

DEP SPECIFICATION

HIGH DENSITY POLYETHYLENE PIPELINES AND PIPING SYSTEMS FOR OILFIELD APPLICATIONS

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DESIGN AND ENGINEERING PRACTICE

DEM1



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the use of high density polyethylene (HDPE) pipe materials for pipelines and piping systems for onshore oil and gas production pipelines and piping systems. The applications cover free-standing HDPE piping systems only. It covers the materials and mechanical design aspects of HDPE pipelines and does not address HDPE pipe flow, hydraulics, pipe sizing for flow regimes and other process related topics.

HDPE pipelines are the subject of several industry standards in use around the world that have been written by several standards bodies including ISO, API, ASTM, CSA, ASME and PPI. This DEP attempts to address the primary related industry standards and incorporate their varied requirements.

This DEP is based on various international industry standards based on location of manufacturing. In North America, ASTM International (ASTM) standards are used; in Europe and some other countries, International Standards Organization (ISO) standards are used with some exceptions existing in both locations. For example, within North America, increased awareness and use of the ISO standards for HDPE pipe manufacturing is occurring within industry. The Contractor determines which standards are best suited for the application based on project conditions.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards.

This is a revision of the DEP of the same number dated February 2018 see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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This DEP is intended for use in facilities related to exploration and production facilities. 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 could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are more stringent and which combination of requirements will be acceptable as regards 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 with the object of obtaining 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.

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 capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

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

1.3.2 Specific definitions

Term	Definition
Blisters	Voids that have either deformed the pipe or fitting wall or have broken the surface.
Categorized Required Strength (CRS Θ, t)	The categorized lower prediction limit of the long term hydrostatic strength at a temperature (Θ) and a time (t) as determined by ISO 9080 and classified in ISO 12162. CRS at 20 °C (68 °F) and 50 years equals the MRS.
Cell Classification	Reference to ASTM D3350 in specifying the polyethylene material parameters where HDPE pipe and fitting materials are classified using cell numbers for Density, Melt Index, Flexural Modulus, and Tensile Strength at Yield, Slow Crack Growth Resistance, the Hydrostatic Design Basis (HDB) and an Ultraviolet (UV) stabilizer.
Chatter Marks	A rough surface such as washboard effect on the interior or exterior surface of the pipe or fitting.
Cracking	Splitting of material evident on the surface of the pipe or fitting.
Crazing	Line cracks at or just under the surface evident by white coloured lines.
Die lines	Longitudinal lines on the internal surface of the pipe and are the result of molten resin being drawn over imperfections on the surface of the die mandrel.
Dimension Ratio	The ratio of a pipe's outside diameter to its wall thickness. Also known as Standard Dimension Ratio
Drag mark	A deformity in the exterior surface of the pipe caused by excessive friction at the sizing box.
Grade (ASTM 3350 based)	A code for polyethylene pipe and fitting materials that consists of the two letter abbreviation for polyethylene (PE) followed by two numbers that designate the density cell classification and the slow crack growth resistance cell classification as defined in ASTM D 3350. The last two digits are the hydrostatic design stress (HDS) divided by 100. For example, PE 3608 is a polyethylene resin material with density class 3 and slow crack growth cell 6 and an HDS of 5500 kPa (800 psi)
Grade (ISO 12162 based)	A code for polyethylene pipe and fitting materials that consists of the two letter abbreviation for polyethylene (PE) followed by two or three numbers that designate the material minimum required strength value (MRS) multiplied by 10, as specified in ISO 12162.

Term	Definition
High Density Polyethylene	A class of polyethylene resins that has a density range of 0.941 to 0.965 g/cm ³ (0.0339 to 0.0347 lbm/in ³).
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.
Hydrostatic Design Stress (HDS)	The maximum tensile hoop stress in the wall of the pipe that if applied continuously for 100,000 hours will not cause failure of the pipe, with a high degree of certainty. It is determined by application of industry specified design factors to the categorized hydrostatic design basis (HDB). The design factor used is based on the specific properties of the polyethylene resin and specified in PPI TR-3.
Installer	Party that is contracted to perform the site installation of HDPE piping that includes pipe procurement and stringing pipe, joining of pipe, trench construction, laying pipe, trench back filling and pressure testing.
Long-term hydrostatic strength (LTHS)	The estimated tensile hoop stress in the wall of the pipe that when applied continuously will cause failure of the pipe at 100,000 hours. This is the intercept of the stress regression line with the 100,000 hour coordinate.
Lot	Means one shipment of raw material (i.e. HDPE resin) received at the Manufacturer's plant, transported by either a hopper truck or a rail hopper car.
Minimum Required Strength (MRS)	The categorized long term hydrostatic strength of HDPE pipe in the hoop direction for a given set of conditions (20 °C (68 °F)), 50 years established in ISO 9080 and classified in ISO 12162.
Pock marks	Smooth depressions on the interior or exterior surface of the pipe or fitting.
Polyethylene resin	Plastic resins prepared by the polymerization of no less than 85 % ethylene and no less than 95 % of total olefins with additional compounding ingredients.
resin Manufacturer	Party that manufactures or supplies pipe resin raw material, such as HDPE or epoxy, to the pipe Manufacturer.
Standard Dimension Ratio	The ratio of a pipe's outside diameter to its wall thickness. Also known as Dimension Ratio.

1.3.3 Abbreviations

Term	Definition
API	American Petroleum Institute
ASTM	ASTM International

Term	Definition
AWWA	American Water Works Association
CRS	Categorized Required Strength
CSA	Canadian Standards Association
DF	Design Factor
DP	Maximum Design Pressure
FM	Factory Mutual
HDB	Hydrostatic Design Basis
HDPE	High Density Polyethylene
HDS	Hydrostatic Design Stress
ISO	International Standards Organization
LCL	Lower Confidence Limit
LTHS	Long Term Hydrostatic Strength
MRS	Minimum Required Strength
NFPA	National Fire Protection Association
NSF	National Sanitation Foundation
PPI	Plastics Pipe Institute
RCP	Rapid Crack Propagation
SCG	Slow Crack Growth
SDR	Standard Dimension Ratio

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 (13).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated February 2018. This is an administrative update only to correct references to DEPs that have been involved in either a merge or a split.

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.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://swwww.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
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. DESIGN AND MATERIAL QUALIFICATION INFORMATION

2.1 GENERAL

1. The Contractor shall verify that designs conform with the Manufacturer's/Supplier's published material specifications that are supported by third party testing procedures for the material.

For the design basis of HDPE pipelines, reference can be made to the design requirements specified in PPI Handbook of Polyethylene Pipe, Chapter 6, AWWA M-55 or ISO 10839.

2. The physical properties of the pipe SHALL [PS] be specified and conform to ASTM D 3350 or ISO 12162 classifications.

The standard resin classification system used in North America is specified in ASTM D 3350 and was originally provided by the Plastics Pipe Institute (PPI). PPI also reviews test results of new resin compounds and if approved, allows their listing as standard resin compounds in PPI TR-4. Generally, the properties are required to fall within ranges specified by ASTM D 3350 for density, slow crack growth resistance, and hydrostatic design basis (HDB), each of which are standardized by dedicated ASTM specifications.

3. The Resin Manufacturer SHALL [PS] determine the long term hydrostatic design stress (LTHS) for the compound to be qualified.

The long term hydrostatic pressure testing is the accepted pipe qualification method endorsed by both ASTM D 2837 in North America and ISO 9080 in Europe and Asia.

4. For firewater systems in North America, HDPE certification under Factory Mutual should be used.

This certification ensures product compliance with national fire codes such as NFPA 24.

5. Refer to DEP 32.30.20.11-Gen., DEP 34.19.20.11-Gen., DEP 80.47.10.30-Gen., and DEP 80.47.10.31-Gen. for Principal's fire protection requirements.
6. HDPE pipe and fittings used for potable water shall comply with ASTM D 3035 and any additional local regulations that apply.
7. Dual certified HDPE pipe for plant fire protection and potable water systems may be used.
8. Use of ASTM F714 instead of ASTM D 3035 shall be subject to approval by the Principal.

2.2 HYDROSTATIC DESIGN BASIS (HDB) AND STRESS (HDS)

2.2.1 General

1. The HDB (Hydrostatic Design Basis) shall be established by ASTM Test Method D 2837, or the corresponding ISO 9080, as applicable.

2.2.2 ASTM D 2837 pipe and fittings qualification

1. For projects following North American standards, LTHS testing shall follow the specifications of ASTM D 2837.
2. For HDPE pipelines in North America, the specified HDB value for both PE3608 and PE4710 shall be 11.03 MPa (1600 psi) validated at room temperature as per ASTM D2837.

3. For design temperatures above the testing temperature, the design pressure rating shall be reduced by application of the temperature correction factors that are published in the applicable industry standards, and additional criteria specified in (2.4).
 - a. ASTM D2837 may be used to qualify HDB for higher temperatures ($>20\text{ }^{\circ}\text{C}$ ($68\text{ }^{\circ}\text{F}$)).
4. HDPE fittings shall be qualified by the Manufacturer/Supplier based on testing of fittings using a hydrostatic testing program that is designed to ensure that the fittings are suitably pressure rated and compatible for the intended HDPE pipe system.
5. HDPE moulded butt fusion fittings shall be qualified per ASTM D 3261 and fabricated per ASTM F 2206.

2.2.3 ISO 9080 pipe and fittings qualification

1. For projects following ISO standards, the LTHS testing shall follow ISO 9080.
2. For HDPE pipelines, categorized as MRS, the following values shall be specified:
 - a. 8.0 MPa (1160 psi) for PE 80.
 - b. 10.0 MPa (1450 psi) for PE 100.
3. ISO 9080 may be used to determine MRS for service temperatures higher than $20\text{ }^{\circ}\text{C}$ ($68\text{ }^{\circ}\text{F}$) ($\text{CRS}(\theta, t)$).
 - a. As an alternative, for higher service temperatures, the minimum required strength (MRS) at $20\text{ }^{\circ}\text{C}$ ($68\text{ }^{\circ}\text{F}$) may be used with the application of a temperature correction factor published in applicable industry standards and the additional criteria specified in (2.4).
4. The Contractor shall determine the appropriate design coefficients when using MRS and CRS (θ, t).

MRS and CRS (θ, t) designations, as determined in accordance with ISO 9080, do not include stress reduction factors (design coefficients) that are required prior to its application for an intended service.
5. HDPE fittings shall be qualified by the Manufacturer/Supplier based on testing of fittings using a hydrostatic testing program that is designed to ensure that the fittings are suitably pressure rated and compatible for the intended HDPE pipe system.
 - a. For gas systems, fittings shall be qualified per ISO 8085.
 - b. For water systems, fittings shall be qualified per ISO 4427-3.

2.3 DETERMINING DESIGN PRESSURE (DP)

Design pressure (DP) or pressure rating is the maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.

The relationship between the HDB, HDS and DP is captured in equation 1.

1. Refer to Part II, Section 2.2 of DEP 01.00.01.30-Gen. for the requirements for evaluating the design pressure.
2. The Contractor shall identify the pressure ratings of all connected equipment and verify that the pipeline cannot be pressured above the design pressure.

3. Equation 1 or Equation 2 shall be used to determine pipeline design pressure for HDPE pipelines based on the DR and application of the design factors.

Tables 2.3.1 and 2.3.2 show design pressures for common pipe DR ratios.

$$DP = 2 \cdot (HDB) \cdot (DF) / (SDR-1) = 2 \cdot (HDS) / (SDR-1) \quad \text{Eqn. 1}$$

$$DF = F \cdot T \cdot F_{\text{Project}} \quad \text{Eqn. 1a}$$

Where:

DP= pipeline design pressure or maximum operating pressure (MOP), MPa;

HDB = hydrostatic design basis per ASTM D2837;

HDS = hydrostatic design stress (HDS) at 23 °C (73 °F), MPa;

DR= ratio of the pipe average outside diameter to pipe minimum wall thickness;

DF = service design factor;

F = service fluid factor;

T = design temperature factor per the standard used (API 15LE, CSA Z662);

F_{project} = additional project design factor determined by the Contractor.

$$DP = 2 \cdot (MRS) \cdot (F_{\text{Project}}) / (C \cdot (SDR-1) \cdot T) \quad \text{Eqn. 2}$$

Where:

DP= pipeline design pressure or maximum operating pressure (MOP), MPa (psi);

MRS = Minimum Required Strength at 20 °C (68 °F), or CRS (Θ,T), MPa (psi);

DR= ratio of the pipe average outside diameter to pipe minimum wall thickness;

C = design coefficient;

T = design temperature factor per the standard used (ISO 4427, ISO 4437);

F_{project} = additional project design factor determined by the Contractor.

PPI TR-4 provides the room temperature HDB for multiple HDPE grades and other plastic pipe resins. For oilfield HDPE pipelines, the two most commonly used grades are PE 3608 and PE 4710.

A maximum hydrostatic design stress (HDS) is another material parameter that is used to determine the pressure rating for HDPE pipe. This parameter is determined by applying a design factor to the HDB. The design factors applied to the HDB to determine the HDS are determined by PPI and published in PPI TR-3 and PPI-TR-9.

**Table 2.3.1 Maximum design pressures (DP) at 23°C (73°F), CSA Z662, API 15LE
Basis, F= 1.0**

DR	PE 3608	PE 3608	PE 4710	PE 4710
	psi	MPa	psi	MPa
7	267	1.8	333	2.3
7.3	254	1.7	317	2.2
9	200	1.4	250	1.7
11	160	1.1	200	1.4
13.5	128	0.9	160	1.1
15.5	110	0.8	138	1.0
17	100	0.7	125	0.9
21	80	0.6	100	0.7

**Table 2.3.2 Maximum design pressure (DP) at 20°C (73°F), ISO 4427, ISO 4437
Basis, C= 1.45**

DR	PE 80	PE 80	PE 100	PE 100
	psi	MPa	psi	MPa
7	267	1.8	333	2.3
7.3	254	1.8	317	2.2
9	200	1.4	250	1.7
11	160	1.1	200	1.4
13.5	128	0.9	160	1.1
15.5	110	0.8	138	1.0
17	100	0.7	125	0.9
21	80	0.6	100	0.7

2.4 DESIGN TEMPERATURE AND TEMPERATURE FACTOR (T)

1. The temperature design basis shall list all normal and abnormal operating conditions from the service fluids, including allowance for environmental exposure.
2. The maximum allowable pipeline design temperature for HDPE pipe material shall be 60 °C (140 °F).

Temperature excursions, even for short durations, weakens HDPE pipe and can cause failure or shorten the life expectancy.

3. Steam-out shall not be allowed for purging, cleaning or clearing HDPE piping.
4. The allowable design pressure shall be calculated based on application of the temperature service factors applied to the design pressure equation.