

GLASS-FIBRE REINFORCED PLASTIC VESSELS

DEP 31.22.30.14-Gen.

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DESIGN AND ENGINEERING PRACTICE



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements for the design, materials selection, manufacture, inspection and testing of glass-fibre reinforced plastic (GRP) vessels, manufactured by filament winding and/or hand lay-up. Vessels both with and without a thermoplastic lining are included. Operating pressures are typically up to 10 bar (ga), and operating temperatures are typically between -40 °C and 100 °C. Typical diameters are up to 5 m, with volumes up to 300 m³.

This is a revision of the DEP of the same number dated September 2002; see (1.6) regarding the main changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them.

The DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production and supply/distribution installations.

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 may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regard 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, installation, and commissioning or management of a project or operation of a facility. The Principal may sometimes 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 its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorized to act for the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Design pressure

maximum operating pressure, intended to be experienced, by the vessel during its service life.

Design temperature

maximum fluid / contents temperature that can be reached during service.

E-glass

glass fibre, consisting mainly of SiO₂, Al₂O₃ and MgO.

ECR or C-glass

glass fibre or synthetic veil having a better chemical resistance against acids than E-glass, used primarily as reinforcement for the resin-rich internal liner.

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 inert "char" layer.

Laminate

resin sheet or moulding reinforced with a form of glass fibre or other suitable material.

Synthetic

primarily polyester fibres, typically used as reinforcement material for the resin rich internal liner, i.e. chemical barrier.

Winding angle

angle of main reinforcement to pipe longitudinal axis, can be either positive or negative.

1.4 ABBREVIATIONS

Cure	Chemical reaction resulting in the final polymerized product
GRE	Glass-fibre reinforced epoxy
GRUP	Glass-fibre reinforced unsaturated polyester
GRVE	Glass-fibre reinforced vinyl ester
GRP	Glass-fibre reinforced plastic
PA	Polyamide
PE	Polyethylene
PEX	X-linked polyethylene
PP	Polypropylene
PTFE	Polytetrafluoroethylene
PVC	Polyvinylchloride
PVDF	Polyvinylidenefluoride
UV	Ultra violet light

1.5 CROSS-REFERENCES

Where cross-references are made, the number of the section or sub-section referred to is shown in brackets.

All publications referred to in this DEP are listed in (10).

1.6 CHANGES FROM PREVIOUS EDITION

The previous edition of this DEP was dated September 2002. The following are the main, non-editorial changes.

Section	Change
General	- Title modified to: Glass-fibre reinforced plastic vessels. - Aligned with DEP 31.40.10.19-Gen. and DEP 31.40.10.20-Gen.
1.	Specific definitions and abbreviations: updated.
2.	Materials: aligned with DEP 31.40.10.19-Gen. and DEP 31.40.10.20-Gen.
4.	Manufacturing: aligned with DEP 31.40.10.19-Gen.
5.	Quality assurance and control: aligned with DEP 31.40.10.19-Gen.
6.	Transportation, handling and storage: aligned with DEP 31.40.10.19-Gen.
7.	Installation: aligned with DEP 31.40.10.19-Gen.
8.	Maintenance and repair: aligned with DEP 31.40.10.19-Gen.
9.	HSE: new section.

1.7 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the DEP Administrator at standards@shell.com. Shell staff may also post comments on this DEP on the Surface Global Network (SGN).

2. MATERIALS

2.1 GENERAL

The material selection process shall ensure that the material is compatible with the service fluids to which it is exposed over the full design temperature range so that the mechanical, physical and chemical properties of the GRP, and liner, 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 Epoxy resins

Epoxy resins are resistant to a wide range of moderately strong acids and alkalis, and most hydrocarbons. There are several types of base epoxy resins and associated curing agents.

Curing agents typically used for epoxy resin are:

- Aliphatic amine;
- Cyclo-aliphatic amine (IPD);
- Aromatic amine (MDA);
- Anhydride.

2.2.2 Polyester resins

Types of polyester resins, typically used for GRP vessels, are:

- Isophthalic polyester. This is a relatively low cost resin, with limited chemical resistance. It is typically used in thermoplastic lined GRP vessels, widely used for underground storage of gasoline;
- Bisphenol-A polyester. This is a high temperature, chemically resistant resin that is extensively used in chemical service;
- Chlorinated polyester. This resin has many of the properties of bisphenol A resins, but has an inherent fire retardant characteristic. This fire resistant property can be enhanced by addition of antimony oxide particles to the resin mix.

2.2.3 Vinyl ester resins

Compared to polyester, vinyl ester resin has very good chemical resistance, especially against acids. High temperature and chemical resistant vinyl ester based resins, e.g. Novolac vinyl ester, are also available.

2.2.4 Temperature limitations

The maximum allowable service temperature of GRP systems depends on the resin type, and shall be in accordance with Table 2.2.4.1.

Table 2.2.4.1 Temperature limitations of GRP

Type of GRP	Maximum allowable temperature	Typical T _g value of fully cured resin
Glass-fibre/epoxy (GRE) - Aromatic-amine cured (MDA) - Cyclo-aliphatic cured (IPD) - Aliphatic-amine cured - Anhydride cured	100 °C 100 °C 85 °C 85 °C	140 °C 140 °C 115 °C 115 °C
Glass-fibre/vinyl ester (GRVE) - Bisphenol A - Novolac	90 °C 100 °C	120 °C 140 °C
Glass-fibre/polyester (GRUP) - Isophthalic - Bisphenol-A - Chlorinated	60 °C 90 °C 80 °C	90 °C 120 °C 110 °C

The temperatures listed in Table 2.2.4.1 are for initial guidance only.

The maximum allowable temperature for GRP, however, may be considerably lower, depending on the aggressiveness of the specific fluid and its concentration.

The minimum recommended temperature for GRP regardless of the resin system is minus 40 °C although lower temperatures may be considered.

2.2.5 Chemical resistance of resins

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, e.g. according to ASTM C 581 (or other equivalent standard). Guidance on the selection of GRP with respect to its chemical resistance is given in Table 2.2.5.1.

Table 2.2.5.1 Chemical resistance of GRP material

Fluid type	GRE Aliphatic	GRE Aromatic	GRE Anhydride	GRVE Vinyl ester	GRP Polyester
Acids	Poor	Poor	Good	Very good	Poor
Alkalis (caustic)	Very good	Very good	Poor	Good	Not resistant
Solvents (BTX)	Good	Good	Poor	Poor	Not resistant
Water sea/brackish	Good	Good	Good	Good	Good

Further information about the chemical resistance of resins typically used for GRP, in a variety of chemical environments, is given in DEP 30.10.02.13-Gen.

2.3 REINFORCING MATERIALS

The principal reinforcing material for the structural GRP wall 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.

Fibre reinforcement materials typically used for GRP are:

- **E-glass** This is the most commonly used type of glass. It is relatively inexpensive and has good mechanical properties., E-glass, however, has limited chemical resistance and shall therefore be protected by the resin from direct exposure to the fluid.
- **C-glass** This has a higher degree of chemical resistance than E-glass. It is used where the fluid may come into contact with the reinforcement, e.g. C-glass veil used in the liner of GRP vessels.
- **ECR glass** This offers improved chemical resistance over C-glass. ECR-glass veil is often used as reinforcement material for the resin rich internal liner when severe corrosive conditions may occur.
- **Synthetic veil** This is composed of primarily (thermoplastic) polyester fibres, typically used as reinforcement material for the resin rich internal liner, in chemical service.
- **Carbon** Single carbon fibre rovings may be included within the GRP to achieve an electrically conductive wall to prevent build up and discharge of static electricity.

2.4 LINING MATERIALS

2.4.1 Thermoset materials

For containment of non-aggressive fluids, e.g. waste water, crude oil, hydrocarbons, etc., an internal resin-rich liner with minimum thickness of 0.5 mm shall be applied, which may be reinforced with C glass or ECR glass veil.

For containment of chemicals, e.g. hydrochloric acid, caustic, etc, a resin-rich liner, reinforced with veil of C glass, ECR glass, synthetic fibre, or other suitable material, e.g. thermoplastic, shall be used. The thickness of the resin-rich liner shall be at least 3 mm, and the fibre reinforcement content shall be in the range 20 % to 30 % by weight.

2.4.2 Thermoplastic materials

For containment of chemicals, e.g. hydrochloric acid, caustic, etc, thermoplastic lining may be required.

Only virgin polymers shall be used for the production of the liner, with a maximum of 0.2% wt of additives. Use of reworked (or re-cycled) materials shall not be permitted. The use of colouring agents should be avoided. A larger quantity of additives may be added if electrically conductive properties are required.

Thermoplastic materials, typically used for liners, are:

- Polyethylene (PE), as specified in ISO 1872;
- Cross-linked PE (PEX), specifications to be agreed by the Principal;
- Polyamide (PA), as specified in ISO 1874;
- Polyvinylidene fluoride (PVDF), as specified in ISO 15014;
- Polypropylene (PP), as specified in ISO 15013;
- Polyvinyl chloride (PVC), as specified in ISO 1163.

2.4.3 Temperature limitations

The maximum allowable service temperature of thermoplastic materials shall be in accordance with Table 2.4.3.1.