DEP SPECIFICATION

GLASS-FIBRE REINFORCED PLASTIC PIPELINE AND PIPING SYSTEMS

DEP 31.40.10.19-Gen.

February 2011

(DEP Circular 20/12 has been incorporated)

DESIGN AND ENGINEERING PRACTICE

DEM1

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the purchase and use of glass-fibre reinforced plastic (GRP) pipeline and piping systems, both onshore and offshore. Its objective is to enable the purchase of GRP components with known and consistent properties from any source.

This DEP is generally applicable to:

a) Onshore pipeline and piping systems and offshore piping systems for non-hydrocarbon applications;

b) Onshore pipelines transporting oil and associated gas;

c) Pipeline and piping systems for chemicals.

d) Onshore and offshore piping systems for hydrocarbon liquids;

e) Onshore pipeline systems for gas transport

The application of GRP piping classes for refining and chemicals is specified in DEP 31.38.01.12-Gen., and includes cooling water, boiler feed water, fire fighting water, demineralised water, and hydrochloric acid.

Note that the abbreviation GRP us used as generic name for a number of glass reinforced plastic pipe systems like GRE, GRUP, GRVE etc.

This DEP is not applicable to:

a) Pipe systems that incorporate internal thermoplastic or elastomeric liners;

b) Fibre reinforced plastic (GRP) downhole tubing and casing.

Application of fibre reinforced thermoplastic lined GRP spoolable pipe is specified in DEP 31.40.10.20-Gen.

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 the DEP of the same number dated January 2010; see (1.6) 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 oil and gas production and gas handling. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process should 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 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.

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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.

1.3.2 Specific definitions

Term	Definition
System design pressure	Maximum operating pressure intended to be experienced by pipeline or piping system during its service life
Design temperature	Maximum fluid temperature that can be reached during service
E-glass	Glass fibre normally used to reinforce GRP pipes. Composition: Alumina-borosilicate glass, ≤ 1% alkali content
E-CR glass	Glass fibre having a better chemical resistance than E-glass. Composition: Aluminia-limesilicate glass, ≤ 1% alkali content
C-glass	Glass fibre having a better chemical resistance than E-glass Composition:Alkali-lime glass ≈ 8% Alkali content
Fittings	Pressure tight fluid containing components with a geometry different from straight pipe (e.g. tees, elbows, reducers etc.)
Hand lay-up	A process for fabricating a composite structure in which discontinuous reinforcements (woven mats, chopped strand mats) are impregnated with a matrix material and are manually applied on a mandrel.
Intumescent coating	A passive fire protection coating which in the presence of fire expands to create an iner “char” layer.
Lot	A production quantity. When referred to pipe manufacture, a lot shall be defined as 100 units. When used in connection with the manufacture of fittings or spools, a lot shall be defined as components manufactured from the same materials during a single shift.
Pipeline system	pipe with component parts subject to the same design conditions and typically used to transport fluids between wells and field facilities, processing plants and storage facilities.
Pipe Spool	Work shop pre-assembled pipe section which often consist of pipe sections with e.g. fittings, tees, flanges, instrumentation etc.

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Term	Definition
	These test spools will be transported to the field and build into the piping or pipeline section.
Piping system	pipe with components subject to the same design conditions and typically used within a processing facility. The piping system also includes pipe supports, but does not include support structures.
Pressure rating	a rating for a component relating to its long term resistance to failure when subjected to either static or cyclic internal pressure loading.
Product family	defines a range of pipes, fittings and joints manufactured by the same Manufacturer, using the same method and having the same constituent materials.
Product sector	sub-division of a product family that groups pipes (plus joints) and fittings into specific diameter and pressure ranges.
Product sector representative	the component taken to be representative of that sector and upon which the basic qualification testing is performed.
Synthetic	Primarily polyester fibres, typically used as reinforcement material for the chemical resistant layer (CRL)
Winding angle	angle of main reinforcement to pipe longitudinal axis, can be either positive or negative.

1.4 ABBREVIATIONS

BTX	benzene, toluene, p-xylene and o-xylene
CRL	Chemical resistance layer
GRE	Glass-fibre reinforced epoxy
GRP	Glass-fibre reinforced plastic
GRUP	Glass-fibre reinforced unsaturated polyester
GRVE	Glass-fibre reinforced vinyl ester
IPD	Cyclo aliphatic amine
LCL	97.5 % confidence limit of the long-term hydrostatic pressure or stress based on a 20-year lifetime
LTHP	extrapolated long-term mean static (or cyclic) failure pressure of a component, tested with free ends, and based on a 20-year lifetime
MDA	Aromatic Amine
$\mathbf{P_{min}}$	Minimum pressure during pressure cycle
$\mathbf{P_{max}}$	Maximum pressure during pressure cycle

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R	Ratio of minimum / maximum pressure during cyclic service
SLT	Standard laboratory temperature
SPL	Single protective layer
$TP_{1000hrs}$	Test pressure to be used in 1000-hour qualification test
T_g	Glass transition temperature
UV	Ultraviolet

1.5 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 (12).

1.6 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated January 2010. The following are the main, non-editorial changes.

Old section	New section	Change
All	All	Informative information removed and added to the informative version of this DEP
1.3.2	1.3.2	Glass types specified in line with EN 13121-1 and EN 13121-2
2.2.1	2.2.1	Added: Maximum allowable temperature of the resin also depends on service fluids
2.2.2	2.2.2	Specified build up of the Chemical Resistant Layer for a number of services. Modified CRL build-up. Changed CRL thickness from 1.5 to 2.5 to allign with industry standards.
2.3	2.3	Added requirment for UV resistant external resin rich layer with a synthetic reinforced veil for service in tropical or desert areas.
3	3	Some sections were removed and moved to informative version of this DEP
4	4	Qualification sections re-arranged in more logical sequence. Several areas moved to informative version of this DEP
7.2.2.2	7.2.2.2	Caviation section: Reformulated. Guidelines rather than descreptive procedure
7.3.2	7.3.2	Occasional loads are conditionally permitted.
7.16.6	7.16.6	Vacuum resistance buried pipelines shall be cacluated using AWWA C950/M45
7.17	7.17	Informative information moved to informative version of this DEP
7.17.3	7.17.3	Figure laminated joints modified to explain taper dimension

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Old section	New section	Change
		requirements
7.17.6	7.17.6	Added section on requirements on O-ring compatiblity (chemical resistance) for threaded joints
7.18	7.18	Added requirement that repair systems shall be qualified as well
8.2	8.2	Added additional requirements on transportation. Nesting smaller pipes inside larger pipes are not allowed.
8.3	8.3	Added requirments for lifting during loading/unloading of GRP pipes
8.4.1	8.4.1	Wooden or polymer timbers/spacers to be used to store pipes
8.4.4	8.4.4	Adhesive/Resin system storage: fire safety requirement for both longer and shorter term storage.
8.4.5	8.4.5	Added reference to guideline (ISO 2230) for storage of elastomer O-rings, gaskets.
9.4.2	9.4.2	Added additional requirements on bonders ID and marking of joints.
9.4.2	9.4.2	Added additional requirements to adhesive bonding activities.
9.4.2.1	9.4.2.1	Added bonder's initial pressure test
9.5.5	9.5.5	Marsh or swamps: additional stresses associated with buoancy and soil instability shall be included in system desigh.
10.3.1	10.3.1	Pressure-Time transient shall be recorded during the hydrotest and filed in the installation quality control documentation.
11	11	Added section on safety precautions during hydrotesting
12	12	European industry standards EN13121-1 and 2 added.
A4	A4	Added addition requirement on acceptance criterion for test joint
A6	A6	Changed period of requalifcation of adhesive bonders from 6 to 3 months (to be in line with the requirments set section

1.7 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal http://sww.shell.com/standards and on the main page of the DEPs DVD-ROM.

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1.8 DUAL UNITS

Amended per Circular 20/12
Dual units have been incorporated throughout this DEP.

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.

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2. MATERIALS

2.1 GENERAL

The material selection process described in this document SHALL [PS] be used to ensure that the material is compatible with both internal conditions (service fluids) and external conditions (wheathering, UV radiation etc.) to which it is exposed over the full design temperature and pressure range, so that the mechanical, physical and chemical properties of the GRP satisfy the design requirements throughout the intended lifetime.

2.2 RESINS

The resins selected shall be of a suitable commercial grade that complies with the technical requirements of the application.

The recommendations of the resin Manufacturer for the use of hardeners, catalysts and accelerators shall be followed.

The resin shall be compatible, over the full design temperature range, with the fluid being contained.

2.2.1 Temperature limitations

MAXIMUM ALLOWABLE TEMPERATURES

The maximum allowable temperature is determined by the resin type, state of cure and service fluids.

Experience of typical GRP systems suggests the following maximum temperatures (in air) , depending on the resin type (Table 1):

Table 1 Temperature limitations for GRP

Type GRP	Maximum allowable operating temperature		Typical T_g value of fully cured resin	
	°C	°F	°C	°F
Glass-fibre/epoxy (GRE)				
- Aromatic-amine cured (MDA)	100	212	140	284
- Cyclo-aliphatic cured (IPD)	100	212	140	284
- Aliphatic-amine cured	85	185	115	239
- Anhydride cured	85	185	115	239
Glass-fibre/vinyl ester (GRVE)				
- Bisphenol A	90	194	120	248
- Novolac	100	212	140	284
Glass-fibre/polyester (GRUP)				
- Isophthalic	60	140	90	194

The temperatures in Table 1 are for initial guidance only.

The maximum allowable operating temperature for GRP as listed in Table 1 may be considerably lower depending on the aggresiveness of the specific service fluid and its concentration.

Thermoplastic liners may be used as a chemical resistance layer (CRL), but this may lower the maximum allowable operating temperature.

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MINIMUM ALLOWABLE TEMPERATURES

The minimum recommended temperature for GRP regardless of the resin system is minus 40 °C (-40°F).

2.2.2 Chemical resistance

The principal reinforcing material for the structural wall of GRP piping shall be a suitable grade of glass fibre having a glass finish compatible with the resin system used. Other types of reinforcement fibres may be used, to be agreed by the Principal.

For more information on available reinforcements contact the Principal.

The resin Manufacturer shall supply chemical resistance data for the relevant service fluids and the specific resin material, quoting the highest known service temperature that the material has been subjected to and, if available, the service life that has been achieved under the service conditions.

The chemical resistance information shall state whether the material has been laboratory tested according to ASTM C 581 or equivalent standard (e.g. EN 13121).

Depending on the aggressiveness of the service fluids, either a single protective layer (SPL) or an internal chemical resistant layer (CRL) [SHALL PS] be applied.

Table 2 provides selection criteria for the the CRL or SPL for a number of specific services, based on the guidelines provided in EN 13121.

Deviation from Table 2 is possible, but only if the pipe Manufacturer can demonstrate that their system is fit for purpose by performance based testing. The EN 13121-2 Annex C provides guidelines for acceptance tests.

Table 2 Restrictions materials selection and internal liner build-up

Service	GRP system	Chemical Resistant Layer
Hydrochloric acid up to 37 % concentration	GRVE	Minimum thickness: 2.5 – 4 mm (0.1 in to 0.16 in) Layer build-up from inner pipe surface to outer surface: • Double veil layer (VL) made of either C-glass or ECR glass • chopped strand mat (CSM) made from ECR glass) with a total mass per unit area greater than or equal to 900 g/m^2 (0.184 lb/ft²). The fibre content of the CRL shall be between 25% and 35% by mass.
Sodium hydroxide (caustic) up to 50% concentration	GRE or GRVE	Minimum thickness: 2.5 - 4 mm (0.1 in to 0.16 in)Layer build-up from inner pipe surface: • Double synthetic veil layer (VL) followed by • a chopped strand mat (CSM) made E-glass or E-CR glass with a total mass per unit area greater than or equal to 900 g/m^2 (0.184 lb/ft²). The fibre content of the CRL shall be between 25% and 35% by mass.

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Service	GRP system	Chemical Resistant Layer
Sodium hypochlorite solution up to 1% and a pH in the range of 9 to 10.	UPVC lined GRVE	Thermo-Plastic Lining (TPL) Unplasticized PVC liner with a thickness of 3 to 4.5 mm (0.12 to 0.18 in)
Water, crude oil, hydrocarbons	GRE	Single Protective Layer (SPL) with a minimum thickness of at least 0.5 mm (20 mil) which may be reinforced with C-glass veil or an ECR glass veil.

For services not listed in Table 2 the Principal can be contacted for more information.

2.3 UV PROTECTION

To protect the external GRP surface against weathering, sunlight, UV, etc., a resin rich external layer shall be applied, with a thickness of at least 0.5 mm (20 mil).

If specified by the Principal, the external resin layer may be pigmented to provide suitable resistance to UV degradation effects, e.g. using carbon black (3 % by weight) filler. To increase UV resistance, the application of an UV resistant coating may also be considered, e.g. white-pigmented polyurethane or epoxy.

In tropical or desert areas with high UV radiation levels, the resin rich outer layer shall be reinforced with a synthetic veil.

2.4 GASKET MATERIALS

The gasket material, e.g. used for flanges, SHALL [PS] match the pressure, temperature and chemical resistance capabilities of the piping system. Further information about the chemical resistance of non-metallic materials in a variety of chemical environments is given in DEP 30.10.02.13-Gen.

For chemical services, expanded PTFE flange gaskets, so-called e-PTFE should be used.

2.5 FIRE RESISTANCE

For applications where improved fire resistance is required, the application of a fire retardant, intumescent coating can be specfied.

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3. MANUFACTURING

3.1 GENERAL

For manufacturing of GRP pipe and its components, filament winding, and/or hand lay-up shall be used. Sand-filled GRP pipe and fittings shall not be used for pipeline and piping systems.

The use of sand/aggregate filled pipe and fittings is not permitted.

3.2 PIPE

Pipe components shall be manufactured by filament winding.

3.3 FITTINGS

Bends (elbows) shall be manufactured by filament winding, or hand lay-up, or by joining standard GRP pipe sections, using laminated joints, to form so-called “mitered bends”.

Tees, and reducing tees shall be manufactured by hand lay-up, or by joining standard GRP pipe sections, using laminated joints.

3.4 FLANGES

3.4.1 General

Flanges shall be manufacturered by filament winding and/or hand lay-up.

The outside diameter and hole spacing of GRP flanges shall meet the requirements of ASME B16.5, the flanges SHALL [PS] be flat faced.

3.4.2 Hand lay-up

Manufacturing of hand lay-up flanges shall be in accordance with ASTM D 5421. For maximum mechanical properties and chemical resistance, flanges SHALL [PS] be post-cured.

3.4.3 Filament winding

Manufacturing of filament wound flanges shall be in accordance with ASTM D 4024. The flanges SHALL [PS] be post-cured

The neck area of the flange SHALL [PS] be reinforced with continuous fibres, e.g. mat or woven rovings.

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4. QUALIFICATION

The qualification programme consists of standard methods for quantifying GRP pipe component performance with respect to internal pressure and elevated temperature.

Qualification of GRP pipe components shall be achieved through performance-based procedures. This effectively means that the GRP Manufacturer shall demonstrate, through testing, that its products will satisfy the design specifications.

The qualification programme

a) Delivers the lower confidence limit (LCL), which is the long term reference strength used for the calculation of the system design pressure;

b) Is used to demonstrate that all components used in a system meet the system design pressure;

c) Provides the baseline data for quality control during manufacturing

For the qualification, the concept of a product family and product sectors is used:

a) A **product family** defines a range of pipes, fittings and joints manufactured by the same Manufacturer, using the same design and fabrication methods and having the same constituent materials.

b) The **family representative** is the component that is taken to be representative of that particular product family. It is the family representative that is tested under ASTM D 2992 to determine the long-term behaviour and LCL, of the product. Testing shall be carried out on pipe product with a diameter of 50 mm (2 in) or larger.

c) A **product sector** is a sub-division of a product family that groups pipes (plus joints) and fittings into specific diameter and pressure ranges.

d) The **product sector representative** for a product sector is the component that is representative of that sector and upon which the basic qualification testing (4.2, 4.3) is performed.

Qualification of the product sector representative also qualifies similar components with smaller diameter which are part of that product sector.

The following product sectors shall be used (Table 3):

Table 3 Product sector definition

Diameter range		< 20 bar (<290 psi)	20 – 50 bar (290 - 725 psi)	50 – 150 bar (725 – 2175 psi)	150 – 250 bar (2175 - 3626 psi)
mm	inches				
< 250	<10	A	F	J	L
250 to 600	10 to 24	B	G	K	
600 to 1000	24 to 40	C	H		
1000 to 1500	40 to 60	D	I		
> 1500	>60	E			

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The qualification programme includes the following tests:

a) **Full regression line testing** on the family representative according to ASTM-2992: delivers the LCL (4.1) used to calculate the system design pressure

b) **1000 hr survival tests** according to ASTM-D1598 carried out on the product sector representative (4.2). Demonstrates that the components in the product sector meet the properties of that of the family representative.

c) **QC baseline testing**, used as the reference data for quality control during manufacturing (4.3). These tests are carried out on the product sector representatives.

4.1 FULL REGRESSION TESTING

For product, piping and pipeline design, the Manufacturer shall establish the LCL_{static} and/or LCL_{cyclic} values for the product family being made. This shall be determined in accordance with the requirements of ASTM D 2992, Procedure A and/or Procedure B, as appropriate, and at a minimum test temperature of 65 ºC, or design temperature if higher, and with unrestrained ends. For GRUP, the maximum test temperature shall be 60 ºC. For the test fluid, fresh water shall be used.

Where a Manufacturer has not established the LCL, a default value shall be used; see Table 4:

Table 4 Default LCL (hoop stress, reinforced wall) values for GRP pipe component

Type GRP	Default LCL_{static}		Default LCL_{cyclic}	
	MPa	ksi	MPa	ksi
Glass-fibre/epoxy (GRE) - Aromatic-amine cured (MDA) - Cyclo-aliphatic cured (IPD) - Aliphatic-amine cured - Anhydride cured	110(≤ 65 ºC) 85 (> 65 ºC)	16 (≤149°F) 12.3(>149°F)	55 (≤ 65 ºC) 43 (> 65 ºC)	8(≤149°F) 6.2 (>149°F)
Glass-fibre/vinyl ester (GRVE) - Bisphenol A - Novolac	70 (≤ 65 ºC) 55 (> 65 ºC)	10.2(≤149°F) 8 (>149°F)	35 (≤ 65 ºC) 28 (> 65 ºC)	5 (≤149°F) 4 (>149°F)
Glass-fibre/ Isopthalic polyester (GRUP)	70 (≤ 60 ºC)	10.2(≤140°F)	35 (≤ 60 ºC)	5 (≤140°F)

4.1.1 Definition of cyclic service

When the number of pressure cycles during the design life of the pipeline or piping system exceeds 7000, and the pressure fluctuation ratio R is smaller than 0.8, then the service shall be considered cyclic.

R is defined as:

$$R = \frac{P_{min}}{P_{max}}$$

Where P_{min} and P_{max} are the minimum and maximum values of the pressure cycle.

NOTE: R = 0 corresponds to fully cyclic service whereas R = 1 corresponds to static service.

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When cyclic pressure qualified components are not available, de-rated static pressure qualified components may be used, to be agreed by the Principal.

The cyclic pressure rating shall be calculated from the following relationship:

$$LCL_{cyclic} = \frac{LCL_{static}}{2}$$

4.2 1000 HOUR QUALIFICATION TEST

4.2.1 General

To qualify, the Manufacturer SHALL [PS] demonstrate by performing 1000-h survival tests that the components to be used for the pipeline or piping system are fit-for-purpose, i.e. capable of meeting the minimum design requirements. Qualification testing SHALL [PS] also include the type of repairs recommended by the Manufacturer.

The 1000-h tests shall be carried out, or witnessed and certified by an independent third party authority, to be agreed by the Principal.

4.2.2 Test requirements

Two replicate samples of the product sector representative shall be selected at random and 1000-h pressure tested according to ASTM D 1598 at 65 °C (149°F) or design temperature if higher, and with unrestrained ends. For GRUP, the maximum test temperature shall be 60 ºC (140°F). For the test fluid, fresh water shall be used.

The 1000-h test shall commence only when the pressure and temperature have stabilised and when no further additions of water are required. During the actual 1000-h test, additions of water shall not be permitted. Interruptions to the required pressure and temperature during the 1000-h test are permitted to a cumulative maximum of 72 hours. Interruptions beyond 72 hours shall render the test invalid and it will need to be repeated. Time lost to interruptions shall be added back ensuring the test period remains at 1000-h.

For qualification testing of large diameter pipe and fittings (> 2000 mm), typically used for (sea)-water cooling systems, and design temperatures typically lower than 50 °C (122°F), a test temperature lower than 65 °C (149°F) may be accepted, to be agreed by the Principal.

Components shall be tested as either single units or, where appropriate, as assemblies made up by the relevant components (pipe+joint, fittings, flanges, instrument/small-bore connections, etc). All individual components, fittings, etc., that are to be used for the piping or pipeline system SHALL [PS] be qualified. Any components or fittings not tested shall not be accepted until they have also been successfully qualified.

The minimum length of pipe between adjacent fittings, or end closures, needed to remove the influence of end-fittings shall not be less than three times the nominal diameter, and shall be at least 1500 mm (60 in).

4.2.3 1000-h test pressure

The following requirements shall apply to all products and Manufacturers, irrespective of whether full ASTM D 2992 long-term regression curves are available or not.

The 1000-h test pressure for static and cyclic service and 20 years design life is provided in Table 5.

Table 5 TP_{1000hr} test pressure for static and cyclic service and 20 years design life

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