

DEP SPECIFICATION

HIGH DENSITY POLYETHYLENE PIPELINES AND PIPING SYSTEMS FOR OILFIELD APPLICATIONS

DEP 31.40.20.39-Gen.

February 2017

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 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; in Europe and some other countries, International Standards Organization (ISO) standards are used for the most part 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 shall determine 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 2012, 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.

Resin Manufacturer - is the party that manufactures or supplies high density polyethylene piping resin granules raw material to the Manufacturer.

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.

Installer – is the 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.

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	Means referencing 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.
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).

See the following examples for PE 4710:

ASTM D3350 classification for polyethylene grade						
	Material	Density, g/cm ³	Density, lbm/in ³	Slow crack growth resistance, hours PENT	Hydrostatic design stress, kPa	Hydrostatic design stress, psi
	Polyethylene	.947-.955	.0341-.0344	> 500	7000 / 70	1000 / 10
ASTM D3350 cell classification	PE	4	4	7	70	10

Term Definition

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. See the following example for PE 100:

ISO classification for polyethylene grade		
	Material	Minimum Required Strength Value (MRS, MPa)
	Polyethylene	MRSx10
ISO 12162	PE	100

High Density Polyethylene A class of polyethylene resins that has a density range of 0.941 - 0.965 g/cm³ (0.0339 to 0.0347 lbm/in³).

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.

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.

Term	Definition
Standard Dimension Ratio and Dimension Ratio	Both terms are interchangeable and mean the ratio of a pipe's outside diameter to its wall thickness.

1.3.3 Abbreviations

Term	Definition
API	American Petroleum Institute
ASTM	ASTM International
AWWA	American Water Works Association
CRS	Categorized Required Strength
CSA	Canadian Standards Association
DP	Maximum Design Pressure
DR	Dimension Ratio
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
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 (14).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated February 2012.

Section/Clause	Change
All	Restructured and clarified requirements, enforced shall/should.
2.2	Restructured and re-worded DEM1 requirement
2.3	Restructured and re-worded DEM1 requirement
2.8	Restructured and re-worded DEM1 requirement
10.1	Restructured DEM1 statement
10.4	Restructured and re-worded DEM1 requirement
11.8	Restructured and re-worded DEM1 requirement
11.10	Restructured and re-worded DEM1 requirement
12.3	Restructured and re-worded DEM1 requirement
12.4	Restructured DEM1 statement
12.5	Restructured and re-worded DEM1 requirement
13.4	Restructured DEM1 statement

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://sww.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. MATERIAL QUALIFICATION GENERAL INFORMATION

2.1 GENERAL

1. The manufacturing process for HDPE pipe shall be by pipe extrusion of molten polyethylene resin compound through various sizing stages to form pipe of the specified diameter and wall thickness.
2. Moulding of pipe sections shall not be used as a pipe manufacturing procedure.
3. After the extrusion process, the hot pipe shall be immediately cooled in controlled stages by external flushing with water.
4. HDPE fittings shall be made by either compression moulding or fabrication from pipe.
Smaller diameter elbows and tees are typically fabricated via compression moulding, and fittings such as Y laterals and larger diameter elbows and tees are typically fabricated from pipe.
5. HDPE pipe Manufacturers shall purchase HDPE resin in bulk as granules from the resin Manufacturer.
6. At the pipe extrusion plant, carbon black shall be added to the raw HDPE resin compound before extrusion into pipe.
 - a. Pre-mixed resin may be supplied from the resin Manufacturer.
7. The pipe's physical properties SHALL [PS] be specified and classified for individual resin grades in accordance with either ASTM D 3350 or ISO 12162, as determined by the Contractor.

The standard resin classification system used in North America is specified in ASTM D3350 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 ASTM D 3350 specified value ranges for density, slow crack growth resistance, and hydrostatic design basis (HDB), each of which are standardized by dedicated ASTM specifications.

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.

HDPE piping is also commonly installed for underground fire protection piping at plants and usually requires some extra certifications such as by Factory Mutual (FM) or other certification agencies that are specified by the local insurance provider.

8. The requirements for HDPE plant fire protection piping should be determined at the project design stage based on local conditions and regulations.

2.2 ASTM D 2837 PIPE AND FITTINGS QUALIFICATION (NORTH AMERICA)

1. The Resin Manufacturer SHALL [PS] determine the long term hydrostatic design stress (LTHS) for the compound to be qualified.
2. In North America, LTHS testing shall follow the specifications of ASTM D2837.

The LTHS is determined based on long term pressure testing of pipe samples using a regression analysis and a graph plot of the pipe failure point stresses versus time. A number of failure data points at various time intervals (minimum 10,000 hours) are obtained.

For standard grades of HDPE such as PE 3608, the results of failure stress versus time-to-failure are plotted with extrapolation of the graph slope to 100,000 hours (11.4 years). The predicted failure stress at 100,000 hours is the LTHS and is determined from the plot.

The LTHS value is then used to determine a categorized stress value termed the hydrostatic design basis (HDB), which is based on the LTHS falling within a specified range of results. For standard grade HDPE material, the lower confidence level (LCL) of 85% is applied but to qualify as higher performance PE 4710, the LCL is increased to 90%.

3. 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.
4. ASTM D2837 may be used to qualify HDB for higher temperatures.

ASTM D2837 does not allow a "knee" or downturn in the stress failure data curve that indicates a transition to a brittle-type failure mechanism. Additional pipe tests are performed to help ensure that no transition to brittle failure occurs before 11.4 years (100,000 hours). For higher performance PE 4710, the testing must show no transition occurs before 50 years (438,000 hours).
5. 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 industry standards, and additional criteria specified in (10) and (11).
6. HDPE fittings shall be qualified by the Manufacturer 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.
7. HDPE moulded butt fusion fittings shall be qualified per ASTM D3261 and fabricated fittings per ASTM F 2206.

2.3 ISO 9080 PIPE AND FITTINGS QUALIFICATION (EUROPE AND ASIA)

1. The Resin Manufacturer SHALL [PS] determine a long term hydrostatic design stress (LTHS) for the compound to be qualified.
2. In Europe and Asia, the LTHS testing shall follow the specifications of ISO 9080.

The LTHS is determined based on long term pressure testing of pipe samples using a regression analysis and a graph plot of the pipe failure point stresses versus time. A number of failure data points at various time intervals are obtained, up to 10,000 hours duration is specified.

The results of failure stress versus time-to-failure are plotted with extrapolation of the graph slope to 438,000 hours (50 years) where the predicted failure stress at 50 years is determined.

The 50 years predicted failure stress is the LTHS. The LTHS result is then used to determine a categorized stress value termed the minimum required strength (MRS) that is based on the LTHS falling within a specified range of results per ISO 12162. The MRS value is the lower value of the category range and is based on the 97.5% LCL.
3. For HDPE pipelines, categorized MRS values of 8.0 MPa (1160 psi) for PE 80 and 10.0 MPa (1450 psi) for PE 100 shall be specified.
4. ISO 9080 may be used to determine MRS for higher service temperatures (CRS (θ , t)).

ISO 9080 allows the use of both ductile and brittle failure data and permits a "knee" in the stress-failure curve before the 438,000 hour projected life.

 - a. As an alternative, for higher service temperatures the minimum required strength (MRS) at 20 °C (68 °F) may be used with the application of a temperature correction factor published in industry standards and the additional criteria specified in (10) and (11).
5. The Contractor's design engineer shall determine the appropriate design coefficients for the particular application when using MRS and CRS (θ , t). See (10) and (11).

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.
6. HDPE fittings shall be qualified by the Manufacturer 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.

2.4 SLOW CRACK GROWTH (SCG) RESISTANCE

ASTM and ISO standards exist for determining SCG resistance and it is specified within ASTM D 3350, API 15LE, ISO 4427 and ISO 4437 pipe standards.

In ASTM D3350, for PE 3608 materials, a minimum value of 100 hours is required and for PE 4710 materials, a minimum value of 500 hours is required. Within ISO 4427 and ISO 4437, 500 hours minimum resistance is specified.

For HDPE resins manufactured today, much higher SCG resistance is available and is specified.

1. For gas pipelines, the minimum SCG resistance characteristic of the pipe compound, as determined by the testing method specified within the applicable industry standard (ASTM D 3350, API 15LE, ISO 4427 and ISO 4437), shall be for a minimum duration of 2000 hours (see Table 3.1).

2.5 RAPID CRACK PROPAGATION (RCP) RESISTANCE

1. Unless mentioned otherwise, RCP resistance need not be specified.

RCP resistance is not normally specified in North American pipe standards or for water systems generally. ISO 4427, Appendix B provides some further general information on RCP for the use and consideration of pipeline designers. ISO 4437 for gaseous pipelines specifies RCP testing. ASTM D 3350 does not require RCP testing for any grades of resin and although RCP resistance is being introduced in some North American pipe standards it is not normally specified at this time.

2.6 DENSITY

Density is used to classify pipe materials. In general, higher density results in increased tensile strength, stiffness, and temperature resistance of HDPE pipe materials.

1. For PE 3608 and PE 80 materials, the compound density value should be within 0.949 g/cc – 0.956 g/cc (0.0342 lbm/in³ – 0.0344 lbm/in³).
2. For PE 4710 and PE 100 materials, compound density values should be within 0.956 g/cc – 0.964 g/cc (0.0344 lbm/in³ – 0.0347 lbm/in³).

2.7 MINIMUM MATERIAL REQUIREMENTS

1. For HDPE pipeline installations, the minimum material requirements shall be based on the pipe manufacturing standard specified for the project, and the additional requirements as specified in (3).

2.8 FUSION JOINING QUALIFICATION

Fusion joining of HDPE is the method of joining pipe or piping components.

1. The fusibility of HDPE material SHALL [PS] be tested by the Manufacturer, including the following criteria:
 - a. demonstration that each compound conforming to ASTM D3350 or ISO 4427-1 is fusible by testing the tensile strength of a butt fusion joint of pipes manufactured from the compound;
 - b. completion of tensile testing to failure, with an acceptance criteria of 100% ductile failure.