

DEP SPECIFICATION

GLASS-FIBRE REINFORCED PLASTIC PIPELINE AND PIPING SYSTEMS

DEP 31.40.10.19-Gen.

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DESIGN AND ENGINEERING PRACTICE

DEM1



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TABLE OF CONTENTS

1.	INTRODUCTION	5
1.1	SCOPE	5
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	5
1.3	DEFINITIONS	6
1.4	CROSS-REFERENCES	8
1.5	SUMMARY OF MAIN CHANGES.....	9
1.6	COMMENTS ON THIS DEP	9
1.7	DUAL UNITS.....	9
1.8	NON NORMATIVE TEXT (COMMENTARY).....	9
2.	MATERIALS	10
2.1	GENERAL	10
2.2	RESINS.....	10
2.3	UV PROTECTION	13
2.4	GASKET MATERIALS	13
2.5	FIRE RESISTANCE.....	13
3.	MANUFACTURING	13
3.1	GENERAL	13
3.2	PIPE	13
3.3	FITTINGS.....	13
3.4	FLANGES	14
4.	QUALIFICATION	14
4.1	GENERAL	14
4.2	FULL REGRESSION TESTING	16
4.3	1000 HOUR QUALIFICATION TEST	17
4.4	BASELINE DATA.....	18
4.5	REQUALIFICATION	20
5.	QUALITY ASSURANCE AND CONTROL	21
5.1	GENERAL	21
5.2	QUALITY CONTROL EQUIPMENT	21
5.3	QUALITY CONTROL TESTS	22
5.4	VISUAL INSPECTION	23
5.5	RETEST	24
5.6	QUALITY CONTROL RECORDS	24
6.	COMPONENT MARKING	25
6.1	GENERAL	25
6.2	REQUIREMENTS	25

7.	SYSTEM DESIGN	25
7.1	GENERAL	25
7.2	ANALYSIS REQUIREMENTS	26
7.3	LOADS	27
7.4	DESIGN PRESSURE	28
7.5	LOAD FACTOR	29
7.6	DESIGN TEMPERATURE	29
7.7	DESIGN ENVELOPE	30
7.8	VACUUM	30
7.9	VIBRATION	30
7.10	CYCLIC LOADING	30
7.11	THERMAL LOADING	31
7.12	BENDING	31
7.13	DEFLECTIONS	32
7.14	SPAN LENGTH	33
7.15	SUPPORTS	33
7.16	BURIED PIPE SYSTEMS	33
7.17	JOINTS	38
7.18	REPAIR PROCEDURE	41
8.	TRANSPORTATION, HANDLING, AND STORAGE	41
8.1	GENERAL	41
8.2	TRANSPORTATION	42
8.3	HANDLING	42
8.4	STORAGE	43
9.	INSTALLATION	44
9.1	GENERAL	44
9.2	INSPECTION	45
9.3	SUPPORTS	45
9.4	JOINTS	45
9.5	BURIED PIPE SYSTEMS	47
10.	SYSTEM TESTING	51
10.1	GENERAL	51
10.2	PREPARATION	51
10.3	PRESSURE TESTING	51
10.4	AFTER COMPLETION OF TESTS	53
11.	HEALTH AND SAFETY	53
11.1	GENERAL	53
11.2	DISPOSAL OF MATERIALS	54
11.3	DUST HAZARDS	54
12.	REFERENCES	55

APPENDICES

APPENDIX A	QUALIFICATION REQUIREMENTS FOR PIPE JOINTER, SUPERVISOR AND INSPECTOR	57
APPENDIX B	HYDROSTATIC TESTING - PRESSURE CHANGE CALCULATION	60

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 is 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 February 2012; see (1.5) regarding the changes.

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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 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 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.

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
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, $\leq 1\%$ alkali content
E-CR glass	Glass fibre having a better chemical resistance than E-glass. Composition: Alumina-limesilicate glass, $\leq 1\%$ alkali content
C-glass	Glass fibre having a better chemical resistance than E-glass Composition: Alkali-lime glass $\approx 8\%$ 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 inner "char" layer.
Lot	A production quantity. When referred to pipe manufacture, a lot is defined as 100 units. When used in connection with the manufacture of fittings or spools, a lot is defined as components manufactured from the same materials during a single shift.

Term	Definition
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. These test spools will be transported to the field and built 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.

1.3.3 Abbreviations

Term	Definition
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
Pmin	Minimum pressure during pressure cycle
Pmax	Maximum pressure during pressure cycle
R	Ratio of minimum / maximum pressure during cyclic service
SLT	Standard laboratory temperature
SPL	Single protective layer
TP1000hrs	Test pressure to be used in 1000-hour qualification test
Tg	Glass transition temperature
UV	Ultra Violet

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 (12).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a full revision of the DEP of the same number dated February 2012. The following are the main, non-editorial changes.

Section/Clause	Change
All	Restructured and clarified requirements, enforced use of shall/should/may for normative statements.

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. MATERIALS

2.1 GENERAL

1. The material selection process described in this DEP SHALL [PS] be used for GRP selection.

The selection process described in this DEP ensures that the material is compatible with both internal conditions (service fluids) and external conditions (weathering, 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

2.2.1 General

1. The resins selected shall be of a suitable commercial grade that complies with the technical requirements of the application.
2. The recommendations of the resin Manufacturer for the use of hardeners, catalysts and accelerators shall be followed.
3. The resin shall be compatible, over the full design temperature range, with the fluid being contained.

2.2.2 Temperature limitations

2.2.2.1 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 might be considerably lower depending on the aggressiveness of the specific service fluid and its concentration.

1. Thermoplastic liners may be used as a chemical resistance layer (CRL).

This might lower the maximum allowable operating temperature.

2.2.2.2 Minimum allowable temperatures

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

2.2.3 Chemical resistance

1. 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.
 - a. Other types of reinforcement fibres may be used, subject to approval of the Principal.

For more information on available reinforcements contact the Principal.

2. 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.
3. The chemical resistance data shall state whether the material has been laboratory tested according to ASTM C 581 or equivalent standard (e.g., EN 13121).
4. 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/m² (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/m² (0.184 lb/ft²). The fibre content of the CRL shall be between 25% and 35% by mass.
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

1. To protect the external GRP surface against weathering, sunlight, UV, a resin rich external layer shall be applied, with a thickness of at least 0.5 mm (20 mil).
2. 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.
3. To increase UV resistance, the application of an UV resistant coating may be considered, e.g., white-pigmented polyurethane or epoxy.
4. 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

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

3. MANUFACTURING

3.1 GENERAL

1. For manufacturing of GRP pipe and its components, filament winding, and/or hand lay-up shall be used.
2. Sand-filled GRP pipe and fittings shall not be used for pipeline and piping systems.
3. The use of sand/aggregate filled pipe and fittings is not permitted.

3.2 PIPE

1. Pipe components shall be manufactured by filament winding.

3.3 FITTINGS

1. 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".
2. 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

1. Flanges shall be manufactured by filament winding and/or hand lay-up.
2. The outside diameter and hole spacing of GRP flanges shall meet the requirements of ASME B16.5.
3. The GRP flanges SHALL [PS] be flat faced.
4. For maximum mechanical properties and chemical resistance, GRP flanges SHALL [PS] be post-cured.

3.4.2 Hand lay-up

1. Manufacturing of hand lay-up flanges shall be in accordance with ASTM D 5421.
2. GRP flanges SHALL [PS] be post-cured.

Post-curing provides maximum mechanical properties and chemical resistance.

3.4.3 Filament winding

1. Manufacturing of filament wound flanges shall be in accordance with ASTM D 4024.
2. Filament wound flanges SHALL [PS] be post-cured.
3. The neck area of the filament wound flange SHALL [PS] be reinforced with continuous fibres, e.g., mat or woven rovings.

4. QUALIFICATION

4.1 GENERAL

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

1. Qualification of GRP pipe components shall be achieved through performance-based procedures.
2. The GRP Manufacturer shall demonstrate, through testing, that its products will satisfy the design specifications.
 - a. Qualification of GRP pipe components shall be achieved by the GRP Manufacturer demonstrating, through testing, that its products will satisfy the design specifications. The qualification programme does the following:
 - *delivers the lower confidence limit (LCL), which is the long term reference strength used for the calculation of the system design pressure;*
 - *is used to demonstrate that all components used in a system meet the system design pressure;*
 - *provides the baseline data for quality control during manufacturing.*

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

- a family representative (1.3.2) is used to qualify a product family (1.3.2) and a product sector representative is used to qualify a product sector. 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;
- 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;
- a **product sector** is a sub-division of a product family that groups pipes (plus joints) and fittings into specific diameter and pressure ranges;
- 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.

1. Testing shall be carried out on pipe product with a diameter of 50 mm (2 in) or larger.
2. The following product sectors A through L identified in Table 3 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			

The qualification programme includes the following tests:

- **full regression line testing** on the family representative according to ASTM-2992: delivers the LCL (4.1) used to calculate the system design pressure;
- **10001000 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;
- **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.

4.2 FULL REGRESSION TESTING

4.2.1 General

1. For product, piping and pipeline design, the Manufacturer shall establish the LCL_{static} and/or LCL_{cyclic} values for the product family being made in accordance with the following.
2. The requirements in (4.2.1, item 1) shall be determined in accordance with the requirements of ASTM D 2992, Procedure A and/or Procedure B, as appropriate:
 - a. at a minimum test temperature of 65 °C, or design temperature if higher;
 - b. with unrestrained ends.
3. For GRUP, the maximum test temperature shall be 60 °C.
4. For the test fluid of full regression testing, fresh water shall be used.
5. Where a Manufacturer has not established the LCL, a default value from Table 4 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 °C) 85 (> 65 °C)	16 (≤149°F) 12.3(>149°F)	55 (≤ 65 °C) 43 (> 65 °C)	8(≤149°F) 6.2 (>149°F)
Glass-fibre/vinyl ester (GRVE) - Bisphenol A - Novolac	70 (≤ 65 °C) 55 (> 65 °C)	10.2(≤149°F) 8 (>149°F)	35 (≤ 65 °C) 28 (> 65 °C)	5 (≤149°F) 4 (>149°F)
Glass-fibre/ Isophthalic polyester (GRUP)	70 (≤ 60 °C)	10.2(≤140°F)	35 (≤ 60 °C)	5 (≤140°F)
Glass-fibre/vinyl ester (GRVE) - Bisphenol A - Novolac	70 (≤ 65 °C) 55 (> 65 °C)	10.2(≤149°F) 8 (>149°F)	35 (≤ 65 °C) 28 (> 65 °C)	5 (≤149°F) 4 (>149°F)
Glass-fibre/ Isophthalic polyester (GRUP)	70 (≤ 60 °C)	10.2(≤140°F)	35 (≤ 60 °C)	5 (≤140°F)

4.2.2 Definition of cyclic service

1. 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.

Where R is defined as Equation 1:

$$R = \frac{P_{\min}}{P_{\max}} \quad \text{Eqn. 1}$$

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.

2. When cyclic pressure qualified components are not available, de-rated static pressure qualified components may be used, to be subject to agreement by the Principal.
3. The cyclic pressure rating shall be calculated from the following relationship in Equation 2:

$$LCL_{\text{cyclic}} = \frac{LCL_{\text{static}}}{2} \quad \text{Eqn. 2}$$

4.3 1000 HOUR QUALIFICATION TEST

4.3.1 General

1. 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.
2. Qualification testing SHALL [PS] include the type of repairs recommended by the Manufacturer.
3. The 1000-h tests shall be carried out, or witnessed and certified by an independent third party authority, to be as agreed by with the Principal.

4.3.2 Test requirements

1. 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.
2. For GRUP, the maximum test temperature shall be 60 °C (140°F).
3. For the test fluid, fresh water shall be used.
4. The 1000-h test shall commence only when the pressure and temperature have stabilised and when no further additions of water are required.
5. 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.

6. 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.
7. Time lost to interruptions shall be added back ensuring the test period remains at 1000-h.

8. 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, subject to be agreed approval by the Principal.

Typically used for (sea)-water cooling systems,

9. Components shall be tested as either single units or, where appropriate, as assemblies made up by the relevant components (e.g., pipe+joint, fittings, flanges, instrument/small-bore connections, etc).
10. All individual components and, fittings, etc., that are to be used for the piping or pipeline system SHALL [PS] be qualified.
11. Any components or fittings not tested shall not be accepted until they have also been successfully qualified.
12. The minimum length of pipe between adjacent fittings, or end closures, needed to remove the influence of end-fittings shall not be the larger of the following:
 - a. three times the nominal diameter;
 - b. 1500 mm (60 in).

4.3.3 1000-h test pressure

1. 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

Service:	Design temperature up to 65 °C (149°F)		Design Temperature between 65 °C and 100 °C (149°F and 212°F)	
	Static	Cyclic	Static	Cyclic
Liquid service	$2.4 \cdot P_{des-static}$	$3.2 \cdot P_{des-cyclic}$	$2.6 \cdot P_{des-static}$	$3.5 \cdot P_{des-cyclic}$
Gas Service	$2.9 \cdot P_{des-static}$	$3.9 \cdot P_{des-cyclic}$	$3.1 \cdot P_{des-static}$	$4.1 \cdot P_{des-cyclic}$

Where P_{des} design pressure for either static or cyclic service for the pipeline or piping system

*For the purpose of GRP qualification, **sour service** is defined as $\geq$ Domain 2 in Figure 1, DEP 39.01.10.11-Gen. and $\geq$ SSC Region 2 of ISO 15156-2.*

2. Where the design life required is in excess of 20 years, the above 1000-h test pressures shall be increased by 3% per 10 years.

4.4 BASELINE DATA

4.4.1 General

1. The Manufacturer shall generate, from the qualification programme baseline values including acceptance criteria for the manufacturing quality control programme.