additional consideration is the cost of replacing the existing pipeline prematurely if corrosion control of the unlined pipe system is ineffective.

2.2 LINER MATERIAL SELECTION

1. All pipe and fittings supplied shall be manufactured from high-density polyethylene material (HDPE) PE 100.
 - a. The qualification of the liner material shall comply with DEP 31.40.20.39-Gen.
2. Application of HDPE shall be within the maximum design temperature given in Table 1.

Table 1 Liner selection based on maximum temperature

	Maximum Design Temperature			
	Gas	Multiphase	Liquid HC	Liquid H ₂ O < 0.5% HC
		With free gas	No free gas	No free gas
HDPE	50 °C (122 °F)	50 °C (122 °F)	65 °C (149 °F)	70 °C (158 °F)

3. If the design temperature of the pipeline is above that listed in Table 1, application shall be subject to approval of the Materials & Corrosion Technical Authority of the Principal and based on an assessment of the collapse resistance of the material at the design temperature and fluid exposure.

3. DESIGN OF THE LINER SYSTEM

3.1 GENERAL

The design of a polymer lined system is determined by chemical compatibility of the polymer liner with the fluids to be transported, the operating installation methodology and pipe hydraulics. Wall thickness is dominated by the required collapse resistance of the liner.

3.2 RESPONSIBILITIES

1. The final design of the liner shall be approved by the designated Technical Authority as follows:
 - a. Collapse calculations to be subject to approval by the Materials & Corrosion Technical Authority of the Principal.
 - b. Mechanical calculations, pull forces and flow calculations to be subject to approval by the Pipelines Technical Authority of the Principal. (TA2) for pipelines.
2. 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.

3.3 FLOW

3.3.1 Flow capacity

A smaller standard dimension ratio (SDR) means a thicker liner wall and therefore a reduced flow.

1. The designer should check that a reduced line flow is acceptable for the given application.
2. The flow calculations should use the liner inside diameter determined from the standard dimension ratio SDR obtained from the collapse design calculations.

The assumption is made that the liner will reach a neutral fit due to swell and creep (slip liner) or stress relaxation (tight fit liner) during service. With this approach, the steel pipe inside diameter is equal to the liner outside diameter.
3. Pressure loss calculations using the following friction factors should be carried out for both the host pipe and the liner material to establish whether the difference in pressure loss due to the reduced line diameter is acceptable.
 - a. 0.005 mm (0.00020 in) for HDPE;
 - b. 0.04 mm (0.0016 in) for new steel;
 - c. 0.4 mm (0.016 in) for lightly corroded steel;
 - d. 3.4 mm (0.13 in) for badly corroded pipe.

This approach assumes a tight liner with very smooth inside diameter and low surface friction appropriate for HDPE.

4. Refer to DEP 31.40.00.10-Gen. for requirements related to flow calculations.

3.3.2 Flow velocity limitations

1. Refer to DEP 31.40.00.10-Gen. for flow velocity limitations.

3.4 PERMEATION

All polymer materials are permeable, which means that gases and fluid will permeate from the bore fluids through the liner and accumulate in the annulus between the liner and the host carbon steel pipe.

The permeation rate depends on the operating temperature and thickness of the liner. Often the fluids consist of mixtures and it is important to recognize that the permeation of individual components may be enhanced by the presence of other components in the mixture.

1. A corrosion assessment shall be carried out to assess the corrosion conditions in the annulus, especially for those situations where H₂S and/or CO₂ are present in the fluids to be transported.

3.5 FACTORS THAT AFFECT THE COLLAPSE RESISTANCE

3.5.1 General

The uptake of fluids will cause swelling of the liner changing the mechanical properties of the liner. This will affect the collapse resistance of the liner.

3.5.2 Swell

Polymers swell because of fluid uptake when exposed to chemicals, including hydrocarbons.

For crude oils, typical swell data for HDPE as a function of API grade and temperature are provided in (Appendix B).

Swell for polymers or services other than shown in (Appendix B) can be determined by exposure tests of the polymer to simulated field conditions.

1. Swell of polymers will affect the resistance against collapse and shall be part of the collapse design assessment.
2. For swell data of polymers other than HDPE, such as PVDF, PA-11, PA-12 and for operating fluids not mentioned in (2.2), the Principal should be consulted.

3.5.3 Reduction of stiffness

1. In the collapse equations, the 5 % secant modulus shall be used for the calculations.
 - a. The modulus shall be corrected for temperature (design temperature value) and fluid uptake.

3.5.4 Chemical compatibility

1. DEP 30.10.02.13-Gen. provides specific guidelines on chemical compatibility of HDPE liners for oil and gas applications.

3.6 COLLAPSE EQUATIONS

3.6.1 General

The wall thickness of the liner is determined by the following aspects:

- *robustness, the practicalities of installation;*
- *collapse resistance for water and stabilized crude service or;*
- *collapse resistance multiphase and gas service.*

Collapse resistance pertains mainly to live crude (multi-phase lines or lines in which gas break-out can occur) or to gas and aims to prevent liner collapse due to annulus gas in combination with liner instability due to swelling and temperature induced expansion. Hydrocarbon liquids and gases permeate through PE liners, accumulate in the annulus between the liner and the carbon steel pipe and can cause collapse in case of pressure fluctuations or depressurization. If the liner wall thickness is sufficient to withstand an annulus pressure equal to the pipeline design pressure (or partial pressure in case of multiphase service), the design is intrinsically safe against collapse.

1. The wall thickness should be sufficient to ensure that the PE pipes can be joined by butt fusion welding, and pulled into the carbon steel pipe.