

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

GLASS-FIBRE REINFORCED EPOXY, POLYESTER AND VINYL ESTER VESSELS AND TANKS

PTS 31.22.30.14

January 2010



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PTS Circular 2010 - 1	PETRONAS 
PTS No:	31.22.30.14
Publication Title:	GLASS-FIBRE REINFORCED EPOXY, POLYESTER AND VINYL ESTER VESSELS AND TANKS
Base PTS Version:	13

This revision of PTS 31.22.30.14 – GLASS-FIBRE REINFORCED EPOXY, POLYESTER AND VINYL ESTER VESSELS AND TANKS has been updated incorporating PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards.

All updates in the document are highlighted in *italic* font.

The previous version of this PTS September 2002 will be removed from PTS binder/ e-repository from herein onwards.

Document Approval

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Revision History

Date	Version	Description of Updates	Author
September 2002	Ro		
December 2010	R1	Periodic review	M Rosdi

PREFACE

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1. INTRODUCTION

1.1 SCOPE

This PTS is a revision and combination of PTS 31.22.30.14 (October 1995) and PTS 31.22.30.34 (October 1995), and consequently the latter publication is now withdrawn.

This PTS specifies requirements for the design, materials, manufacture, inspection, testing, erection, maintenance and disposal of glass-fibre reinforced plastic (GRP), i.e., polyester (GRUP), vinyl ester (GRVE) and epoxy (GRE) vessels and tanks, manufactured by the wet lay-up process. Constructions both with and without a thermoplastic lining are included. Operating pressures are typically up to 10 bar (gauge), temperatures between -30°C and 110°C and diameters up to 5 m, with volumes up to 300 m^3 .

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part of or manage by the PETRONAS, and to Contractors nominated by them (i.e. the distribution code is "C", as defined in PTS 00.00.05.05).

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

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS the Contractor shall determine by careful scrutiny which of the requirements are the 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 PTS 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 PTS 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 Abbreviations and specific definitions

CSM: chopped strand mat

Cure: the chemical reaction resulting in the final polymerized product.

FRP: fibre-reinforced plastic

Gel coat: A thin layer of resin on the surface of a laminate, that may or may not be reinforced with a fabric or tissue.

GRE: glass-fibre reinforced epoxy

GRVE: glass-fibre reinforced vinyl ester

GRP: glass-fibre reinforced plastic

GRUP: glass-fibre reinforced unsaturated polyester

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

Tank: container for the storage of fluids subject only to its own hydrostatic head and freely vented to atmosphere.

UD: uni-directional laminate

Vessel: closed container subject to applied pressure or vacuum, with or without hydrostatic head.

WR: woven roving (cloth, plan weave)

1.4 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 PTS are listed in (8).

1.5 SUMMARY OF CHANGES FROM PREVIUOS EDITION

The previous edition of this PTS was dated September 2002. Other than editorial changes, a summary of the main changes since the last edition is given below:

Section	Changes
3.6	'The Shell Safety Committee' has been changed to ' <i>Group Electrical GTS</i> '
8	Reference changed from SHELL Standard to <i>PETRONAS</i> Standard and 'Shell Safety Committee' to ' <i>Group Electrical GTS</i> '

2. MATERIALS

2.1 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 Suppliers 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.

If specified by the Principal, the external resin layer may be pigmented to provide suitable resistance to UV degradation effects and/or earthing requirements.

2.1.1 Polyester resins

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

- Isophthalic polyester. This is a relatively low cost resin, which is rarely used for chemical services. It is typically used in thermoplastic lined GRP vessels and widely used in underground GRP gasoline storage tanks. The minimum glass transition temperature, T_g , is 90 °C;
- Bisphenol A polyester. This is a high temperature, chemically resistant resin that is extensively used in chemical service. It is a general-purpose resin and is easy to manufacture. The minimum glass transition temperature, T_g , is 120 °C;
- 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. The minimum glass transition temperature, T_g , is 110 °C.

2.1.2 Vinyl ester resins

Compared to polyester, vinyl ester resins have improved corrosion resistance. High temperature resistant vinyl ester versions, e.g. Epoxy-Novolac, are also available. The minimum glass transition temperature, T_g , is 115 °C.

2.1.3 Epoxy resins

Epoxy resins have excellent resistance 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 - Good resistance against caustics and solvents. Resistance against acids is fair. Minimum glass transition temperature, T_g , is 115 °C;
- Cyclo Aliphatic Amine – Excellent resistance against caustics and solvents. Resistance against acids is fair. Minimum glass transition temperature, T_g , is 140 °C;
- Aromatic Amine - Excellent resistance against caustics and solvents. Resistance against acids is fair. Minimum glass transition temperature, T_g , is 140 °C;
- Anhydride – Excellent resistance against acids. Resistance against caustics and solvents is poor. Minimum glass transition temperature, T_g , is 115 °C.

2.1.4 Temperature limitations

The maximum allowable temperature is determined by the resin type and state of cure. Experience of typical GRP systems suggests the following maximum allowable temperatures, depending on resin type:

Table 1: Temperature limitations

Resin Type	Temperature limit
Epoxy	110 °C
Vinyl ester	100 °C
Polyester	70 °C

The temperatures listed in Table 1 are for initial guidance only.

The maximum operating temperature for GRP may, however, be considerably lower, depending on the aggressiveness of the specific fluid and its concentration and the specific curing agent of the resin system. Information about chemical resistance of GRP materials is given in PTS 30.10.02.13-Gen.

2.2 REINFORCING MATERIALS

The reinforcing material shall be a suitable grade of glass fibre having a glass finish compatible with the resin system used.

Glass-fibre materials typically used for GRP vessels and tanks are:

- **E-glass**, the most commonly used type of glass. It is relatively inexpensive and has good mechanical properties. However, E-glass has limited chemical resistance and shall therefore be protected by the resin from direct exposure to the fluid;
- **C-glass** has a high degree of chemical resistance. It is used where the fluid may come into contact with the reinforcement, e.g., C-glass veils used in liner of vessels and tanks;
- **ECR glass** offers improved chemical resistance over E-glass and is only slightly more expensive. ECR-glass is often used for internal surface veils when severe corrosive conditions occur.
- **Synthetic**, primarily polyester fibres, typically used as reinforcement material for the resin rich internal liner, i.e., chemical barrier.
- **Carbon** is typically used for low weight, high strength and stiffness FRP structures, including high-pressure vessels. Single carbon fibre rovings may be included within the structural laminate of GRP vessels to achieve an electrically conductive laminate to prevent build up and discharge of static electricity.

2.3 MECHANICAL PROPERTIES

The mechanical properties of the laminate layers shall be not less than the values given in Table 2:

Table 2: Minimum mechanical properties for GRP laminate

Type of reinforcement	Glass content (by mass)	Tensile Strength (MPa)	Young's Modulus (GPa)	Lap shear strength (MPa)
CSM	28 % - 45 %	200	14	7
WR	45 % - 55 %	250	16	6
UD-laminate	65 % - 75 %	500	28	6

CSM: chopped strand mat;
WR: cloth, plain weave;
UD: unidirectional laminate (fibre direction), e.g., filament wound.

2.4 CHEMICAL BARRIER

2.4.1 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 structural wall satisfy the design requirements throughout the intended lifetime.

The Manufacturer shall supply chemical resistance data for the relevant service fluids and the specific 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 other equivalent standard) and shall state the life expectancy for the intended service.

Information about chemical resistance of non-metallic materials in a variety of chemical environments is given in PTS 30.10.02.13-Gen.

2.4.2 Thermoplastic lining

A number of thermoplastic materials are available as liner materials, e.g., unplasticised polyvinyl chloride (UPVC), polypropylene (PP), polyvinylidene fluoride (PVDF), ethylene chlorotrifluoroethylene (ECTFE) and fluorinated ethylene propylene copolymer (FEB). The minimum lining thickness is specified in (5.6).

2.4.3 Thermoset lining

To achieve the optimum chemical barrier properties, the thermoset lining shall consist of the following:

- (a) Surface layer. A resin-rich surface layer reinforced with C glass or ECR glass surfacing mat, synthetic fibres or other suitable material, with a thickness between 0.25 mm and 0.50 mm.
- (b) Backing layer. A backing layer normally containing a minimum of 1.2 kg/m² chopped glass strand or chopped strand mat with a soluble binder with between 25 % and 33 % glass content by mass.

For resin systems with which long-term experience has been gained under the given operating conditions, the backing layer may be reduced to 0.6 kg/m² chopped glass strand or chopped strand mat.

2.4.4 External layer

The laminate construction shall be provided with a gel coat, i.e., resin-rich outer layer that may or may not be reinforced with fibres or tissue, and a thickness between 0.25 mm and 0.50 mm.

3. DESIGN ASPECTS

3.1 MANUFACTURER CAPABILITY

It is essential that the Principal has a good grasp of the performance capability required for the GRP vessel and tank before the contract is awarded to the Manufacturer. Performance issues shall include but not be limited to:

- maximum pressure likely to be encountered in service;
- chemical environment;
- maximum and minimum temperature;
- requirements for internal fixtures;
- need for fire rating and protection;
- static electricity;
- erosion and abrasion;
- static and dynamic loads applied during manufacture, transport, installation and service;
- potential for mechanical abuse during transport, installation and service;
- interface with internal and external fittings, fixtures and equipment;
- inspection requirements;
- future requirements for modifications and tie-ins;
- ability to carry out repairs.

Strain gauges may be incorporated into the design of GRP vessels and tanks to monitor dynamic stress (strain) loadings.

The Manufacturer shall be able to demonstrate that he can satisfy all these issues from the outset, including a successful track record of manufacture of vessels of the same type and similar size.

3.2 DESIGN CODES

3.2.1 Selection

Unless otherwise specified by the Principal, the AD-Merkblatt N1 design code (3.2.2) should be used. It is presently the most common design code used by GRP vessel and tank Manufacturers.

Alternatively, design codes by BS 4994 (3.2.3), ASME BPVC – Section X (3.2.4), or ASME RTP-1 (3.2.5) may be used, if specified by the Principal. However, vessels designed to these codes may be more expensive than those designed to AD-Merkblatt N1.

3.2.2 AD-Merkblatt N1

The AD-Merkblatt N1 Code addresses the demands made on the materials and manufacture, and the calculation and testing of pressure vessels and their components fabricated from glass-fibre reinforced thermosetting plastics (GRP). The Code may be appropriately employed for other fibre reinforcements. Protective layers and liners made from other materials may be used where appropriate, provided their suitability has been demonstrated. The AD-merkblatt design method is based on stresses, i.e., force per unit area. From each specific laminate the strength and stiffness properties are determined by actual tests. These values are used in the stress formulae to obtain a minimum wall thickness.

AD-Merkblatt N1 requires that appropriate allowance be made for the expected mechanical, chemical and thermal demands made on the pressure vessel. The chosen criterion of