

**SPECIFICATION AND
RECOMMENDED PRACTICE
FOR THE USE OF
GRP PIPING OFFSHORE**

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PART 1
PHILOSOPHY AND SCOPE

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FOREWORD

This five part Document Suite has been developed by a consortium of Offshore Design Engineering Ltd and AEA Technology on behalf of and under the guidance of the Fibre Reinforced Plastic (FRP) Workgroup of the United Kingdom Offshore Operators Association (UKOOA).

The objective of this Document Suite is to provide the offshore oil and gas industry and the supporting engineering and manufacturing industry with mutually agreed specifications and recommended practices for the design, purchase, manufacturing, qualification testing, handling, storage, installation, commissioning and operation of glass reinforced plastic (GRP) piping systems offshore.

At ODE, the Project Manager for the work was Mr. P. Wright and at AEA Technology, Dr. G. Eckold. The UKOOA steering group comprised Mr. C. J. Houghton (Phillips Petroleum Company UK Ltd), Mr. J. D. Winkel (Phillips Petroleum Company, Norway), Dr. R A Connell and Mr. J. Milnes (Shell UK Exploration & Production), Dr. P. A. C. Medicott (BP Research), Mr. I. Wattie and Mr. G. Walker (Conoco UK Ltd).

In addition an Industrial Advisory Group was formed comprising manufacturers, engineering design and fabrication companies, recognised specialists, the Certifying Authorities and the Health and Safety Executive, who met with ODE/AEA and UKOOA on three occasions during the project phase and reviewed the documents during their development.

This group comprised:

Mr. M. Bishopp	Health and Safety Executive
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Mr. R. Stokke	S. I. (Norway)

It is the intention of the UKOOA FRP Workgroup that this Document Suite is adopted by the International Standards Organisation (ISO) to facilitate its widest use in industry and so that new developments in materials, testing and experience in the use of glass reinforced plastic piping, can be accommodated through future revisions.

Every reasonable effort has been made to ensure that this publication is based on the best knowledge available up to the time of finalising the text. However, no responsibility of any kind for any injury, delay, loss or damage can be accepted by ODE, AEA, UKOOA or others involved in its publication.

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1 INTRODUCTION

1.1 DOCUMENTATION SCHEME FOR THE USE OF GRP OFFSHORE

This Document Suite of Specifications and Recommended Practice for the use of GRP piping offshore forms part of Tier 2 of a three tier documentation scheme proposed by UKOOA to facilitate the use of GRP offshore (reference Figure 1).

The Document Suite adopts a performance-based approach to address functional criteria and allow the safe and cost-effective use of GRP piping offshore. **The Document Suite should be used in conjunction with the "Guidance" which identifies the issues which need to be considered.** The Document Suite is specific to the use of glass reinforced thermoset plastic resins. Other types of fibre reinforcement (FRP) are not addressed.

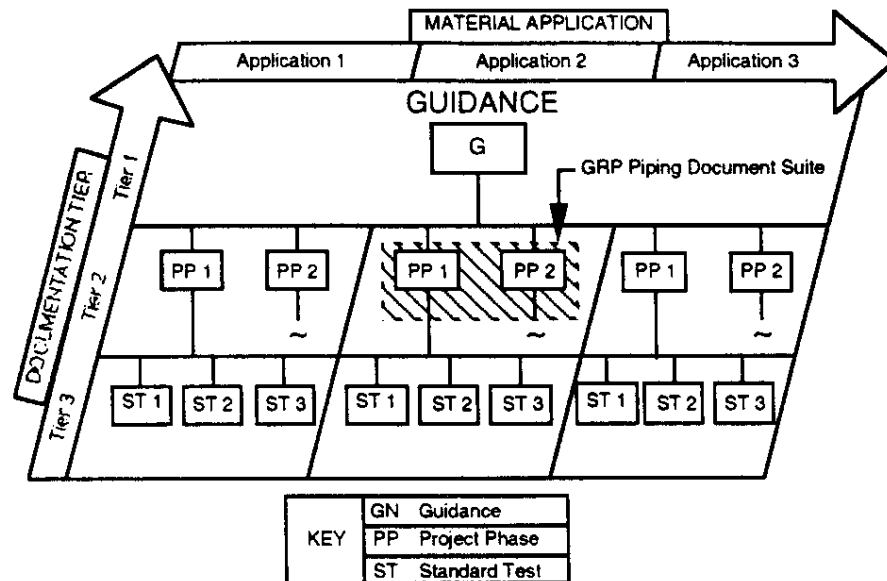


Figure 1 - The 3 Tier/Multi-Application Documentation Scheme

Tier 1 consists of a single document; Guidance. This document is essentially philosophical in nature and identifies the issues that must be considered in using GRP offshore. The document provides an overview of potential applications of GRP, including piping. It is principally an outline document and refers to the underlying Tier 2 documents for more detailed guidance and specifications on the particular applications.

Tier 2 consists of sets of documents, each relating to a particular application (e.g. piping as in this Document Suite). These documents specify the relevant performance requirements for each application and provide guidance on how to achieve that performance. The specifications are 'performance-based' rather than prescriptive, and address each stage of the project. Performance-based specifications are discussed in section 1.5.

Tier 3 typically consists of specific standards and test methods, published by national and international bodies, e.g. ASTM, BS, DIN, ISO etc. These documents define standard test procedures for physical features such as mechanical properties etc. but do not normally include specific performance requirements. Current ASTM, BS, ISO etc. standards already exist to cover most of these aspects. In some specialist applications, e.g. jet fire test procedures, standards are still under development.

1.2 DOCUMENT SUITE USERS

The Document Suite is intended for use by all suitably qualified parties involved in the procurement, design, manufacture, installation and operation of GRP piping systems. Typical parties will include:

- operators;
- manufacturers;
- design engineers;
- fabricators and installation contractors;
- inspection, repair and maintenance contractors;
- Certifying Authorities and Government Agencies.

Each part, with the exception of Part 1, has been targeted at one or more of these parties. Part 1 has been written as a general introduction and is therefore relevant to all parties.

1.3 DOCUMENT SUITE PURPOSE

The Document Suite is intended, along with relevant Tier 3 documents, to form the basis of specifications for design, purchase, installation and maintenance of GRP piping systems.

1.4 DOCUMENT SUITE LAYOUT

This Document Suite of Specifications and Recommended Practice for the use of GRP Piping Offshore is divided into five parts. It is intended that the parts, with the exception of Part 1, follow the individual phases in the life cycle of a GRP piping system, i.e. from design through manufacture to operation. Each part is therefore aimed at the relevant parties involved in that particular phase.

Each part may be considered as a separate document (with main users as outlined below), requiring little or no reference by the user to the other parts.

Part 1 (Philosophy and Scope) presents the basis of the Document Suite. It identifies the applications that the Document Suite is intended to cover, together with anticipated end users. Additional sections define component and GRP terminology as well as defining standard abbreviations, symbols and units. Main users will include all parties in the life cycle of a typical GRP piping system. Part 1 should be used in conjunction with the Part of specific relevance.

Part 2 (Components and Manufacture) is a purchase specification and addresses qualification procedures, preferred dimensions, and quality assurance during manufacture. In addition, guidance on the purchasing of components is included in the form of a standardised datasheet. Main users will be the Principal, GRP Piping Manufacturers and Certifying Authorities.

Part 3 (System Design) contains the recommended practice for designer qualifications, structural design, hydraulic design, detailing and fire endurance. Its objective is to ensure that piping systems, when designed using the components qualified in Part 2, will meet the specified performance requirements. Main users will be the Principal, Design Contractors, Certifying Authorities and Government Agencies.

Part 4 (Fabrication and Installation) encompasses recommended practices for inspection, on-site handling, system testing and methods of repair. Health and Safety issues during fabrication and installation are also covered. Its objective is to ensure that piping systems when installed will meet the specified performance requirements. Main users will be the Principal, Fabrication/Installation Contractors and Certifying Authorities.

Part 5 (Operation) covers the recommended practices for the following aspects of operation: guidance on the contents of operator documentation (e.g. design assumptions, as-built drawings etc.); inspection (e.g. defect type, significance of defects, inspection frequency and inspection techniques); repair and

maintenance; modifications and tie-ins to existing systems; and health/safety aspects associated with repair and modification. Its objective is to ensure that piping systems will continue to meet the specified performance requirements throughout their life. Main users will be the Principal, IRM (Inspection, Repair and Maintenance) Contractors, Certifying Authorities and Government Agencies.

1.5 PERFORMANCE BASED MATERIAL SELECTION

This Document Suite advocates the use of a standard methodology for materials selection that is based on performance and not prescription, called "Performance Based Material Selection" (PBMS). PBMS reflects true functional needs, excludes arbitrary requirements, and does not prescribe materials. The four key steps to PBMS are:

- a) identification and documentation of all performance factors relevant to the application;
- b) quantification of functional performance requirements;
- c) qualification of materials for technical acceptability;
- d) final selection.

The above methodology provides a standardised auditable approach to material selection.

2 SCOPE

2.1 APPLICATIONS

This Document Suite primarily defines the requirements for low to medium pressure (typically 0-40bar) GRP piping systems with nominal diameters between 25mm and 1200mm at working temperatures between -40°C and 95°C for non-hydrocarbon applications on Offshore Installations.

Typical applications on Offshore Installations for the use of GRP piping will include:

- service (or process) water;
- cooling medium;
- potable water;
- grey water (non hazardous waste);
- non hazardous drains;
- non hazardous vents;
- chemicals;
- firewater ringmain;
- firewater wet deluge;
- firewater dry deluge;
- produced water;
- ballast water.

It is anticipated that the Document Suite could be extended to cover other applications, diameters, pressures and temperatures where it can be shown that safety and risk to personnel, the Facilities and the environment will not be compromised.

Offshore Installations are defined as non land-based, mobile, fixed or subsea units engaged in the exploration for and production of hydrocarbons. No limit is placed on the geographic location of these units.

All components that form part of a GRP piping system are covered, including:

- pipe;
- bends;
- reducers;
- tees;
- supports;
- flanges;
- joints (including adhesives, O-rings and gaskets).

The use of this Document Suite for marine (i.e. shipping) or land-based petrochemical applications is not specifically excluded. However, attention is drawn to the potentially different service conditions that may be encountered, and for other more pertinent standards which may apply, refer to section 6.

2.2 MATERIALS

The Document Suite covers GRP piping systems. GRP is defined in the context of this Document Suite as thermosetting resins reinforced with glass fibres. Reinforcement will normally be E glass but other glass fibres such as R and S glass, ECR glass and C glass may be used to provide improved performance. Other types of fibre reinforcement (with the exception of carbon fibres used non-structurally to improve conductivity) are not covered. Typical resins are epoxy, polyester, vinylester, methyl methacrylate and phenolic. Thermoplastic liners are also excluded from this Document Suite.

2.3 MANUFACTURING METHODS

This Document Suite covers the use of GRP piping systems manufactured by the following methods:

- filament winding;
- hand lay-up;
- centrifugal casting.

Other methods are not specifically excluded provided it can be demonstrated that the specified performance criteria can still be met.

3 REFERENCES

The following Tier 1 Guidance Notes and Tier 3 codes, standards and specifications are an integral part of this Document Suite.

3.1 TIER 1 DOCUMENTS

UKOOA "Guidance for Fibre Reinforced Plastics Use Offshore".

3.2 TIER 3 DOCUMENTS

3.2.1 International Organization for Standardization (ISO)

ISO 7005-3	Specification for Copper Alloy and Composite Flanges.
ISO 7370	Glass Fibre Reinforced Thermosetting Plastics (GRP) Pipes and Fittings - Nominal Diameters, Specified Diameters and Standard Lengths.
ISO 9000	Quality Management and Quality Assurance Standards, Guidelines for Selection and Use.
ISO 9001	Quality Systems, Model for Quality Assurance in Design/Development, Production, Installation and Servicing.

3.2.2 American Society for Testing and Materials (ASTM)

ASTM C 177	Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded Hot Plate Apparatus.
ASTM C 581	Standard Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fibre Reinforced Structures intended for Liquid Service.
ASTM D 257	Test Methods for Determining Chemical Resistance or Conductance of Insulating Materials.
ASTM D 635	Test Method of Rate of Burning and/or Extent and Time of Burning of Self-supporting Plastics in a Horizontal Position.
ASTM D 696	Test Method for Coefficient of Linear Thermal Expansion of Plastics.
ASTM D 1598	Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure.
ASTM D 1599	Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings.
ASTM D 2105	Test Method for Longitudinal Tensile Properties of Reinforced Thermosetting Plastic Pipe and Resin Tube.
ASTM D 2143	Test Method for Cyclic Pressure Strength of Reinforced Thermosetting Plastic Pipe.
ASTM D 2563	Practice for Classifying Visual Defects in Glass-reinforced Plastic Laminate Parts.
ASTM D 2584	Test Method for Ignition Loss of Cured Reinforced Resins.
ASTM D 2863	Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index).

- ASTM D 2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fibreglass" (Glass Fibre Reinforced Thermosetting Resin) Pipe and Fittings.
- ASTM D 3567 Practice for Determining Dimensions of "Fibreglass" (Glass Fibre Reinforced Thermosetting Resin) Pipe and Fittings.
- ASTM E 84 Test Method for Surface Burning Characteristics of Building Materials.
- ASTM E 162 Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source.
- ASTM E 662 Test Method for Specific Optical Density of Smoke Generated by Solid Materials.
- ASTM E 906 Test Method for Heat and Visible Smoke Release Rates for Materials and Products.

3.2.3 American Society of Mechanical Engineers (ASME/ANSI)

- ANSI B 31.3 Chemical Plant and Petroleum Refinery Piping
- ANSI B 16.5 Pipe Flanges and Flanged Fittings

3.2.4 British Standards Institution (BSI)

- BS 476: Part 7 Method for Classification of the Surface Spread of Flame of Products.
- BS 5958 Code of Practice for Control of Undesirable Static Electricity.
- BS 6401 Method for Measurement, in the Laboratory, of the Specific Optical Density of Smoke Generated by Materials.
- BS 6853 Code of Practice for Fire Precautions in the Design and Construction of Railway Passenger Rolling Stock.
- BS 6920 Suitability of Non-metallic Products for Use in Contact with Water Intended for Human Consumption with Regard to Their Effect on the Quality of the Water.
- PD6503: Part 2 Guide to the Relevance of Small Scale Tests for Measuring the Toxicity of Combustion Products of Materials and Composites.

3.2.5 Naval Engineering Standards (NES)

- NES 711-2 Determination of the Smoke Index of the Products of Combustion from Small Specimens of Material.

3.2.6 International Maritime Organisation (IMO)

- IMO A.653 (16) Recommendation on Improved Fire test Procedures for Surface Flammability of Bulkhead, Ceiling and Deck Finish Materials.

3.2.7 International Electro-technical Commission (IEC)

- IEC 332-2 Test Methods on Electric Cables Under Fire Conditions.

3.2.8 Deutsches Institut für Normung (DIN)

- DIN 50049 Bescheinigungen über Materialprüfen.

4 DEFINITIONS

4.1 GENERAL

For the purposes of this Document Suite, the following general definitions apply:

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal is ultimately responsible for ensuring that safety and all other issues are addressed. The Principal may also include an agent or consultant, authorised to act for the Principal.

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction and commissioning for a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer** is the party which manufactures or supplies equipment to perform the duties specified by the Contractor.

The **Operator** is the party which assumes ultimate responsibility for the operation and maintenance of the piping system. The operator may or may not be the same as the Principal or Principal's agent.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

The word **may** indicates a preference.

4.2 TECHNICAL

For the purposes of this Document Suite, the following technical definitions apply:

accelerator: A substance which, when mixed with a catalyst or a resin, will speed up the chemical reaction between catalyst and resin.

anisotropic: Exhibiting different properties when tested along axes in different directions.

active fire protection: Method whereby fire is extinguished by application of substances such as Halon, water, CO₂, foam, etc.

carbon fibre: Fibre produced by the pyrolysis of organic precursor fibres (such as rayon, polyacrylonitrile and pitch) in an inert environment.

centrifugal casting: Production technique for fabricating pipes in which the composite material is positioned inside a hollow mandrel designed to be heated and rotated as the resin is cured.

collapse pressure: The external pressure differential which causes buckling collapse of a component.

component: Any pipe, prime connection or fitting covered by this specification.

CPR: Cyclic pressure rating, derived in accordance with the requirements of this specification (bar).

cure: To change irreversibly the properties of a thermosetting resin by chemical reaction, i.e., condensation, ring closure, or addition. Cure may be accomplished by the addition of a curing (cross-linking) agent, with or without heat and pressure.

cure cycle: The time/temperature/pressure cycle used to cure a thermosetting resin system.

curing agent: A catalytic or reactive agent that, when added to a resin, causes polymerization. Also called hardener.

delamination: Separation of the layers of material in a laminate, either locally or covering a wide area.

design external pressure: The maximum positive external pressure differential intended to be experienced by a component during its service life.

design pressure: The maximum positive internal pressure differential intended to be experienced by a component during its service life.

design temperature: The maximum fluid temperature for each design condition that can be reached during that operating condition.

epoxide: Compound containing the oxirane structure: a three-member ring containing two carbon atoms and one oxygen atom.

failure: The transmission of fluid through the wall of a component or via a joint, resulting in rupture or weeping.

fibre: A general term used to refer to a filamentary material with a finite length that is at least 100 times its diameter and prepared by drawing from a molten bath, spinning or deposition on a substrate. Filaments are usually of extreme length and very small diameter, usually less than 25 microns. Normally, filaments are not used individually and are assembled as twisted (yarn) or untwisted (tow) bundles comprising hundreds of filaments.

fibre reinforced plastic (FRP): A general term for a plastic based composite that is reinforced with any type of fibre, not necessarily glass.

filament winding: A process for fabricating a composite structure in which continuous reinforcements (filament, wire, yarn, tape, or other), are either previously impregnated with a matrix material or impregnated during the winding.

fire endurance: Ability to maintain functional performance in a fire.

fire reaction properties: Material properties which contribute to spread of fire and smoke/toxic emissions.

fitting: A generic name for a component of any type other than pipe.

flame retardants: Certain chemicals that are used to reduce or eliminate the tendency of a resin to burn.

flanges: Face flanges with bolt circle and face dimensions as per ANSI B16.5.

free ends: A pressure testing arrangement using pipe end closures of a type such that internal pressure produces longitudinal, as well as hoop and radial, stresses in the component wall (also termed unrestrained ends).

furnace test: A test in a compartment furnace where the time-temperature curve to be followed is to a defined standard.

gel coat: A quick-setting resin applied to the surface of a mould and gelled before lay-up. The gel coat becomes an integral part of the finished laminate, and is usually used to provide specific service characteristics (see liner).

glass fibre reinforced plastic (GRP): A thermosetting plastic based composite that is reinforced with glass fibres.

glass transition temperature (T_g): The glass transition temperature of an amorphous polymer is the temperature at which the polymer undergoes a marked change in properties on cooling from the melt. This observed change in properties is associated with the virtual cessation of local molecular motion in the polymer. Below their glass-transition temperature, amorphous polymers have many of the properties associated with ordinary inorganic glasses whilst above this temperature the polymers possess rubbery characteristics.

hardener: A substance or mixture added to a plastic composition to promote or control the curing action by taking part in it.

heat distortion point: The temperature at which a standard test bar deflects a specified amount under a stated load. Now called Deflection Temperature.

heat flux: The quantity of heat per unit area.

hydrocarbon fire: A fire caused by a pool of hydrocarbon liquid igniting.

impregnate: In reinforced plastics, the saturation of the reinforcement with a resin.

Intumescent: Passive fire protection coating which in the presence of fire expands, to create an inert 'char' layer is referred to as intumescent.

jet fire: A turbulent diffusion flame resulting from the combustion of a fuel continuously released with some significant momentum in a particular range of directions.

laminae: Thin sheets of woven fibres built up into a flat or curved arrangement.

to laminate: Uniting laminae with a bonding material, usually with pressure and heat (normally used with reference to flat sheets, but can also refer to tubes). A product made by such bonding is referred to as a laminate.

liner: In a filament-wound component, the continuous resin rich coating on the inside surface, used to protect the laminate from chemical attack or to prevent leakage under stress.

LTHP: Long term hydrostatic (estimated failure) pressure (bar gauge) of a component variant determined in accordance with ASTM D 2992, with free ends, at 65°C or higher.

LTHS: Long term hydrostatic (estimated failure) strength (hoop stress MPa) of a pipe determined in accordance with ASTM D 2992, with free ends, at 65°C or higher.

mandrel: The core tool around which resin-impregnated reinforcement is wound to form pipes and structural shell shapes.

matrix: The essentially homogeneous resin or polymer material in which the fibre system is imbedded in a laminar arrangement. Thermoplastic and thermoset resins may be used; as well as metals, ceramics and glasses.

mechanical joint: A joint between GRP piping components not made by bonding. Typically involves use of proprietary devices.

nominal diameter: A numerical designation of size which is common to all components in a piping system other than components designated by outside diameters or by thread size. It is a convenient round number for reference purposes and is only loosely related to manufacturing dimensions.

ovality: The irregularity of the circular section of a component, quantified by the difference in the largest and smallest cross-sectional axes.

passive fire protection: Method whereby fire damage is minimised by use of sacrificial or non-combustible coatings.

performance standards: Defined limits placed on characteristics of materials, products, or services.

pipe supports: Consist of fixtures and structural attachments as follows:

a. **fixtures** - fixtures include elements which transfer the load from the pipe or structural attachment to the supporting structure or equipment. They include hanging type fixtures, such as hanger rods, spring hangers, sway braces, counterweights, turnbuckles, struts, chains, guides and anchors; and bearing type fixtures, such as saddles, bases, rollers, brackets, and sliding supports.

b. **structural attachments** - structural attachments include elements which are bonded or moulded into the pipe, such as clips, lugs, rings, clamps, clevises, straps and skirts.

piping: Assemblies of piping components used to convey, distribute, mix, separate, discharge, meter, control, or restrict fluid flows.

piping components: Mechanical elements suitable for joining or assembly into pressure-tight fluid-containing piping systems. Components include pipe, fittings, flanges, gaskets, bolting, valves, and devices such as expansion joints, flexible joints, pressure hoses, liquid traps, strainers and in-line separators.

piping system: Interconnected piping subject to the same set or sets of design conditions. The piping system also includes pipe supports, but does not include support structures.

Poisson's Ratio: The ratio of lateral strain to the corresponding longitudinal strain below the proportional limit.

polyester (thermosetting): A class of resin produced by dissolving unsaturated, generally linear, alkyd resins in a vinyl-type active monomer such as styrene, methyl styrene, or diallyl phthalate. Cure is effected through vinyl polymerization using peroxide catalysts and promoters or heat to accelerate the reaction.

proportional limit: The greatest stress which a material is capable of sustaining without deviation from proportionality of stress and strain.

postcure: Additional elevated-temperature cure, usually without pressure, to improve final properties and/or complete the cure, or decrease the percentage of volatiles in the compound. In certain resins, complete cure and ultimate mechanical properties are attained only by exposure of the cured resins to higher temperature than those of curing.

pot life: The length of time that a catalysed thermosetting resin system retains a viscosity low enough to enable processing and sufficient reactivity to achieve specified properties after processing.

pressure rating: A rating for a component, relating to its long term resistance to failure when subjected to either static or standardised cyclic internal pressure loading.

qualification: The process of demonstrating that a component is in accordance with the requirements of Part 2 of this Document Suite.

rated temperature: Maximum service temperature at which a pressure rating, qualified in accordance with Part 2 of this Document Suite, is deemed valid.

reducers: Components that allow pipes of different sizes to be connected.

reinforcement: A strong material embedded into a matrix to improve its mechanical properties. Reinforcements are usually long fibres, whiskers, particulates, and so forth. The term should not be used synonymously with filler.

restrained ends: A pressure testing arrangement using a pipe sealing device or mechanism such that internal pressure produces hoop and radial stresses only in the component wall.

roving: A number of strands, tows, or ends collected into a parallel bundle with little or no twist.

service design factor (S_f): A dimensionless factor ≤ 1 used to lower the maximum acceptable pressure rating to take into account different uncertainties on the product behaviour or the loads that the component has to bear. S_f is the inverse of a safety factor.

sizing agent: A coating on glass fibres used to promote bonding of glass reinforcement to resin.

SLT: Standard laboratory temperature as defined by ASTM D 618 with standard tolerance, i.e. $23 \pm 2^\circ\text{C}$.

SPR: Static pressure rating, derived in accordance with requirements of this specification (bar).

STHP: Short term hydrostatic (burst) pressure (bar gauge) determined in accordance with ASTM D 1599, with free ends, at SLT.

System: An assembly consisting of a representative range of pipes, fittings, connections, attachments, supports and associated coatings (where required) as would be found in service.

thermoset: A plastic which, when cured by application of heat and/or chemical reaction, changes into a substantially infusible and insoluble material.

tow: An untwisted fibrous bundle.

tow tex: The weight of a fibrous bundle expressed in terms of mass per unit length.

type (component): Components of common function. Pipes, prime connections, flanges, reducers, tees and elbows are examples of different component types.

Type Testing: The exposure of a system to a fire insult to qualify the assembled system components for a defined range of service conditions.

variant (component): Any component with a unique combination of nominal diameter, type and pressure rating.

vinyl esters: A class of thermosetting resins containing esters of acrylic and/or methacrylic acids, many of which have been made from epoxy resin. Cure is accomplished as with unsaturated polyesters by copolymerization with other vinyl monomers, such as styrene.

winding angle: Angle of main reinforcement to pipe longitudinal axis; can be either positive or negative.

5 ABBREVIATIONS

For the purposes of this Document Suite, the following abbreviations apply:

ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
BSI	British Standard Institute
CPR	cyclic pressure rating
D_i	mean inside diameter
DIN	Deutsches Institut für Normung
DEn	Department of Energy (U.K.)
DSC	differential scanning calorimetry
FRP	fibre reinforced plastic
GRP	glass reinforced plastics
IEC	International Electro-technical Commission
IMO	International Maritime Organisation
ISO	International Organisation for Standardization
LCL	lower confidence limit
$LTHP_c$	long term hydrostatic pressure (cyclic)
$LTHP_s$	long term hydrostatic pressure (static)
$LTHS_c$	long term hydrostatic strength (cyclic)
$LTHS_s$	long term hydrostatic strength (static)
NDT	non-destructive testing
NES	Naval Engineering Standard
NPR	Nominal Pressure Rating
OLF	Oljeindustriens Landsforening (Norwegian equivalent of UKOOA)
pcd	pitch circle diameter
R_i	inside radius
R_o	outside radius
S_f	service design factor
SCF	stress concentration factor
SIF	stress intensification factor
SLT	standard laboratory temperature
SPR	static pressure rating
STHP	short term hydrostatic pressure
T_g	glass transition temperature
UKOOA	United Kingdom Offshore Operators Association

Note: Subscript (s) = static rating
Subscript (c) = cyclic rating

6 BIBLIOGRAPHY

- | | | |
|------|---------------------|---|
| API | SPEC 15HR | Specification for High Pressure Fiberglass Line Pipe |
| API | SPEC 15LR | Specification for Low Pressure Fiberglass Line Pipe |
| BSI | BS 6464 | Reinforced Plastic Pipes, Fittings and Joints for Process Plants |
| BSI | BS 7159 | Design and Construction of GRP Piping Systems for Individual Plants or Sites |
| IMO | DE 33/6/2 | Guidelines For the Application of Plastic Pipe on Ships |
| OLF | | OLF Recommended Guidelines on the Specification for Composite Piping Offshore |
| OMAE | Paper,
June 1993 | Extending the GRP Option: A Performance-based Purchase Specification for GRP Pipes and Fittings (based on API-15HR/API-15LR),
E. T. Provost. |

PART 2
COMPONENTS AND MANUFACTURE

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1 SCOPE

This part of the Document Suite of Specifications and Recommended Practices for the use of GRP Piping Offshore is a **purchase specification**. It defines requirements relevant to the qualification and manufacture of GRP piping and fittings.

Its objective is to enable the purchase of GRP components with known and consistent properties from any source. Main users of the document will be the Principal and the Manufacturer. **It should be read in conjunction with Part 1: "Philosophy and Scope"**.

The requirements apply to qualification procedures, preferred dimensions, quality programmes, component marking, handling, storage, transportation and documentation.

2 QUALIFICATION PROGRAMME

The qualification programme primarily consists of standard methods for quantifying component performance with respect to internal pressure (static or cyclic) and external pressure, with optional methods for quantifying potable water, static electricity and fire performance.

The qualification programme also includes testing of components in order to provide data for:

- quality control;
- system design.

2.1 PRESSURE RATING QUALIFICATION

2.1.1 General

2.1.1.1 Pressure Rating Terminology

Manufacturers shall assign all components both a lower confidence limit (LCL) and a nominal pressure rating (NPR).

The LCL is a value equivalent to the lower (97.5%) confidence limit of the component's LTHP. It should be regarded as similar to metallic piping schedules. The LCL shall be calculated using the following equation:

$$\text{LCL} = f_1 \times \text{LTHP} \quad \text{Equation (1)}$$

The NPR is a nominal pressure rating (in bar) for the component supplied by the manufacturer. The determination of the NPR may involve the application of an empirical service factor to the LTHP (typically 0.5, reference API 15HR). The manufacturer shall state the basis for the quoted NPR.

Part factor f_1 shall be determined as the ratio of the 97.5% confidence limit of LTHP_s and the mean value of LTHP. In the absence of sufficient data to calculate the confidence limit, a default value of 0.85 shall be used.

Part factor f_2 is a factor of safety the magnitude of which is related to confidence in the pipework system, the nature of the application and the consequences of failure.

Part factor f_3 accommodates non-pressure-induced axial loads and their effect on the pressure rating of the component. Examples of such loads are, bending at supports due to selfweight of pipe and contents and loads generated through thermal expansion of the pipe system. Manufacturers shall derive their own value of f_3 based on a non-pressure axial stress of 10MPa. Full consideration shall be taken of the shape of the allowable stress envelope.

Ratings may be either static or cyclic, i.e. LCL_s or LCL_c and NPR_s or NPR_c according to the test method used.

The system design pressure is:

$$f_2 \times f_3 \times \text{LCL} \quad \text{Equation (2)}$$

For the background to the pressure rating methodology, reference should be made to Part 3: "System Design".

2.1.1.2 Testing Requirements

The pressure ratings of all components shall be verified in accordance with the requirements described in the following sections.

The objective of the pressure rating qualification procedures is to verify the proposed pressure rating of each component. They are intended as prototype tests and therefore need not be repeated for each order or project. However, changes to any of the product characteristics detailed in section 2.1.5 shall require re-qualification.

Components can be tested as either single units or where appropriate as assemblies made up with pipe sections in order that the integrity of the joint, as well as that of the component body, are verified. There shall be a pipe length of not less than three times the nominal diameter between adjacent fittings or end closures. All qualification tests shall be conducted with unrestrained ends such that the full pressure induced axial load is borne by the component. All joints shall be made up in accordance with the Manufacturer's instructions for field assembly as detailed in section 7.4.

All tests specified shall be carried out by, or witnessed and certified by independent third-party authorities approved by the Principal.

The qualification of each component shall be documented in both a qualification report and a summary as detailed in section 7.2.1.

2.1.1.3 Component Definitions

The definitions; **product family**, **product family representative**, **product sectors**, **component variants** and **representative products** are used in order to rationalise the requirements for qualification testing, whilst controlling the use of results beyond their limits of applicability.

A **product family** defines a range of pipes, fittings or joints with the same nominal geometry (e.g. 45° and 90° elbows) and manufactured by the same method, but with differing nominal diameters and pressure ratings. For example, an 80mm/30bar bend and a 500mm/10bar bend manufactured in the same way and with the same basic geometry may belong to the same product family.

The **product family representative** is the component that is taken to be representative of that particular product family.

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

A **component variant** is an individual component (i.e. 80mm/30bar bend) within a particular product sector.

The **representative product** for a product sector is the component variant taken to be representative of that sector and upon which the basic qualification testing is performed.

Example product sectors and representative products are shown in Table 2.1.1.3.

Table 2.1.1.3 – Component Selection Parameters

Component Type	Product Sector		Representative Product	
	Diameter (mm)	Pressure Rating (bar)	Diameter (mm)	Pressure Rating (bar)
Joints & Fittings	50 to 150	0 to 40 ¹	150	40 ²
	150 to 300	0 to 40 ¹	300	40 ²
	300 to 450	0 to 40 ¹	450	40 ²
	450 to 600	0 to 40 ¹	600	40 ²
	600 to 800	0 to 40 ¹	800	40 ²
	800 to 1200	0 to 40 ¹	1200	40 ²

- Note:*
1. This document suite covers the use of low to medium (typically 5-40bar) pressure GRP piping systems; for pressure ratings above 40bar, additional product sectors should be defined.
 2. or maximum pressure rating for product sector if lower.

2.1.1.4 Standard Service Conditions

Pressure ratings are qualified on the basis of the following assumptions:

- a) the standard service life shall typically not exceed 20 years;
- b) the effect of chemical degradation from the transported medium is no more than that of the test medium;
- c) the component's maximum temperature rating shall not exceed the qualification test temperature.

For different transported media and variations in service temperature, reference should be made to Part 3: "System Design".

2.1.2 Static Pressure Ratings

Static pressure ratings for pipes, joints and fittings, shall be qualified in accordance with sections 2.1.2.1 to 2.1.2.3. An overview of the qualification requirements for GRP joints and fittings is given in Table 2.1.2.

2.1.2.1 Pipes

The LTHS_s (long-term hydrostatic strength) of the representative product shall be determined. The recommended procedure is ASTM D 2992 Procedure B.

The representative product selected shall not be less than 50mm nominal diameter.

Table 2.1.2 – Qualification Requirements for Joints and Fittings

Options	Representative Product	Component Variant
1 (Long term)	$LCL \leq 0.85 \times (\text{Test Pressure})_{10,000 \text{ hours}}$	$LCL \leq \left(\frac{LCL}{STHP} \right)_{\text{REPRESENTATIVE PRODUCT}} \times (STHP)_{\text{COMPONENT VARIANT}}$
2 (Medium term)	$LCL \leq 0.85 \times \left(\frac{\text{Test Pressure}}{k} \right)_{1000 \text{ hours}}$ where k is derived from regression line calculated for the product family representative	$LCL \leq \left(\frac{LTHP}{STHP} \right)_{\text{REPRESENTATIVE PRODUCT}} \times (STHP)_{\text{COMPONENT VARIANT}}$
3 (Short term)	See section 2.1.2.2 and 2.1.3.2 (Qualification Option 4: Design Methods)	$LCL \leq \frac{(STHP)_{\text{COMPONENT VARIANT}}}{Z \times 0.85}$ where Z is an empirical factor from Tables 2.1.2.2 and 2.1.3.2

Note: All pressures are in bar.

In addition, the STHP of the representative product shall be determined by testing 5 replicate samples in accordance with ASTM D 1599 and shall be taken as the lower deviated (2 standard deviations) value of the replicate samples. The STHP of any pipe variant shall be taken as the lower of two values. Testing shall be at SLT (Standard Laboratory Temperature). Samples shall be from the same production lot as those used in the long term test.

The LCL_s of the representative product shall be calculated in accordance with either Equation (1) or (2).

$$LCL_s \leq f_1 \times LTHS_s \times 10 \times \left(\frac{R_o^2 - R_i^2}{R_o^2 + R_i^2} \right) \quad \text{Equation (1)}$$

(for $D/t \leq 10$)

$$LCL_s \leq f_1 \times LTHS_s \times 10 \times 2 \times (t/D) \quad \text{Equation (2)}$$

(for $D/t > 10$)

Where LCL_s = lower confidence limit for static pressure in bar as defined in section 2.1.1.1
 f_1 = statistical factor as defined in section 2.1.1.1
 R_o = outside radius of reinforced wall (mm)
 R_i = inside radius of reinforced wall (mm)
 t = reinforced wall thickness (mm)
 D = mean diameter of reinforced wall, i.e. $(2R_i + t)$
 $LTHS_s$ = static long-term hydrostatic strength in MPa

The LCL_s and STHP of pipe variants may be scaled using either Equation (1) or (2) as appropriate.

The qualification report for each qualified component variant shall satisfy the general requirements listed in section 7.2.1.

As an alternative, pipe may be qualified using the short-term tests of Qualification Option 3, for joints and fittings.

2.1.2.2 Joints and Fittings

The static pressure rating of joints and fittings shall be qualified by using one of the three following options:

Qualification Option 1: Long-term survival tests

This option permits qualification of a Representative Product's LCL_s based on a long-term survival test. The test pressure is based on the regression line obtained for equivalent pipe, described in section 2.1.2.1. The objective of this procedure is to demonstrate that the Representative Product's performance is equal, or superior, to the equivalent pipe.

Two replicate samples of the Representative Product shall be selected at random and pressure tested according to test method ASTM D 1598 at the rated temperature. The test duration shall be 10,000 hours. The applied pressure shall not be less than the lower confidence limit for the equivalent pipe at 10,000 hours.

In addition, the STHP of the representative product shall be determined by testing five replicate samples in accordance with ASTM D 1599. The STHP of the Representative Product shall be taken as the lower deviated value (two standard deviations) of the five replicate samples. Testing shall be at SLT (Standard Laboratory Temperature). Samples shall be from the same production lot as those used in the medium term test. (The STHP shall also be used as the baseline value in subsequent production quality control tests).

Component Variants shall be qualified by demonstrating that their proposed LCL_s satisfy the following criterion:

$$(LCL_s)_{\text{COMPONENT VARIANT}} \leq (LCL_s)_{\text{REPRESENTATIVE PRODUCT}} \times \frac{STHP_{\text{COMPONENT VARIANT}}}{STHP_{\text{REPRESENTATIVE PRODUCT}}}$$

The STHP of the component variant shall be the lower of two replicate samples tested at SLT in accordance with ASTM D 1599. (The STHP shall also be used as the baseline value in subsequent production quality control tests).

The component variant's rated temperature shall not exceed the rated temperature of the Representative Product.

The qualification report for each qualified component variant shall detail the LTHP and STHP tests and shall satisfy the reporting requirements of section 7.2.1.

Qualification Option 2: Medium-term survival tests

This option permits qualification of a representative product's LCL_s based on a medium-term survival test. The test pressure is based on the ASTM D 2992 Procedure B regression line obtained for the product family representative. The objective of this procedure is to demonstrate that the Representative Product's performance is equal, or superior, to the product family representative i.e. that the slope of the regression line for the Representative Product is not steeper than that for the Product Family Representative. The LTHP_s of the Product Family Representative shall be determined in accordance with ASTM D 2992 Procedure B.

Note: The regression line for the equivalent straight pipe may be used if it can be demonstrated that it is at least as steep as that for the Representative Product.

Two replicate samples of the Representative Product shall be selected at random and pressure tested according to test method ASTM D 1598 (as amended in section 2.1.2.3) at the rated temperature. The test duration shall be 1000 hours. The applied pressure shall not be less than the predicted lower confidence limit for the representative fitting at 1000 hours.

In the absence of data for the product family representative a conservative gradient may be used. The test pressure (bar gauge) shall be calculated, based on the proposed LTHP_s as follows:

$$\text{Test pressure} \geq \text{LTHP}_s \times K_s$$

where, for epoxy systems up to 65°C, $K_s = 1.25$ for filament wound fittings and pipe, and $K_s = 1.43$ for full or partial hand lay-up.

Note: The 1000 hour qualification test pressure is calculated from the proposed pressure rating for the component and corresponds to 85% of the expected ASTM D 2992 procedure B regression line failure pressure at the test duration. Default gradients, G, of the regression line $\{\text{Log}(\text{pressure or stress}) = A - G \times \text{log}(\text{hours})\}$ are assumed to be 0.075 and 0.1 for filament wound and hand lay-up components respectively.

In addition, the STHP of the representative product shall be determined by testing five replicate samples in accordance with ASTM D 1599. The STHP of the Representative Product shall be taken as the lower deviated (two standard deviations) value of the five replicate samples. Testing shall be at SLT (Standard Laboratory Temperature). Samples shall be from the same production lot as those used in the medium term test. (The STHP shall also be used as the baseline value in subsequent production quality control tests).

Component variants shall be qualified by demonstrating that their proposed LCL satisfies the following criterion:

$$(\text{LCL}_s)_{\text{COMPONENT VARIANT}} \leq (\text{LCL}_s)_{\text{REPRESENTATIVE PRODUCT}} \times \frac{\text{STHP}_{\text{COMPONENT VARIANT}}}{\text{STHP}_{\text{REPRESENTATIVE PRODUCT}}}$$

The STHP of the component variant shall be the lower of two replicate samples tested at SLT in accordance with ASTM D 1599. (These values of STHP shall also be used as the baseline value in subsequent production quality control tests).

The Component Variant's rated temperature shall not exceed the rated temperature of the Representative Product.

The qualification report for each qualified component variant shall detail the medium term and STHP tests, and shall satisfy the reporting requirements of section 7.2.1.

Qualification Option 3: Short-term burst tests.

This option permits qualification of a component variant's LCL_s based on its STHP. Long or medium term pressure tests are not required. The option makes a conservative estimate of LCL_s based on the component variant's measured STHP and an empirical factor, Z_s . The STHP of the component variant shall be the lower of two replicate samples tested at SLT in accordance with ASTM D 1599.

Note: In this option the component variant STHP for quality control purposes (reference section 4.3.3), shall be taken as the equivalent of the mean STHP of the Representative Product.

The pressure rating shall satisfy the following criterion:

$$(\text{LCL}_s)_{\text{COMPONENT VARIANT}} \leq \frac{(\text{STHP})_{\text{COMPONENT VARIANT}}}{Z_s \times f_1}$$

where $f_1 = 0.85$

For epoxy systems, the value of Z_s shall be taken from Table 2.1.2.2. For other resins, the Manufacturer shall demonstrate Z values based upon long-term regression data.

Table 2.1.2.2 - Values for empirical factor Z_s (epoxy systems only)

Manufacturing method	Z_s
Filament wound: fittings and $\pm 55^\circ$ pipe	3
Full or partial hand-lay: all components	4

The rated temperature for a component qualified by this option shall not exceed 65°C . (This temperature limit is due to the Z_s values being derived from ASTM D 2992 data).

Qualification Option 4: Design Methods

For certain Component Variants, design calculations based on LCLs of similar components within the same Product Sector may be considered as an alternative to the ASTM D 1599 short term burst tests.

For bends and reducers, internal pressure generates membrane stresses only and these are amenable to calculation.

For joints, stress systems are more complex and scaling based on load per unit area can be misleading as stress distributions are not uniform. A strategy by which joint designs are validated on the basis of load per unit circumference could be considered. For example, a joint which is qualified for 10bar service for 500mm diameter could be used for 20bar service at 250mm diameter. A similar approach could be applied to tee joints where load per unit circumference at the junction could be used as the test criterion.

Design methods should be checked and approved to the satisfaction of the Principal.

The qualification report for each qualified component variant shall detail the long-term and STHP tests and shall satisfy the reporting requirements of section 7.2.1.

2.1.2.3 Limited Cyclic Qualification Testing

The ability of components nominally qualified for static pressure ratings to also withstand limited cyclic service shall be demonstrated by limited cyclic pressure testing their Representative Product.

The experimental basis of the testing shall be ASTM D 2143 except that the provisions of this specification shall take precedence where their requirements differ.

In this qualification test, two replicate samples shall be tested under nominally identical pressure loadings. It is a survival test hence no regression analysis is required. Testing shall be at SLT ($23 \pm 2^\circ\text{C}$). The test fluid may be fresh water. The results may be reported alone, or included in the qualification report but shall in either case meet the relevant reporting requirements of ASTM D 2143 and section 7.2.1.

Wherever practicable the standard cycling rate of 25 ± 2 cycles per minute as per ASTM D 2143 should be used. Where this cannot be maintained then a slower rate is acceptable so long as the actual rate used is monitored and recorded in the qualification test report.

Each test pressure cycle shall range between not more than 10% and not less than 150% of the NPR_s .

A failure within 5000 pressure cycles is unacceptable.

2.1.3 Cyclic Pressure Ratings

Cyclic pressure ratings for pipes, joints and fittings, shall be qualified in accordance with sections 2.1.3.1 to 2.1.3.3. An overview of the qualification requirements for GRP joints and fittings is given in Table 2.1.2.

2.1.3.1 Pipes

The $LTHS_c$ (long-term hydrostatic strength) of the representative product shall be determined. The recommended procedure is ASTM D 2992 Procedure A.

The representative product selected shall not be less than 50mm nominal diameter.

In addition, the STHP of the representative product shall be determined by testing 5 replicate samples in accordance with ASTM D 1599 and shall be taken as the lower deviated (2 standard deviations) value of the replicate samples. The STHP of any pipe variant shall be taken as the lower of two values. Testing shall be at SLT (Standard Laboratory Temperature). Samples shall be from the same production lot as those used in the long term test.

The LCL_c of the representative product shall be calculated in accordance with either Equation (1) or (2).

$$LCL_c \leq f_1 \times LTHS_c \times 10 \times \left(\frac{R_o^2 - R_i^2}{R_o^2 + R_i^2} \right) \quad \text{Equation (1)}$$

(for $D/t \leq 10$)

$$LCL_c \leq f_1 \times LTHS_c \times 10 \times 2 \times t / D \quad \text{Equation (2)}$$

(for $D/t > 10$)

Where LCL_c = lower confidence limit for cyclic pressure in bar as defined in section 2.1.1.1
 f_1 = statistical factor as defined in section 2.1.1.1
 R_o = outside radius of reinforced wall (mm)
 R_i = inside radius of reinforced wall (mm)
 t = reinforced wall thickness (mm)
 D = mean diameter of reinforced wall, i.e. $(2R_i + t)$
 $LTHS_c$ = cyclic long-term hydrostatic strength in MPa

The LCL_c and STHP of pipe variants may be scaled using either Equation (1) or (2) as appropriate.

The qualification report for each qualified component variant shall satisfy the general requirements listed in section 7.2.1.

As an alternative, pipe may be qualified using the short-term tests of Qualification Option 3 for joints and fittings.

2.1.3.2 Joints and Fittings

The cyclic pressure rating of joints and fittings shall be qualified by using one of the three following options:

Qualification Option 1: Long-term survival tests

This option permits qualification of a Representative Product LCL_c based on a long-term survival test. The test pressure is based on the regression line obtained for equivalent pipe, described in section 2.1.3.1. The objective of this procedure is to demonstrate that the Representative Product's performance is equal, or superior, to the equivalent pipe.

Two replicate samples of the Representative Product shall be selected at random and pressure tested according to test method ASTM D 2143 (as amended in section 2.1.2.3) at the rated temperature. The test duration shall be 15×10^6 cycles. The applied pressure shall not be less than the lower confidence limit for the equivalent pipe at 15×10^6 cycles.

In addition, the STHP of the representative product shall be determined by testing five replicate samples in accordance with ASTM D 1599. The STHP of the Representative Product shall be taken as the lower deviated (two standard deviations) value of the five replicate samples. Testing shall be at SLT (Standard Laboratory Temperature). Samples shall be from the same production lot as those used in the medium term test. (The STHP shall also be used as the baseline value in subsequent production quality control tests).

Component variants shall be qualified by demonstrating that their proposed LCL_C satisfies the following criterion:

$$LCL_C \text{ COMPONENT VARIANT} \leq (LCL_C) \text{ REPRESENTATIVE PRODUCT} \times \frac{STHP_{\text{COMPONENT VARIANT}}}{STHP_{\text{REPRESENTATIVE PRODUCT}}}$$

The STHP of the component variant shall be the lower of two replicate samples tested at SLT in accordance with ASTM D 1599. (The STHP shall also be used as the baseline value in subsequent production quality control tests).

The component variant's rated temperature shall not exceed the rated temperature of the Representative Product.

The qualification report for each qualified component variant shall detail the long term and STHP tests and shall satisfy the reporting requirements of ASTM D 2143 and section 7.2.1.

Qualification Option 2: Medium-term survival tests

This option permits qualification of a representative product's LCL_C based on a medium-term survival test. The test pressure is based on the ASTM D 2992 Procedure A regression line obtained for the product family representative. The objective of this procedure is to demonstrate that the Representative Product's performance is equal to, or superior to, the product family representative i.e. that the slope of the regression line for the Representative Product is not steeper than that for the Product Family Representative. The $LTHP_C$ of the Product Family Representative shall be determined in accordance with ASTM D 2992 Procedure A.

Note: The regression line for the equivalent straight pipe may be used if it can be demonstrated that it is at least as steep as that for the Representative Product.

Two replicate samples of the Representative Product shall be selected at random and pressure tested according to test method ASTM D 2143 (as amended in section 2.1.2.3) at the rated temperature. The test duration shall be 1.5×10^6 cycles. The applied pressure shall not be less than the predicted lower confidence limit for the representative fitting at 1.5×10^6 cycles.

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In the absence of data for the product family representative a conservative gradient may be used. The test pressure (bar gauge) shall be calculated on the proposed pressure ratings as follows:

$$\text{Test pressure} \geq \text{LTHP}_S \times K_S$$

where for epoxy systems up to 65°C, $K_S = 0.8$ for filament wound fittings and pipe, and $K_S = 0.9$ for full or partial hand lay-up.

Note: The 1.5×10^6 cycle qualification test pressure is calculated from the proposed pressure rating for the component and corresponds to 85% of the expected ASTM D 2992 Procedure A regression line failure pressure at the test duration. Default gradients, G , of the regression line $\{\text{Log}(\text{pressure or stress}) = A - G \times \text{Log}(\text{cycles})\}$ are assumed to be 0.12 and 0.15 for filament wound and hand lay-up components respectively.

In addition, the STHP of the representative product shall be determined by testing five replicate samples in accordance with ASTM D 1599. The STHP of the Representative Product shall be taken as the lower deviated value (two standard deviations) of the five replicate samples. Testing shall be at SLT (Standard Laboratory Temperature). Samples shall be from the same production lot as those used in the medium term test. (The STHP shall also be used as the baseline value in subsequent production quality control tests.)

Component variants shall be qualified by demonstrating that their proposed LCL satisfies the following criterion:

$$(\text{LCL}_C) \text{ COMPONENT VARIANT} \leq (\text{LCL}_C) \text{ REPRESENTATIVE PRODUCT} \times \frac{\text{STHP}_{\text{COMPONENT VARIANT}}}{\text{STHP}_{\text{REPRESENTATIVE PRODUCT}}}$$

The STHP of the component variant shall be the lower of 2 replicate samples tested at SLT in accordance with ASTM D 1599. (These values of STHP shall also be used as the baseline value in subsequent production quality control tests).

The Component Variant's rated temperature shall not exceed the rated temperature of the Representative Product.

The qualification report for each qualified component variant shall detail the medium term and STHP tests, and shall satisfy the reporting requirements of ASTM D2143 and section 7.2.1.

Qualification Option 3: Short-term burst tests.

This option permits qualification of a component variant's LCL_C based on its STHP. Long or medium term pressure tests are not required. The option makes a conservative estimate of LCL_C based on the component variant's measured STHP and an empirical factor, Z_C . The STHP of the component variant shall be the lower of two replicate samples tested at SLT in accordance with ASTM D 1599.

Note: In this option the component variant STHP, for quality control purposes (reference section 4.3.3), shall be taken as the equivalent of the mean STHP of the Representative Product.

The pressure rating shall satisfy the following criterion:

$$\text{LCL}_C \leq \frac{\text{STHP}_{\text{COMPONENT VARIANT}}}{Z_C \times f_1}$$

where $f_1 = 0.85$

For epoxy systems, the value of Z_C shall be taken from Table 2.1.3.2. For other resins the Manufacturer shall demonstrate Z values based upon long-term regression data.

Table 2.1.3.2 - Values for Empirical Factor Z_c (epoxy systems only)

Manufacturing method	Z_c
Filament wound: fittings and $\pm 55^\circ$ pipe	10
Full or partial hand-lay: all components	12

The rated temperature for a component qualified by this option shall not exceed 65°C. (This temperature limit is due to Z_c values being derived from ASTM D 2992 data).

Qualification Option 4: Design Methods

For certain Component Variants, design calculations based on the lower confidence limits of similar components within the same product sector may be considered as an alternative to the ASTM D 1599 short term burst tests.

For bends and reducers, internal pressure generates membrane stresses only and these are amenable to calculation.

For joints, stress systems are more complex and scaling based on load per unit area can be misleading as stress distributions are not uniform. A strategy by which joint designs were validated on the basis of load per unit circumference could be considered. For example, a joint which is qualified for 10bar service for 500mm diameter could be used for 20bar service at 250mm diameter. A similar approach could be applied to tee joints where load per unit circumference at the junction could be used as the test criterion.

Design methods should be checked and approved to the satisfaction of the Principal.

The qualification report for each qualified component variant shall detail the long term and short term hydrostatic pressure tests and shall satisfy the reporting requirements of ASTM D 2143 and section 7.2.1.

2.1.4 External Pressure/Vacuum Resistance

Each component's collapse pressure shall either be measured in accordance with ASTM D 2924 at the maximum rated temperature, or predicted (for buckling failure) in accordance with the method described in Part 3: "System Design".

2.1.5 Requalification

Changes to a component as defined by Table 2.1.5 shall invalidate the component's previous qualification.

Table 2.1.5 - Changes in Component Design Requiring Requalification

	Minor change	Major change
Reinforcement	filament diameter tow tex reinforcement finish (sizing) reinforcement manufacture process reinforcement composition	
Resin and Adhesive	curing system curing temperature curing schedule	resin/adhesive type
Internal Surface	composition curing schedule/temperature thickness	
Design		geometry, dimensions winding angle ($>\pm 4.5^\circ$) reinforcement weight weight fraction ($>\pm 3\%$)

Modified component variants shall be individually requalified in accordance with the requirements of sections 2.1.2 and 2.1.3.

However, where a minor change as defined by Table 2.1.5 has been made systematically to all previously qualified component variants of a particular type in a Product Sector, then the qualification of those variants may be group-revalidated by requalifying the representative product (i.e. of that type and product sector) in accordance with sections 2.1.2 and 2.1.3. The qualification reports and summaries of each such revalidated variant shall be amended to include reference to this revalidation and details both of the changes made and the revised manufacturing procedure used for its production.

For major changes as defined in Table 2.1.5 and all other changes, which will affect the performance of the component, the modified component shall be deemed to be a new product and it shall be qualified in accordance with sections 2.1.2 and 2.1.3. Group qualification shall not be acceptable.

2.1.6 Component Data for Production Quality Control Baselines

The following additional information shall be generated for each component variant used in the qualification programme in order to establish baseline values for the production quality control programme.

2.1.6.1 Degree of Cure

The degree of cure shall be determined by differential scanning calorimetry (DSC) in accordance with Annex C.

Where the LCL of a component variant is derived from testing at temperatures other than SLT, the degree of cure shall be determined on a component variant from the same production lot as the tested component variant.

2.1.6.2 Glass Content

The percentage of fibreglass reinforcement shall be determined in accordance with ASTM D 2584. Three samples shall be taken from three locations situated 120° apart in the same component cross section.

2.1.7 Minimum Thickness

In order to provide sufficient robustness, the minimum reinforced wall thickness of all components should be not less than 3mm.

2.1.8 Key Component Dimensions

The following dimensions shall be determined in accordance with ASTM D 3567:

- ID;
- OD;
- weight;
- total wall thickness;
- reinforced wall thickness.

2.2 OPTIONAL QUALIFICATION REQUIREMENTS

In addition to the qualification requirements of section 2.1, components shall also be qualified for the following requirements when specified by the Principal.

2.2.1 Potable Water Certification

Where potable water certification is specified, pipe, fittings, O-rings, gaskets and adhesives should be tested and certified as suitable in accordance with BS 6920. Alternative certification (e.g. BRL-K 532 from KIWA) may be allowed, subject to agreement with the Principal.

Piping shall also carry official approval as required by the national health or certifying authorities in the country of use.

2.2.2 Static Electricity

Where conductive components are specified, the resistivity shall be tested in accordance with ASTM D 257.

All component variants shall be tested and shall have an electrical surface and volume resistivity of not more than 10^5 ohms and 10^3 ohm.metre respectively.

The (measured) resistivity shall be effective over the design life and shall not be impaired by normal service, handling or installation.

2.2.3 Impact Resistance

Impact resistance shall be assessed if required by tests agreed between the Principal and the Manufacturer. For further details, reference should be made to Part 3: "System Design".

2.2.4 Low Temperature

Where appropriate, low temperature mechanical properties shall be determined by tests agreed by the Principal and the Manufacturer.

2.2.5 Chemical Resistance

Where appropriate, chemical resistance shall be determined by tests agreed between the Principal and the Manufacturer.

2.3 FIRE PERFORMANCE

2.3.1 Pipe System Fire Classification Code (Type Test Envelopes)

The pipe system fire classification code provides a means of defining the required fire performance of a pipe system in terms of service conditions and severity of fire threat.

The following is a proposal for such a fire coding system. Note that it has still to be agreed by the appropriate authorities and organisations and is subject to further revision. It is included for guidance purposes and the user of this document should check the availability of an updated and endorsed version.

The Fire Classification Code is designated by a five field number: A.B.C/xxx-(D.E) where service function A, fire type B and performance C/xxx, D and E are assigned prescribed levels in decreasing order of severity representative of offshore requirements. The minimum standard (default value 9) is indicative of either unlimited or unquantified performance. A value 0 for a particular performance category C, D or E is indicative of the non-availability of fire test data.

- A = Service**
= 1 hydrocarbon
= 2 empty
= 3 critical flowing water initially empty for minimum of 1 minute
= 4 critical flowing water initially stagnant for minimum of 1 minute
= 5 critical flowing water
= 6 other, eg chemical
= 9 other non critical water based service
- B = Fire Type**
= 1 full scale jet fire
= 2 medium scale jet fire
= 3 hydrocarbon fire (NPD curve)
= 4 hydrocarbon fire mitigated by cooling effects of firewater deluge
= 5 cellulosic fire
= 6 cellulosic fire mitigated by cooling effects of firewater sprinkler system
= 9 other less severe fire exposure
- C/xxx = Endurance (degree of integrity and endurance time in minutes)**
C
= 1 no exchange of media between inside and outside of pipe permitted
= 2 function maintained, fluid exchange/loss limited and quantified
= 3 function maintained, fluid exchange/loss limited but unquantified
= 4 maintain integrity but fluid exchange/loss unlimited
= 9 endurance not quantified or required
= 0 no test data available
- /xxx**
= /020 endurance greater than 20 minutes
= /060 endurance greater than 60 minutes
= /120 endurance greater than 120 minutes
= /180 endurance greater than 3 hours etc.
- D = Fire Reaction: Spread of Fire and Heat Release**
= 1 no spread of fire permitted
= 2 spread of fire is limited (SOLAS class 1)
= 3 spread of fire is limited (SOLAS class 3)
= 4 spread of fire is limited (SOLAS class 3)
= 9 spread of fire unlimited or not quantified
= 0 no test data available

- E**
- = Fire Reaction: Smoke and Toxicity
 - = 1 representative of needs within a safe area
 - = 2 levels must not exceed 10 minute emergency exposure level
 - = 3 levels must be acceptable within evacuation time
 - = 4 levels are limited
 - = 9 levels unlimited or not quantified
 - = 0 no test data available

2.3.2 Fire Test Procedures

This section describes the procedures and major performance factors that should be addressed when designing a "type test" programme to prove the fire and blast performance of GRP piping systems. It is recommended that all tests are recorded on video tape where practicable.

With respect to pipe diameter, consideration should be given to qualifying a range of diameters. However modification to any of the following key parameters shall require requalification of the system.

1. Generic fibre type
2. Generic resin type.
3. Decrease in wall thickness.
4. Roving angle change.
5. Change in fibre volume fraction.
6. Change in fire protection applied or a change in retardant additives.
7. Up-rating of design pressure.
8. Change of joint design.

2.3.2.1 Manufacturer and System Identification

Any testing performed must include the full description of the manufacturer's name and unique product code, including any details of fire protection applied.

2.3.2.2 System Tests

Blast Resistance Testing

Where blast testing is considered necessary the blast should be simulated by deflecting the test system to a degree determined from calculation. The minimum blast overpressure is 0.3 bar and the test should include any further deflection cycles which would occur until the oscillations were damped down. The allowable blast overpressure shall be related to the support spacing.

Hydrocarbon Fire Testing

This document adopts the hydrocarbon fire curve (Figure 2.3.2.2) accepted by the HSE and the NPD and shows a comparison of the hydrocarbon and cellulosic fire curves. The system under test should be exposed to these conditions in such a way that the flames or radiation can directly contact the surface of the system under test and that the temperatures are air temperatures measured adjacent to the item under test. Tests may be performed using either open (eg burners or hydrocarbon pool fires) or closed (eg furnace) testing facilities. Where justified by a risk analysis, the temperature may be reduced after an initial period to simulate the cooling effect of fire water.

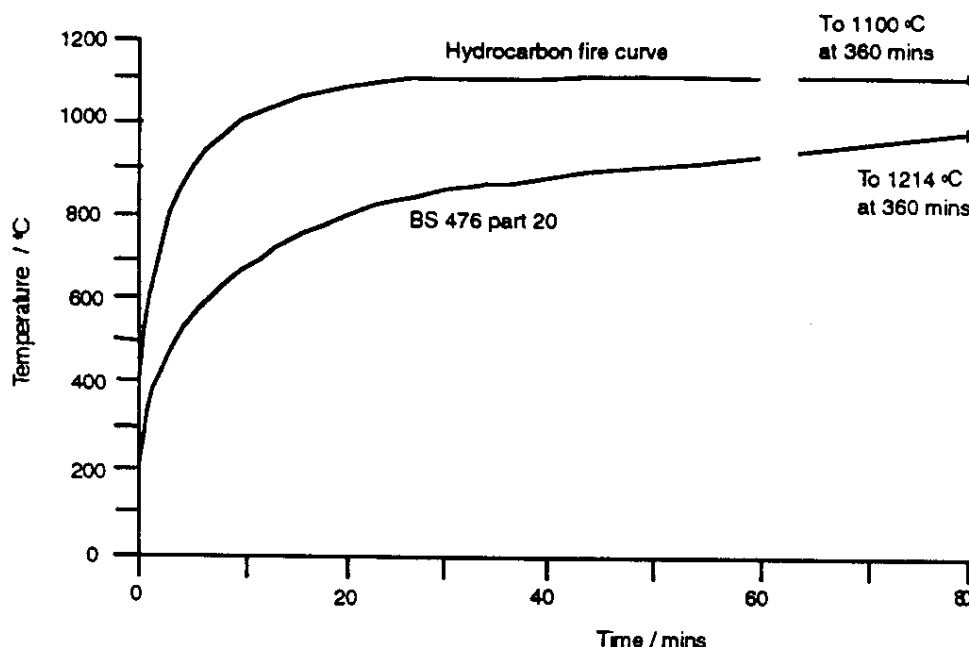


Figure 2.3.2.2 Comparison between Furnace Time / Temperature Curves

Jet Fire Testing

The HSE and NPD are currently developing, in collaboration with industry, a standard/recommended procedure for medium scale jet fire testing. It is expected to define jet fire test requirements for GRP pipework in accordance with the latter medium scale jet fire "standard" when it becomes available. However, full flame engulfment of the systems under test is important and it may therefore be necessary to conduct large scale tests on larger pipe diameters (e.g. above 150mm approx.) and for complex system tests.

Endurance Time

The dry endurance time (where applicable) is the period of time from exposure to the fire, until the system becomes water-filled. The wet exposure time is the period from the moment the water-filled system is exposed to the fire, to the moment the fire exposure is terminated, with water still flowing at the required flow rate and pressure.

The test procedure will identify the periods for dry exposure, stagnation exposure and flowing exposure. The minimum recommended dry exposure time is 1 minute.

Where endurance is required it is proposed that the minimum total endurance time permitted by the coding system is 20 minutes.

Flow and Pressure Retention

After the fire test the piping must be able to withstand the operational pressure of the system. The percentage flow loss due to weepage shall be determined for the system tested. Test reports should include comment on relative weepage of different system components.

2.3.2.3 Representative Assembly System Testing

The performance based philosophy of fire testing is applied to systems under test. Rather than individual components requiring testing a representative system should be tested. This shall include typical pipe, fittings, flanges, all proposed joint types, supports and fire protection if any is used. Other factors which may need to be addressed are: the orientation of the piping with respect to stagnant conditions and the effect of blast.

2.3.2.4 Laboratory Tests

Where GRP systems are fabricated from a generic type of material it is sufficient to test the material rather than complete assemblies.

Surface Spread Of Flame

The method most appropriate for testing of spread of flame has yet to be agreed.

The surface spread of flame shall be determined from one of the following tests:

- British Standard BS 476, Part 7 (1987): Method for the Classification of the Surface Spread of Flame of Products;
- IMO resolution A 653(16) 'Recommendation on Improved Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling and Deck Finish Materials' modified in accordance with Annex E;
- ASTM E 84 'Test Method for Surface Burning Characteristics of Building Materials'
- ASTM E 162 'Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source';
- ASTM D 635 'Test Method of Rate of Burning and/or Extent and Time of Burning of Self-supporting Plastics in a Horizontal Position';

Where vertical pipes may be used, consideration should be given to defining performance standards in accordance with IEC 322-2, 'Test Methods on Electric Cables Under Fire Conditions'.

Further details of these tests are given in Annex D.

Heat Release

Heat release can be measured using the cone calorimeter in accordance with ISO DIS 5660. Where appropriate heat release should be quantified in terms of total heat release per unit area as a function of time, heat flux input, and wall thickness.

Smoke Testing

The method most relevant to testing of smoke generation has yet to be agreed. The following tests should be considered when assessing smoke generation.

- IMO Resolution A214 (VII) 'Improved Provisional Guidelines on Test Procedures for Primary Deck Coverings'.
- ASTM E-662, 'Test Method for Specific Optical Density of Smoke Generation by Solid Materials', may be refined to incorporate the use of curved pipe;
- ASTM D2863-87, 'Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-like Combustion of Plastics';

- ASTM E906-83, 'Heat and Visible Smoke Release Rates for Materials and Products';
- BS 6401, 'Measurement in the Laboratory of Specific Optical Density of Smoke generated by Materials';
- BS6583, 'Code of Practice for Fire Precautions in the Design and Construction of Railway Passenger Rolling Stock';
- Naval Engineering Standard NES 711, issue 2, January 1981, 'Determination of the Smoke Index of the Products of combustion from Small Specimens of Materials'.

Toxicity

There is at present no specific test for toxicity. Test procedures are being developed and will be included in future revisions of this specification when complete. In the meantime it is suggested that the following are considered:

- NES 713, issue 3, March 1985: "Determination of the Toxicity Index of the Products of Combustion from Small Specimens of Materials".
- BS PD6503: Part 2: 1988, "Toxicity of Combustion Products Part 2, Guide to the relevance of Small Scale Tests for Measuring the Toxicity of Combustion Products of Materials and Composites".

2.3.3 Fire Test Results

The fire test should be witnessed to verify that the results for all the relevant performance parameters have achieved the defined test standards. In the event that any parameter fails to meet the required performance standard the following options can be considered prior to re-test.

- i) modify base materials
- ii) provide additional protective coating
- iii) re-design system

The manufacturer's product shall be assigned a pipe classification code **A.B.C/xxx-(D.E)** (to include relevant performance parameters) where the fire tests have been independently witnessed and the results verified.

2.4 COMPONENT PROPERTIES FOR SYSTEM DESIGN

Where applicable, the Manufacturer shall perform the relevant tests in order to determine values for the following properties at both SLT and maximum rated temperature unless noted otherwise for each product family :

- a) **Long-term Hydrostatic Strength Regression Line Gradient** at the maximum rated temperature in accordance with ASTM D2992 Procedure B.
- b) **Thermal Coefficient of Expansion** in the axial direction determined in accordance with ASTM D 696.
- c) **Hoop Tensile Modulus** determined in accordance with Annex B.
- d) **Poisson's Ratio** for a Hoop Tensile Load and the resulting axial contraction in accordance with Annex C.
- e) **Poisson's Ratio** for an Axial Tensile Load and the resulting hoop contraction in accordance with ASTM D 2105 but modified in order to measure hoop contraction.
- f) **Short-term Axial Strength and Tensile Modulus of Elasticity** determined in accordance with ASTM D2105 for each representative product.
- g) **Short-term Hydraulic Failure Pressure** of each component variant across the connection at SLT in accordance with ASTM D 1599.
- h) **Axial Bending Modulus** determined in accordance with ASTM D 2925.
- i) **Thermal Conductivity** of component and protective coatings determined for the radial direction in accordance with ASTM C177.
- j) **Density** of component.
- k) **Proportional Limit** in the hoop and axial directions determined in accordance with c) and f).
- l) **Part Factor f_1**
- m) **Part Factor f_3** based on a non-pressure axial stress of 10MPa.

Full background data for all the tests shall be made available upon request.

3 PREFERRED PRESSURE RATINGS AND DIMENSIONS

3.1 NOMINAL PRESSURE RATINGS

Pipe systems should be assigned one of the following nominal pressure ratings (NPR) expressed in bars:

1, 2.5, 4, (5), 6, (8), 10, 12, 16, 20, 25, 32, 40

where the ratings expressed in parentheses should be regarded as 'non-preferred'.

3.2 DIMENSIONS

Pipes and fittings should preferably be manufactured to the following dimensions.

3.2.1 Nominal Diameters

The nominal diameter, in mm of pipes and fittings as defined in ISO 7370, should be one of the following values:

25, 40, 50, 80, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 900, 1000, 1100, 1200

3.2.2 Bend Radii

The standard minimum bend radius should be 1.5 times the nominal diameter.

3.2.3 Fitting Lengths

The preferred maximum overall length of fittings (bends, tees and reducers) denoted as L_{max} in Figure 3.2.3 shall be in accordance with Table 3.2.3a and 3.2.3b.

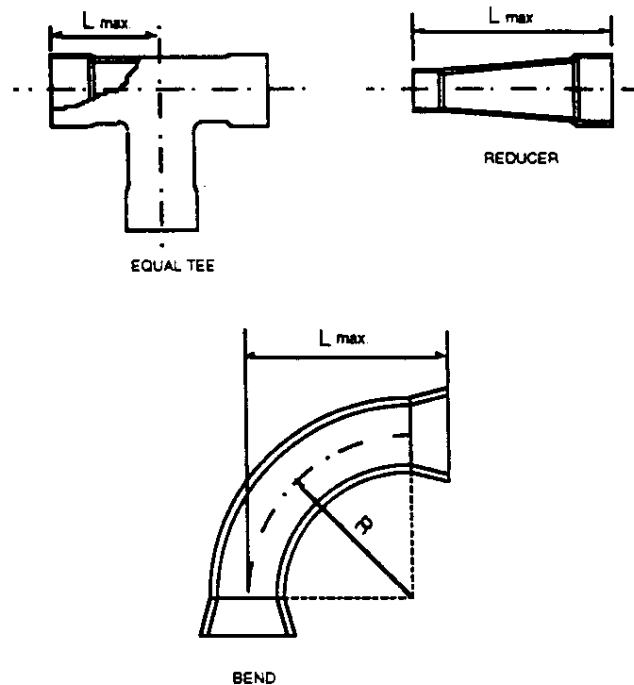


Figure 3.2.3 - Fitting Lengths

Fitting lengths can in practice be reduced if prefabricated spools (spools fabricated from straight pipe lengths and laminated to form segmental elbows, tees, reducers, etc.) are used instead. For further details of this, reference should be made to the Manufacturer.

Table 3.2.3a - Preferred Maximum Overall Length Of Bends and Tees

Nominal pipe size Dia (mm)	Preferred length, L _{max}	
	Bends (mm)	Tees (mm)
25	100	80
40	120	120
50	130	150
80	180	160
100	220	180
150	320	250
200	420	260
250	520	310
300	620	340
350	700	400
400	780	460
450	780	500
500	860	550
600	1030	660
700	1050	700
800	1200	740
900	1290	770
1000	1430	850
1100	1540	900
1200	1660	960

Table 3.2.3b - Preferred Maximum Overall Length of Concentric Reducers

Reduced Dia (mm) \ Max Dia (mm)	40	50	80	100	150	200	250	300	350	400	500	600	700	800	900	1000	1100	1200
25	200	220																
40		225	300															
50			250	350														
80				315	450													
100					380	600												
150						430	650											
200							500	700										
250								550	750									
300									600	800								
350										700	900							
400											830	1030						
500												925	1125					
600													950	1150				
700														975	200			
800															1000	1300		
900																1025	1350	
1000																	1050	1400
1100																		1075

3.2.4 Support spacing

Pipe should be capable of spanning the minimum horizontal distances as specified in Table 3.2.4 when carrying a fluid with a specific gravity of 1.0 at SLT. Spans are assumed to be simply supported, and are based on the criteria that axial bending stresses do not exceed 10MPa, and that deflections do not exceed either 12.5mm or 0.5% of the span.

The table represents indicative values for use in preliminary layout design. These shall be re-assessed during detailed system design.

Table 3.2.4 - Guidance Span Lengths

Nominal Diameter	Span (m)
25	2.0
40	2.4
50	2.6
80	2.9
100	3.1
150	3.5
200	3.7
250	4.0
300	4.2
350	4.8
400	4.8
450	4.8
500	5.5
600	6.0
700	6.5
800	7.0
900	7.0
1000	7.5
1100	7.5
1200	8.0

4 QUALITY PROGRAMME FOR MANUFACTURE

4.1 GENERAL REQUIREMENTS

The pipe Manufacturer shall have a quality assurance and quality control system which meets the requirements of ISO 9000. For the purpose of this Specification, a pipe Manufacturer shall be considered a 'Special Process' as defined in ISO 9001, Section 4.9.2.

The supplier shall identify manufacturing processes and activities that affect component performance and shall ensure that these processes and activities are adequately controlled in accordance with ISO 9001, Section 4.9. Critical processes or activities for which procedures must be developed and maintained include, but are not limited to, the following:

- raw material (including ancillaries) acceptance (raw materials shall not be used prior to passing acceptance tests, i.e. ISO 9001, Section 4.10.1.2 does not apply) ;
- raw material (including ancillaries) storage;
- resin mixing;
- component fabrication;
- curing (including time and temperature monitoring);
- component variant identification;
- marking, packing, handling and transportation.

In addition a quality plan and flow diagram shall be produced (drawn in the context of a factory plan, showing all the proposed tests and inspections during component fabrication);

All records, documents and procedures shall be made available for inspection upon request by the Principal.

It shall be the responsibility of the Manufacturer to maintain copies of the relevant records, documents and procedures for a minimum of five years from the date of commissioning acceptance.

4.2 QUALITY CONTROL EQUIPMENT

All inspection, measuring, and testing equipment shall be maintained and calibrated as described in ISO 9001, Section 4.11 with the following exceptions for pressure measuring devices:

- a) test pressure measuring devices shall be either pressure gauges or pressure transducers with a full-scale range of no more than two times the test pressure and shall be accurate to at least $\pm 0.5\%$ of full scale range;
- b) a dead weight testing device shall be available at the Manufacturer's facility to calibrate gauges;
- c) all pressure measuring devices shall be calibrated to a certified standard every six months.

4.3 QUALITY CONTROL TESTS

Pipe and fittings furnished to this specification should be tested in accordance with sections 4.3.1 to 4.3.7 at a minimum frequency of one test per lot, unless otherwise stated. A pipe lot should consist of 500m or fraction thereof for one size, wall thickness or grade in continuous production. A fittings lot should consist of the smaller of 100 units or the batch quantity irrespective of size, type or pressure rating.

4.3.1 Hydrostatic Mill Test

After full curing, 10% of the produced pipe and fittings shall be hydrostatically tested by the Manufacturer to 1.5 times its nominal static pressure rating (under no circumstances shall the test pressure cause stresses to exceed the proportional limit). Hydrostatic test pressure shall be maintained for a minimum of two minutes in order to ascertain there is no leakage. Where practicable test components shall have unrestrained ends. Test temperature shall be ambient.

In the event of any failure, additional testing shall be proposed by the Manufacturer and agreed with the Principal.

4.3.2 Degree of Cure

Degree of cure shall be determined by differential scanning calorimetry (DSC) according to Annex C at a minimum frequency of once per shift for each resin system used and for each production line. DSC tests shall also be conducted on fittings at a frequency of one per 100 units irrespective of size, type or pressure rating.

If the T_g is less than the minimum value (minus 5°C tolerance) measured on the qualified component variant in the qualification tests, then the production lot shall be rejected, subject to the retest option of Section 4.3.8.

4.3.3 Short-time Failure Pressure

The STHP, determined in accordance with ASTM D 1599 at SLT, of at least one sample per production lot shall be determined. If the STHP is less than 85% of the mean STHP for the representative product established in the qualification testing, then the production lot shall be rejected, subject to the retest option of section 4.3.8. DSC tests in accordance with Annex C shall be made on all pressure test samples.

4.3.4 Glass Content

The glass content (mass fraction expressed as percentage) of at least one sample per production lot shall be determined in accordance with ASTM D 2584. If the glass content is not within $\pm 3\%$ of that of the qualified component in the qualification tests then the production lot shall be rejected, subject to the retest option detailed in section 4.3.8.

4.3.5 Visual Inspection

All pipe and fittings shall be visually inspected for compliance with the requirements stated in Table 4.3.5, and if appropriate either repaired or rejected. After all minor repairs, a hydrostatic mill test in accordance with section 4.3.1 shall be performed on the component.

Table 4.3.5 – Visual Defects

Defect type	Description	Acceptance criteria	Corrective action
Burn	Thermal decomposition evidenced by distortion or discolouration of the laminate surface.	None permitted	Reject
Chip	Small piece broken from edge or surface. If reinforcement fibres are broken, the damage is considered to be a crack.	If there are undamaged fibres exposed over any area; or no fibres are exposed but an area greater than 10mmx10mm lacks resin.	Minor repair
		If there are no fibres exposed, and the area lacking resin is less than 10mmx10mm	Accept
Crack	Actual separation of the laminate, visible on opposite surfaces, and often extending through the wall. Reinforcement fibres are often visible/broken.	None permitted	Reject
Crazing	Fine hairline cracks at or under the surface of the laminate. White areas are not visible as for cracks.	Crack lengths greater than 25.0mm	Minor repair
		Crack lengths less than 25.0mm	Accept
Dry spot	Area of incomplete surface film where the reinforcement has not been wetted by resin.	None permitted	Reject
Fracture	Rupture of the laminate with complete penetration. Majority of fibres broken. Visible as lighter coloured area of interlaminar separation.	None permitted	Reject
Inclusion	Foreign matter wound into the laminate	None permitted	Reject
Pit (pinhole)	Small crater in the surface of the laminate, with its width approximately of the same order of magnitude as its depth.	Diameter greater than 0.8mm, and/or depth greater than 10% of wall thickness	Minor repair
		Diameter less than 0.8mm, and depth less than 10% of wall thickness	Accept
Restriction	Excessive resin, adhesive, foreign matter on the internal wall of pipe/fittings.	None permitted	Remove by careful grinding.
Wear scratch	Shallow mark caused by improper handling, storage and/or transportation. If reinforcement fibres are broken, the damage is considered to be a crack.	If there are undamaged fibres exposed over any area; or no fibres are exposed but an area greater than 10mmx10mm lacks resin.	Minor repair
		If there are no fibres exposed, and the area lacking resin is less than 10mmx10mm	Accept

(Based on ASTM D 2563: Practice for Classifying Visual Defects in Glass Reinforced Plastic Laminate Parts)

4.3.6 Wall Thickness

Total wall thickness shall be determined by calliper on every joint. Reinforced wall thickness shall be determined by ASTM D 3567 once per every production lot. Total and reinforced wall thicknesses shall be as specified in Table 4.3.6; any out of tolerance components shall be rejected.

Table 4.3.6 - Wall Thickness Tolerances

Dimension	Tolerance
Total Wall Thickness	+22.5%* -0%
Reinforced Wall Thickness	+22.5%* -0%

**The plus-tolerance on total and reinforced wall thickness for fittings shall refer to the spot having the minimum wall thickness.*

4.3.7 Resistivity

Where conductive pipe is specified, the resistivity of at least one sample per production lot shall be determined in accordance with ASTM D 257. If the resistivity is more than 5% above that of the qualified component, the lot shall be rejected subject to the retest option of section 4.3.8.

4.3.8 Retest

If any specimen fails to conform to any of the specified requirements of sections 4.3.2, 4.3.3, 4.3.4 or 4.3.7 it shall be rejected, but the Manufacturer may elect to make retests on five additional replicate samples selected at random from the same production lot. If all the retest samples conform to the requirements then the remainder of the production lot shall be accepted. If any retest specimen fails to conform then the production lot shall be rejected.

4.4 QUALITY CONTROL RECORDS

4.4.1 Purpose

The quality control records are required to substantiate that all components manufactured to this specification conform to the specified requirements.

4.4.2 Records Control

Quality control records required by this specification shall be:

- a) legible, identifiable, retrievable and protected from damage, deterioration or loss;
- b) retained by the Manufacturer for a minimum of five years following the date of commissioning acceptance;
- c) signed and dated.

4.4.3 Records to be Maintained by Manufacturer

The Manufacturer shall maintain the following records for a minimum of 5 years:

- a) Test results in accordance with section 4.3;
- b) Any records related to Manufacturer's process documentation.

4.4.4 Prefabrication Documentation

Raw material certificates to DIN Standard 50049 3.1.B shall be available for review by the Principal prior to the start of manufacture.

4.4.5 Production Quality Control Reports

The Manufacturer shall prepare a set of quality control reports for the supplied components. These reports shall demonstrate that the delivered components have been manufactured in accordance with the requirements listed herein.

The quality control report shall:

- a) identify the components (including type, nominal diameter and pressure rating), their date of manufacture, production lot(s) and the manufacturing procedure used for their production;
- b) reference the prefabrication documentation of section 4.4.4;
- c) report the quality control tests of sections of 4.3.1 to 4.3.7.

5 COMPONENT MARKING

5.1 GENERAL

Pipe and fittings manufactured in accordance with this Document Suite shall be marked by the Manufacturer as specified in section 5.2. Additional markings as desired by the Manufacturer or as requested by the Principal are not however prohibited. Markings shall be applied by paint or ink stencil, decal, or both as agreed upon between the Principal and Manufacturer. Markings shall be permanent, shall not overlap, and shall be applied in such manner as not to damage the pipe or fittings. Markings shall be applied on the pipe and fittings within one metre of the end.

5.2 REQUIREMENTS

All pipes and fittings shall be permanently marked with:

- Manufacturer's name;
- product line designation;
- LCL, clearly indicating whether cyclic or static;
- nominal pressure rating (NPR), clearly indicating whether cyclic or static;
- nominal diameter;
- lot or production number;
- date of manufacture (cure);
- Manufacturer's identification code;
- the specification number of this Document Suite;
- limitations (permissible bolt torques etc).

Strapping down of GRP pipe stacks may be necessary to prevent damage during high winds. Suitable tie-downs such as nylon straps or padded metal strapping should be used to secure the stack. Caution should be used to prevent damage when securing the stack.

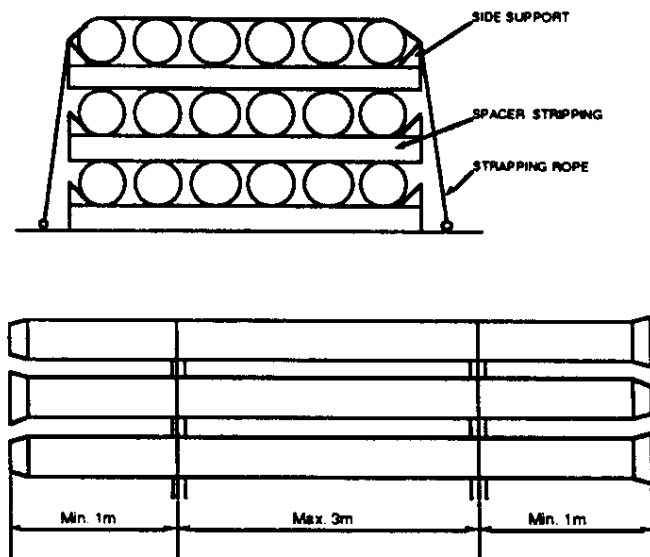


Figure 6.2.1 – Stacking Of Pipes

6.2.2 Fittings

Fittings may be shipped in crates or boxes and may be stored in these crates or boxes provided the package is undamaged and suitable for long-term storage. End protection of fittings and flanges must remain in place during storage.

6.2.3 Pipe Spools

Pipe spools should be packed by the Manufacturer to avoid damage during transportation. If possible, the pipe spools shall be stored with this temporary protection in place. End protection of fittings and flanges must remain in place during storage. Pipe spools shall not be stacked.

6.2.4 Adhesive / Resin Systems

Adhesive kits and resin systems shall be stored in the original packaging in accordance with the pipe Manufacturer's recommendations and safety regulations applicable to the storage location.

Storage conditions for the adhesive and resin systems shall be in accordance with the Material Safety Data Sheet (MSDS) for the material in question. Particular attention shall be taken of the recommended storage temperatures, and the requirement to keep certain materials apart for fire safety reasons.

6.2.5 Ancillaries

Ancillary materials (elastomeric O-rings, flange gaskets, locking strips, reinforcements and lubricants) shall be stored in accordance with the Manufacturer's recommendations. Due regard shall be paid to exposure to direct sunlight (UV radiation), and extremes of temperature.

7 DOCUMENTATION

This section provides a checklist of documentation required for the order and supply of components in accordance with this specification.

7.1 PURCHASE ORDER DOCUMENTATION

The Principal shall provide the Manufacturer, in the invitation to tender with the minimum following information:

- a) the design pressure and design external pressure;
- b) details of media to be transported (i.e. chemical composition, erosive nature, etc);
- c) the service cyclicity: either 'static' or 'cyclic';
- d) ambient and fluid temperatures (maximum and minimum);
- e) anticipated flow velocity;
- f) potable water service requirements (if any);
- g) conductivity requirements;
- h) requirements for internal resin rich liners to provide additional protection against chemical attack;
- i) requirements for internal liners to provide additional protection against erosion.
- k) the requirements for the supervision of installation by the Manufacturer.

A sample enquiry sheet (to be completed by the Principal and transmitted to the Manufacturer) is provided in Annex A.

7.2 QUALIFICATION DOCUMENTATION

The Manufacturer shall provide the Principal with proof of compliance with the qualification requirements of section 2. The following sections summarise the requirements.

7.2.1 Qualification Reports

Qualification reports, as detailed below, shall be produced for each component variant, and shall be supplied by the Manufacturer if so requested by the Principal.

- a) Manufacturer's identification of products;
- b) DSC data on all test samples, where specified;
- c) glass content of all test samples, tested in accordance with ASTM D 2584;
- d) date of manufacture and production lot of test samples;
- e) reference to manufacturing procedure, including version number and issue date used for production of test samples;
- f) constituent material details including types, manufacturer/supplier, delivery/batch data;

- g) such additional information, including dimensions of samples, required by the ASTM test procedure specified for each qualification test method;
- h) copy of, or reference to, Manufacturer's instructions for field assembly;
- i) specific requirements for the qualification option used;
- j) for static pressure ratings, confirmation of compliance with the representative product 'limited cyclic qualification test';
- k) report of the testing carried out to establish the published values detailed in section 2. The testing may be reported in detail in the qualification report, or reported separately and referenced therein.

SI units shall be used in all qualification reports.

7.2.2 Qualification Summaries

Qualification summaries, containing selective information from the qualification report, shall be produced for each component variant, and shall be supplied by the Manufacturer if so requested by the Principal.

7.2.3 Potable Water Approval Certificates

Potable water approval certificates shall be provided if specified by the Principal.

7.3 PRODUCTION QUALITY CONTROL DOCUMENTATION

The Manufacturer shall provide the Principal with proof of compliance with the quality control requirements of section 4. The following sections summarise the requirements.

7.3.1 Manufacturing Procedure

A manufacturing procedure, in accordance with section 4.1 shall be available for each component variant to be supplied.

The manufacturing procedure shall be provided, if requested by the Principal, prior to the start of manufacture.

7.3.2 Raw Material Certificates

Raw material (including ancillaries) certificates, in accordance with section 4.1, shall be available for the raw materials of all components to be supplied.

The certificates shall be provided, if requested by the Principal, prior to the start of manufacture.

7.3.3 Production Quality Control Reports

Production quality control reports, in accordance with section 4.4 shall be provided for all supplied components within five working days, or other agreed period, after delivery of the complete order or part thereof.

7.4 INSTALLATION DOCUMENTATION

The Manufacturer shall provide the Principal with the following documentation to facilitate the proper assembly and installation of his products:

- instructions for field assembly of all joint types supplied;
- instructions for the installation of the piping system supplied.

7.5 PUBLISHED VALUES

7.5.1 Properties

Where applicable, the Manufacturer shall publish values for the following properties for each product family determined in accordance with section 2.3.

- a) LCL_S and/or LCL_C;
- b) nominal pressure rating (NPR_S and/or NPR_C);
- c) rated temperature;
- d) external pressure resistance;
- e) ASTM D 2992 regression data;
- f) radial thermal conductivity;
- g) coefficient of axial thermal expansion;
- h) hoop tensile modulus;
- i) axial tensile modulus;
- j) axial bending modulus;
- k) Poisson's ratio; axial/hoop, and hoop/axial;
- l) proportional limit;
- m) electrical resistance;
- n) flame spread;
- o) toxic emissions;
- p) smoke generation.

7.5.2 Dimensions

Manufacturers shall publish the following information for each qualified component.

7.5.2.1 Pipes

The following dimensions, with tolerances where applicable, shall be given:

- a) pipe inside and outside diameter;
- b) minimum total wall thickness;
- c) structural wall thickness;
- d) liner thickness;
- e) overall pipe length;
- f) effective pipe length;

- g) outside and inside diameter of the end;
- h) length of joint;
- i) form of spigot and socket;
- j) spigot and socket taper angle.

7.5.2.2 Fittings

The following dimensions, with tolerances where applicable, shall be given:

- a) fitting inside and outside diameter;
- b) minimum total wall thickness;
- c) structural wall thickness;
- d) liner thickness;
- e) overall fitting length;
- f) effective fitting length;
- g) length of joint;
- h) form of spigot and socket;
- i) spigot and socket taper angle;
- j) bend radius (where appropriate).

7.5.2.3 Flanges

The following dimensions, with tolerances where applicable, for flanges shall be given:

- a) thickness of flange;
- b) rating;
- c) bolt hole circle and diameter.

7.5.2.4 Pipe Spools

The following dimensions, with tolerances where applicable, shall be given:

- a) face to face;
- b) centre-line to face;
- c) centre-line to centre-line;
- d) flange offset;
- e) flange face alignment.

ANNEX A INQUIRY SHEET

1. PRINCIPAL/AGENT			
	PRINCIPAL		AGENT
COMPANY			
CONTACT			
TELEPHONE			
TELEFAX			
TELEX			
2. PROJECT			
PROJECT NAME			
LOCATION			
TYPE OF SYSTEM			
FLUID COMPOSITION			
SPECIAL OPERATIONS (E.G. STEAM OR HP WATER CLEANING)			
3. SERVICE CONDITIONS			
DESIGN PRESSURE (bar)			
SERVICE CYCLICITY (static or cyclic)			
DESIGN EXTERNAL PRESSURE (bar)			
MAXIMUM FLUID TEMPERATURE (°C)			
MINIMUM FLUID TEMPERATURE (°C)			
MAXIMUM AMB. TEMPERATURE (°C)			
MINIMUM AMB. TEMPERATURE (°C)			
4. ADDITIONAL ITEMS			
IS MANUFACTURER'S SUPERVISION OF INSTALLATION REQUIRED?			
IS POTABLE WATER HEALTH CERTIFICATION REQUIRED?			
IS CONDUCTIVE PIPE REQUIRED?			
FIRE CLASSIFICATION CODE			
ARE IMPACT TESTS REQUIRED?			
5. AUTHORITY			
Name		Signature	Date

ANNEX B DETERMINATION OF THE HOOP TENSILE MODULUS AND POISSON'S RATIO

B.1 SCOPE

This Annex describes a method to determine the hoop tensile modulus and Poisson's ratio for a hoop tensile load and the resulting axial contraction.

B.2 DEFINITIONS

- B.2.1** Hoop tensile modulus is defined as the hoop tensile stress divided by the hoop strain under the condition of uniaxial hoop tensile stress.
- B.2.2** Poisson's ratio is defined as the ratio of axial strain to hoop strain as measured by strain gauges on the pipe pressurised to its rated pressure in accordance with the following procedure.

B.3 APPARATUS

- B.3.1** A pressure source with a calibrated pressure measuring device.
- B.3.2** Strain gauge monitoring equipment and gauges.
- B.3.3** A test fixture as shown in Figure B.1.

B.4 TEST SPECIMENS

- B.4.1** Size – The sample length 'L' shall be at least ten times the nominal pipe outside diameter.
- B.4.2** Number of specimens – Three specimens shall be tested for each pipe being evaluated.
- B.4.3** The samples selected shall be standard production pipe.

B.5 TEST PROCEDURE

- B.5.1** Apply two strain gauges to each specimen as shown in Figure B.1. One strain gauge shall be oriented to measure strain in the axial direction. The other strain gauge shall be oriented to measure strain in the hoop direction. Standard strain gauging practices shall be followed.
- B.5.2** Insert the test fixture into the test specimen as shown in Figure B.1.
- B.5.3** Zero the strain gauges.
- B.5.4** Pressurise the specimen to its rated internal pressure.
- B.5.5** Record the hoop and axial strain.

B.6 CALCULATIONS

Poisson's ratio for piping is defined as the axial strain divided by the hoop strain.

B.6.1 Determine the hoop stress by the following formula:

$$\sigma_h = P \times \frac{R_o^2 + R_i^2}{R_o^2 - R_i^2} \text{ for } 2R_o / t < 10$$

or

$$\sigma_h = P \times \frac{R_i}{(R_o - R_i)} \text{ for } 2R_o / t \geq 10 \text{ (or } P \times \frac{D}{2t} \text{ where } D = 2R_i + t)$$

where:

σ_h = hoop stress

P = internal pressure

R_i = the inside radius of the structural wall

R_o = the outside radius of the structural wall

t = structural wall thickness.

The inside radius and structural wall thicknesses are determined by ASTM D 3567.

B.6.2 Hoop tensile modulus is the hoop tensile stress divided by the hoop strain.

B.7 REPORT

The report shall include the following items.

B.7.1 Complete identification of the test samples including material and Manufacturer's name.

B.7.2 Pipe dimensions, including nominal size, reinforced wall thickness, inside diameter and length.

B.7.3 The applied pressure.

B.7.4 The measured hoop and axial strain and the calculated hoop stress.

B.7.5 The hoop tensile modulus and Poisson's ratio.

B.7.6 The test temperature.

B.7.7 Start date and completion of tests.

B.7.8 Test laboratory and supervisor of tests.

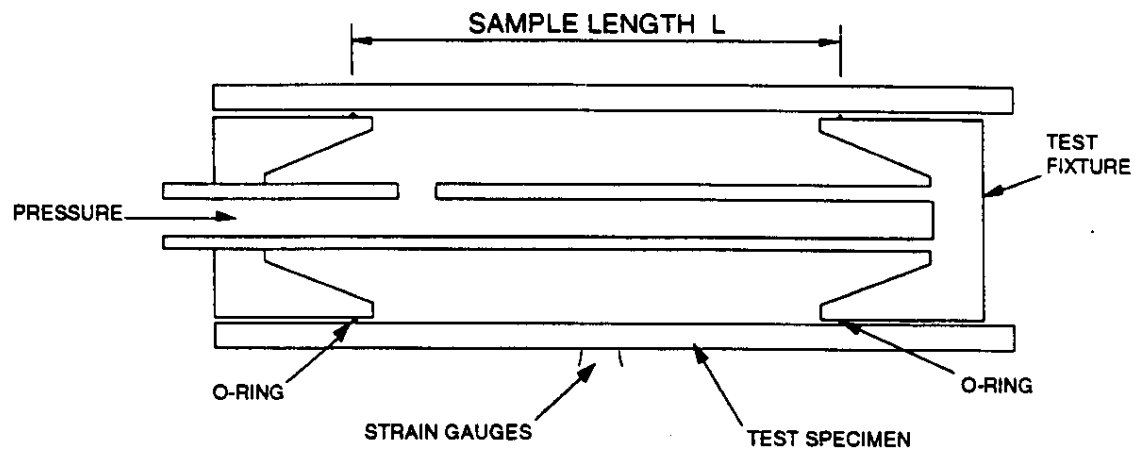


Figure B.1 - Typical Test Setup to Determine Hoop Tensile Modulus and Poisson's Ratio

ANNEX C TEST METHOD FOR DETERMINATION OF DEGREE OF CURE BY DIFFERENTIAL SCANNING CALORIMETRY (DSC)

C.1 SCOPE

This test determines the degree of cure of a fibreglass pipe test specimen relative to statistically significant values obtained from typical production product.

C.2 DEFINITION

Glass transition temperature is defined as the midpoint of the inflection temperature at the DSC curve (heat flow v. temperature).

C.3 APPARATUS

Differential scanning calorimeter (DSC). The DSC equipment shall be calibrated in accordance to the DSC Manufacturer at a frequency specified by the DSC Manufacturer, or at six-month intervals, whichever is shorter.

C.4 TEST SPECIMENS

C.4.1 Size

The size of the specimen is limited by the size of the DSC sample pan. Specimens can be either a chip or filed into a fine powder to provide easy weighing and uniform contact with the pan.

C.4.2 Location

For any given piece of piping, samples should be taken from both the outer and inner surfaces. If the pipe sample has a liner, then a specimen should be taken from the liner as well as the inner and outer edges of the over-wrap.

C.5 PROCEDURE

C.5.1 Maximum heating rate is 20°C/minute.

C.5.2 Run the scan from room temperature to at least 30°C above the expected glass transition temperature and no more than 250°C.

C.5.3 Obtain the T_{g1} (midpoint of the inflection in the DSC curve).

C.6 REPORT

The report shall include the following items.

C.6.1 Complete identification of the specimens including material, Manufacturer's name, and lot number.

C.6.2 Pipe dimensions, including nominal size, minimum wall thickness, and average outside diameter. For reinforced thermosetting pipe, wall thickness, and outside diameter shall be reinforced dimensions only. Unreinforced thicknesses (i.e. liner) shall also be reported.

C.6.3 Number of specimens tested and location of specimen from the pipe.

C.6.4 Heat-up rates for DSC initial temperature and final temperature scans.

C.6.5 Record of glass transition temperature (inflection value) for the scan as T_{g1} .

C.6.6 Date of test.

C.6.7 Test laboratory and supervisor of tests.

ANNEX D METHODS FOR DETERMINING FLAME SPREAD PROPERTIES

BS 476, Part 7

Determines the tendency of materials to support spread of flame across their surfaces. It was originally developed to assess whether the spread of flame along the walls of a corridor with a fire at one end was faster than a person could run to escape. It consists of a 1 m² radiant panel which gives out approximately 300 kW. A sample which is 900 mm long by 225 mm high is placed with its short edge approximately 225 mm from the face of the radiant panel, at right angles to it. A small flame approximately 75 mm to 100 mm long plays on the end of the panel nearest the furnace for 1 minute. The progress of any flame along the sample is monitored and for a Class 1 result flame must not travel more than 165 mm within the 100 minute test duration.

IMO Resolution A.653(160)

Specifies test procedures for determining the flame spread characteristics of bulkhead, wall and ceiling linings. As the best sample configuration only considers flat surfaces, modifications as detailed in Annex E are necessary in order to account for the curvilinear surface of pipes.

ASTM E162

Uses an inclined flat specimen as the test sample although results obtained using a panel of curved pipe segments are thought to be representative. The heat source is a vertical radiant panel maintained at 670°C facing the test panel which is oriented 30 degrees from vertical. A test normally takes about 10 minutes to complete. Results are reported as a flame spread index which may vary from zero (asbestos cement board) to 100 (red oak).

ASTM E84

Specifies a 25 foot tunnel test which is expensive and complicated to operate. However, small scale laboratory tests, such as the two foot flame tunnel tests can be used to simulate the larger scale tests.

ASTM D635

Establishes the time and extent of burning of a plastic laminate coupon supported in the horizontal position and subjected to flame from a bunsen burner at one end.

IEC 322-2

Has been developed for testing the vertical flame spread for electrical cables. This may also be considered suitable for determining the flame spread of GRP pipes, although it may be too severe for smaller pipes and pipes that are nested together.

ANNEX E TEST METHOD FOR FLAME SPREAD OF GRP PIPING

Flame spread of GRP piping should be determined by IMO resolution A.653(16) entitled "Recommendation on Improved Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling and Deck Finish Materials" with the following modifications.

1. Tests should be made for each pipe material and size.
2. The test sample should be fabricated by cutting pipe lengthwise into individual sections and then assembling the sections into a test sample as representative as possible of a flat surface. A test sample should consist of at least two sections. The test sample should be 800 mm \pm 5 mm long. All cuts should be made normal to the pipe wall.
3. The number of sections that must be assembled together to form a test sample should be that which corresponds to the nearest integral number of sections which should make a test sample with an equivalent linearised surface width between 155 mm and 180 mm. The surface width is defined as the measured sum of the outer circumference of the assembled pipe sections that are exposed to the flux from the radiant panel.
4. The assembled test sample should have no gaps between individual sections.
5. The assembled test sample should be constructed in such a way that the edges of two adjacent sections should coincide with the centreline of the test holder.
6. The individual test sections should be attached to the backing calcium silicate board using wire (No. 18 recommended) inserted at 50 mm intervals through the board and tightened by twisting at the back.
7. The individual pipe sections should be mounted so that the highest point of the exposed surface is in the same plane as the exposed flat surface of a normal surface.
8. The space between the concave unexposed surface of the test sample and the surface of the calcium silicate backing board should be left void.
9. The void space between the top of the exposed test surface and the bottom edge of the sample holder frame should be filled with a high temperature insulating wool if the width of the pipe segments extend under the side edges of the sample holding frame.

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PART 3
SYSTEM DESIGN

ANNEX A: CALCULATION OF EXTERNAL COLLAPSE PRESSURE OF GRP PIPES

The buckling collapse pressure, P_c , of GRP pipes shall be calculated by the following equation:

$$P_c = 2.5 \times (E_{\text{eff}} / (1 - \gamma_{12} \times \gamma_{21})) \times (t/r)^3$$

where:

- t = wall thickness of pipe (mm)
- r = mean pipe radius; pipe centre to mid-wall (mm)
- E_{eff} = effective modulus (MPa); see below
- γ_{12} = Poisson's ratio; axial-hoop
- γ_{21} = Poisson's ratio; hoop-axial
- P_c = critical external pressure (bar)

Note: (i) Where γ_{12} and γ_{21} are not known, γ_{12} and γ_{21} may conservatively be taken as equal to zero.

(ii) These equations apply for thin 'long' tubes (usually regarded as those with $r/t > 10$) subjected to uniform external pressure only. They do not include effects of any axial loads or local contact loads. Whilst 'short' tubes show higher collapse resistance, most practical geometries are in the 'long' category.

Estimation of the Effective Modulus

The effective modulus shall be calculated as:

$$E_{\text{eff}} = (E_a \times E_{21})^{0.25}$$

Where E_{1t} and E_{2t} are the axial tensile modulus and hoop flexural modulus, respectively, of the pipe wall.

Alternatively, for $\pm 55^\circ$ filament wound pipe the effective modulus may be approximated, for the purpose of these calculations, as 85% of the hoop flexural modulus or 80% of the hoop tensile modulus.

Definitions of Poisson's ratios

Following normal practice, the pipe laminate Poisson's ratios are defined as:

- γ_{12} = $-e_1/e_2$ for an applied axial tensile load only
- γ_{21} = $-e_2/e_1$ for an applied hoop tensile load only

where subscripts 1, 2 refer to pipe axial and hoop directions respectively.

Experimental derivation of Poisson's ratios

Values of Poisson's ratios can be experimentally derived by measuring axial and hoop strains, using electrical resistance strain gauges, on pipe specimens loaded as follows:

- a) derivations of γ_{12} : mechanically applied axial tensile load
- b) derivations of γ_{21} : internal pressurisation with "restrained end" closures (as defined by ASTM D 1599) such that the axial pressure-induced load is borne by the closures jig and not the pipe.

Further details of experimental procedures can be found in ASTM D 2105. Care should be taken in all these tests not to load pipes beyond their linear elastic range.

Depending on the outcome of continuing investigative research it is expected that jet fire testing will qualify a system for hydrocarbon and cellulosic fires and hydrocarbon fire testing will qualify a system for cellulosic fires as well.

B1.3 FLUID FLOW CONDITIONS

To rationalise type testing the following three sets of conditions have been adopted for type testing: Dry, Stagnant and Flowing. Where there is a significant risk of a steam trap being formed on a stagnant line then it should be qualified as a dry system.

For the same time period dry testing will qualify systems for stagnant and flowing conditions and stagnant testing will qualify systems for flowing conditions.

B1.4 DRY ENDURANCE TIME

The dry endurance time is the period of time from exposure to the fire, until the system becomes water-filled. This condition will primarily apply to firewater deluge piping. Typical dry exposure times resulting from risk assessment will be in the range 1 to 5 minutes but may be longer.

B1.5 WET EXPOSURE TIME

The wet exposure time is the period from the moment the water-filled system is exposed to the fire to the moment the fire is terminated or the minimum required system endurance time previously defined, with water still flowing at the required pressure/flow rate. The combined dry and wet exposure times should be the minimum acceptable period of fire exposure as defined in section 9.4.1 but will not be less than 20 minutes.

B1.6 PRESSURE AND FLOW RETENTION

The failure mode of GRP piping exposed to a fire is generally gradual or progressive. The pipe will begin to weep through the wall rather than fail in a complete and catastrophic manner. A degree of weeping is permissible, as long as the function of the pipework is not affected. The level of this weeping is thus a critical factor. It is anticipated that the majority of offshore requirements will be satisfied by a weep rate which will not reduce the flow below the rate required. After the fire test is complete the piping must be able to withstand the operational pressure of the system while maintaining the required flow rate.

B2 FIRE REACTION TESTS

The emissions of smoke/toxic gases, heat release and rate of flame spread are physical properties of the material used, and it is acceptable for measurements to be made on a laboratory scale.

The selection of a suitable laboratory test method should take account of:

- the type of fire threat
- the location and the possibility of thermal feedback from convection currents and nearby reflective surfaces.
- the orientation of the pipework

B2.1 SPREAD OF FIRE

B2.1.1 Heat Release and Spread of Flame

For many locations the flame spread properties of GRP piping may not be significant. However for some applications it is possible that these characteristics may need to be controlled.

ANNEX B: TYPE TEST VARIABLES AND SUGGESTED MINIMUM PERFORMANCE LEVELS

A number of parameters are considered below, some refer to the survivability and others refer to the fire reaction. For any particular GRP piping system it is likely that only some of them will be relevant, and could thus be considered to be critical performance requirements. For example the smoke and toxicity parameters are only likely to be required if the pipework is to be used in accommodation, control or enclosed areas and escape routes.

The parameters identified in this section can be sub-divided into those which will require the evaluation of their performance to be based on a system test, and those which can be evaluated in a laboratory test. In general smoke, toxicity, heat release and flame spread can be considered physical properties of a system, independent of the geometry and consequently need only be tested on laboratory scale tests. Other performance properties will require full system tests.

B1 ENDURANCE TESTS

B1.1 BLAST OVERPRESSURE

The exposure of a system to a blast prior to a fire may be an important part of any simulated testing. Blast overpressure is the value of the blast, to which the system may be exposed prior to the fire test. It is anticipated that piping systems can be satisfactorily evaluated by the application of simulated dynamic pressure forces. Associated deflections are dependent on the stiffness of the GRP system and the distance between pipe supports.

B1.2 FIRE TYPE

In order to minimise the number of fire test variables, two fire type scenarios are considered for endurance testing, hydrocarbon pool fire and jet fire. A cellulosic fire has not been included as this fire type is less severe than a hydrocarbon fire; systems that withstand a hydrocarbon fire will withstand a cellulosic fire.

The hydrocarbon fire test essentially reproduces the effect of the rupture of a vessel or piping system releasing a large quantity of oil which then ignites. There are a number of codes and standards which use different values for the effect of this fire. (It should be noted that recent work has shown furnace tests to be generally less severe than hydrocarbon pool fires on account of the heat release contribution from the GRP itself, the reduction of free oxygen and poor ventilation within the furnace.)

For some applications the severity of the fire insult may be mitigated by the cooling effects of firewater. In such circumstances, depending on the outcome of a risk analysis, the temperature after an initial period may be reduced to eg. 650 deg C. This temperature represents the maximum temperatures where the integrity of the steel structure is intact.

A hydrocarbon jet fire comprises a turbulent diffusion flame resulting from the combustion of a gaseous or liquid fuel, which is continuously released with significant momentum in a particular direction. It is characterised by an instantaneous, high heat flux and is highly erosive due to the high flow velocities produced. The heat flux may vary widely and release conditions will be affected by the size of the opening through which the hydrocarbon gas is escaping. Fuel type will also have a major effect on the characteristics of a jet fire. Large-scale jet fire tests conducted to date, have attempted to simulate the type of fire that may arise for example due to high pressure hydrocarbon gas escaping from a leaking flange joint or a defective weld, in topside process pipework. A typical condition might involve the sonic release of pressurised methane gas through a small diameter orifice at a feed rate of e.g. 2-3 kg/s, producing a flame approximately 20m in length and subjecting objects in its path to a heat flux of approximately 250 kW/m² and velocity of about 60 m/s.

To avoid the need for routine large-scale jet fire testing, a standard for medium scale jet fire testing is currently being developed.

BS476: Part 7 takes account of the combined effect of factors such as ignition characteristics and the extent to which the surface of the product spreads flame. The influence on these factors of any underlying materials, in relation to their ability to influence the rate of fire growth is also taken into account. The test result is a function of distance travelled and the rate of lateral spread of flame. Classes 1 & 2 as defined by this standard comply with the SOLAS low spread of flame criteria.

B2.1.2 Post Fire Exposure Flaming

In certain circumstances, eg. where active firefighting systems are not available it may be necessary to specify a maximum period for a GRP pipe to self-extinguish.

B2.2 SMOKE AND TOXICITY

B2.2.1 Smoke Performance

Unless the system is intended for use in a normally manned area or is adjacent to escape routes (not normally manned?), smoke density is not considered to be a critical factor. When it is intended for use in these areas, the optical density should not exceed 2 when exposed to the IMO Resolution A214 (VII) test. It should be noted that in practice it is necessary to consider the rate of smoke development which will be related to the rate of heat release and fire growth.

B2.2.2 Toxicity Performance

In open or well ventilated areas the relevance of toxicity testing becomes questionable, as significant dilution with "fresh" air will reduce the harmful effects, thus, such testing of smoke produced from burning GRP may not be required. For most GRP that is not fire-protected or insulated the release of toxic emissions is mostly confined to the release of CO and CO₂ and the production of irritant gasses does not arise to any significant extent.

Where an enclosed area contains GRP the toxicity of the fumes should be below the 10 minute "emergency" exposure limits listed below. Where a GRP product does not contain an element which on combustion will give rise to toxic fumes, it is reasonable to exclude the requirement for testing of the relevant toxin. For example if the product contains no sulphur, it is reasonable to assume that no sulphur dioxide will be produced, however it should be remembered that all nitrogen bearing toxins will require testing as nitrogen is present in the atmosphere.

Carbon Monoxide	1500 ppm
Carbon Dioxide	50000 ppm (5%)
Hydrogen Cyanide	50 ppm
Nitrogen Dioxide (or NOX)	30 ppm
Phosgene	2 ppm
Sulphur Dioxide	30 ppm
Ammonia	400 ppm
Chlorine	30 ppm
Hydrogen Chloride	30 ppm

Smoke and toxicity limits/durations should be related to the duration that personnel will be present.

The smoke testing of any system is difficult to simulate realistically, as the performance of a material in a "real" fire will be directly influenced by the flow of surrounding air which can dilute the smoke produced and can also affect the degree of combustion of the smoke particles to CO and CO₂. The designer should therefore be aware that the smoke testing of GRP is only useful as a qualitative evaluation of the hazard.

2 DESIGNER QUALIFICATIONS

A GRP piping system designer shall have a formal mechanical engineering qualification from a recognised institution and shall be able to demonstrate relevant piping design experience which includes the use of GRP.

1 SCOPE

This part of the Document Suite of Specifications and Recommended Practices for the use of GRP Piping Offshore gives recommendations for the **design** of GRP piping systems.

Its objective is to ensure that piping systems, when designed using the components qualified in Part 2: "Components and Manufacture", will meet the specified performance requirements. Main users of the document will be the Principal and Design Contractors. **It should be read in conjunction with Part 1: "Philosophy and Scope".**

The requirements and recommendations apply to designer qualifications, layout dimensions, hydraulic design, structural design, detailing and fire endurance.

3.1.3 Part Factor f_3

Part factor f_3 is a term to allow for the effects of non-pressure-induced loads. With isotropic materials such as steel the effects of combined loading are greatly simplified as hoop and axial strengths are identical and this results in a significant margin in strength to accommodate additional axial loading. For anisotropic materials such as filament wound GRP, the hoop and axial strengths can be significantly different.

Notations used for stress analysis:

σ_a^b	=	axial stress, due to bending
σ_a^p	=	axial stress, due to pressure
σ_h^p	=	hoop stress, due to pressure
σ_{he}	=	allowable hoop stress

Figure 3.1.4a shows an allowable design envelope for an isotropic material. For the condition of internal pressure with unrestrained ends the pressure induced axial stress σ_a^p is half the pressure induced hoop stress σ_h^p . This means that 50% of the available axial strength is available for additional loads, typical of which would be loads at supports due to selfweight of pipe and contents, and system loads which are generated by thermal expansion.

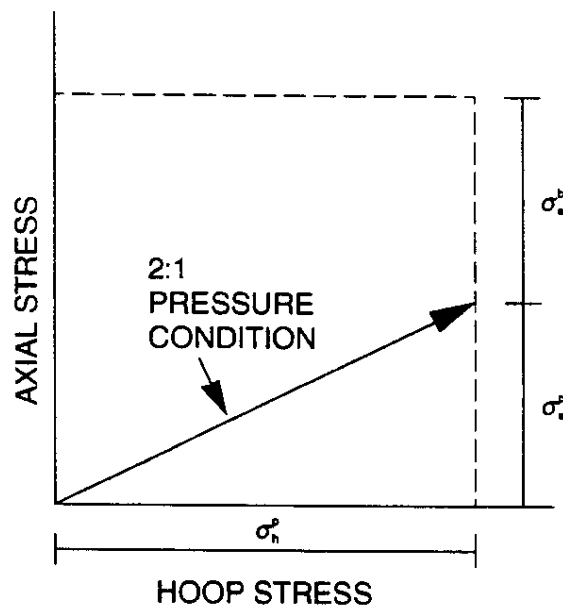


Figure 3.1.4a – Design Envelope for Isotropic Material

For commercially available filament-wound GRP pipe components, the design approaches adopted by vendors generally attempt to optimise performance for the 2:1 pressure condition (system with closed ends) and hoop strengths therefore tend to be significantly greater than axial strengths. Figure 3.1.4a shows an approximate design envelope. There are two important features. Firstly, there is no additional margin for non-pressure-induced axial stress at the outer region of the envelope for the 2:1 pressure case and, secondly, the axial tensile strength can be lower than the axial stress at the 2:1 pressure case. The ratio of these strengths, r , can range between unity, i.e. where the design envelope is a rectangular box, which would be typical of a high winding angle, (e.g. $> \pm 70^\circ$), and ratios which approach 0.6 for lower winding angles.

3 BACKGROUND TO PRESSURE RATING QUALIFICATION

3.1 PRESSURE RATING METHODOLOGY

Manufacturers assign all components both a lower confidence limit (LCL) and a nominal pressure rating (NPR).

The LCL value is equivalent to the lower (97.5%) confidence limit of the component's LTHP. It should be regarded as similar to metallic piping schedules. The LCL shall be calculated using the following equation:

$$\text{LCL} = f_1 \times \text{LTHP}.$$

The NPR is a nominal pressure rating (in bar) for the component supplied by the manufacturer. The determination of the NPR may involve the application of an empirical factor to the LTHP. The manufacturer shall state the basis for the quoted NPR.

Ratings may be either static or cyclic, i.e. LCLs or LCLc and NPRs or NPRc, according to the test method used.

NOTE: *All design calculated shall be based on LCL only, not on NPR.
The design pressure shall be $\text{LCL} \times f_2 \times f_3$.*

3.1.1 Part Factor f_1

Part factor f_1 provides a measure of the degree of scatter in the long-term pressure tests and is that value by which mean strength data must be downrated to provide an appropriate level of confidence in LTHP. The alternative methods employed in its determination are:

- a) evaluation of the 97.5% confidence limits from test data. Part factor f_1 is then the ratio of the lower confidence limit and the mean value at the extrapolated design life.
- b) use of a default value of 0.85.

The default value of 0.85 has been demonstrated to be appropriate by reference to available vendor test results. For regression procedures other than those described in ASTM D2992 the same principle applies in that the process, in conjunction with f_1 , shall result in the 97.5% LCL on LTHP. If the procedure results directly in a LCL value then $f_1 = 1$.

3.1.2 Part Factor f_2

Part factor f_2 is a factor of safety for which a default value of 0.67 is usually taken. It is related to confidence in the pipework system, the nature of the application and the consequences of failure. It should allow for the effects of occasional overloading such that hydrotesting can be safely accommodated. It should be noted that there are no established links between the effects of long term loading and those of higher loads which are of short term duration. Ensuring that the value for f_2 is equal to, or less than, the inverse of, for example, the hydrotest over-pressure would represent a conservative lower limit.

The f_2 value should be agreed between the Principal and relevant approval authority.

The derivation of f_3 is illustrated graphically in Figure 3.1.4b, where $f_3 = \frac{\sigma_a^b}{\sigma_{hs}}$

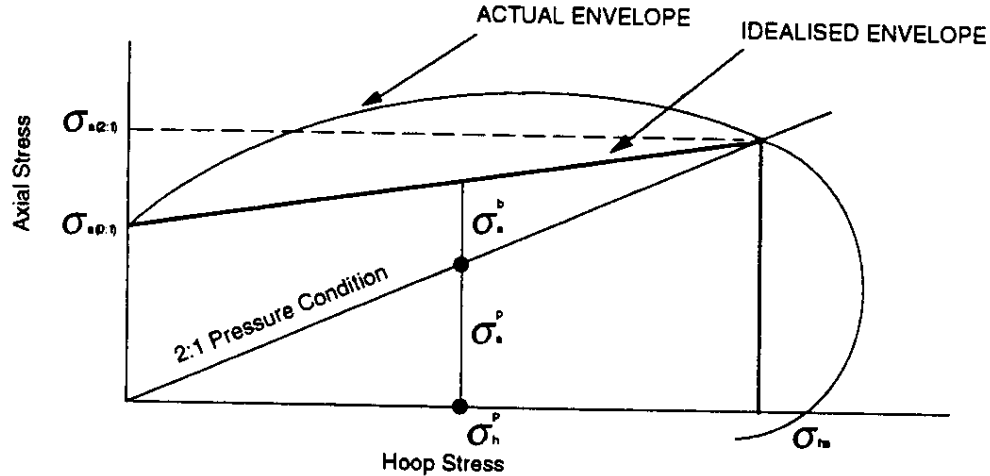


Figure 3.1.4b – Derivation of f_3

The magnitude of axial bending stress is dependent on the details of individual pipe systems and layouts. A value of 10MPa is found to be the typical stress level induced through bending at supports due to selfweight. With respect to thermally induced stresses it is not possible to derive a single value; calculations are too system specific. However, experience indicates that adopting a default value of 10MPa would allow sufficient scope for system design. In certain cases the two axial stress components will be coincident, but to employ a combined value of 20MPa for qualification purposes would be unnecessarily conservative. In those circumstances where the bending stress exceeds this value, selection of a higher rated component would be necessary. Under such circumstances the non-pressure-induced axial load capability of a component, σ_a^b , is given by:

$$\sigma_a^b = \sigma_{hs} \times \frac{r}{2} \times (1 - r') + (\sigma_a^p)'(r') \quad \text{Equation (2)}$$

where:

- $(\sigma_a^p)'$ = axial stress assumed in establishing the pressure rating, i.e. the value used in equation (1)
- r' = ratio of design pressure to pressure rating
- σ_{hs} = allowable hoop stress at the 2:1 condition.

For circumstances where it can be demonstrated that the axial stress is less than 10 MPa, equation (1) may be used to compute f_3 .

The procedures for calculating part factor f_3 are applicable to both pipe and fittings. For the purposes of the calculation of part factor f_3 for fittings, an equivalent $LTHS_f$ is required which is determined by the product of the $LTHP_s$ of the component and the ratio $LTHS_f/LTHP_s$ for the pipe. The calculation of component $LTHS_s$ does not represent an attempt to evaluate actual stress levels within the joint or fitting. It provides an equivalent value normalised with respect to the characteristics of the straight pipe to enable the effect of non-pressure-induced axial loads to be estimated.

For adequate design, the sum of the axial stress $\sigma_a^b + \sigma_a^s$, must lie within the design envelope and it is this which leads to the requirement for an additional part factor f_3 . It can be shown that this calculation can be carried out from knowledge of the applied axial bending stress, σ_a^b , the ratio of axial strengths, r , and the long term hydrostatic strength (LTHS) at the 2:1 condition:

$$f_3 = 1 - \frac{2\sigma_a^b}{r \times f_1 \times \text{LTHS}} \quad \text{Equation (1)}$$

where σ_a^b = axial bending stress due to system loads.

$$r = \frac{\sigma_{ax(0.1)}}{\sigma_{ax(2.1)}}$$

$\sigma_{ax(2.1)}$ = long term axial strength at the 2:1 condition.

$\sigma_{ax(0.1)}$ = long term axial tensile strength in the axial direction at the 0:1 condition (i.e. zero pressure), calculated in accordance with the following formula:

$$\sigma_{ax(0.1)} = \sigma_{axs(0.1)} \times \frac{\sigma_{ax(2.1)}}{\sigma_{axs(2.1)}}$$

$\sigma_{axs(0.1)}$ = short term axial tensile strength at the 0:1 condition (i.e. zero pressure).

$\sigma_{axs(2.1)}$ = short term axial tensile strength at the 2:1 condition.

Notes:

1. Part factor f_1 appears in the calculation of f_3 because the design is based on the lower confidence limit of the long-term hydrostatic strength.
2. It is acknowledged that the procedure for determining the axial strength parameter r is approximate. Long term testing may be used but there are no available documented test methods. An alternative could be used whereby medium term testing, eg 1000 hrs, is conducted on a pipe loaded with a combination of pressure and bending the value of the latter being determined by a specified level of axial stress. Such a test method would also require pressure test data (without additional bending load) at similar time scale in order to estimate the uniaxial tensile strength and then the ratio r .

both axial and hoop pressure stresses. However, as the SCF for bending has been shown to be unity, impact on total pressure stresses is not significant (unlike for bends where comparatively large circumferential stresses are generated).

For the range of winding angles normally considered in commercial products, typically $\geq 55^\circ$, design envelopes of the type shown in Figure 3.1.4b are appropriate. If winding angles significantly less than these are employed it may be found that the strength under pressure with no end load, i.e. uniaxial hoop tension, can be less than that under the 2:1 condition. This effect can be identified by comparing pressure test results under the two conditions.

3.2 CHEMICAL DEGRADATION

Although GRP piping components generally show good resistance to chemicals, this does not mean that GRP piping systems can be used for the transportation of all media.

The effect of chemical degradation from either the transported medium or the external environment shall be considered on both the pressure and temperature ratings. In particular, it should be noted that certain chemicals (e.g. brine) can reduce T_g (the glass transition temperature of the laminate) without corresponding reductions in mechanical properties.

Reference should be made to manufacturers' data where available. In general, the aqueous fluids specified in the ASTM D 2992 based qualification procedures are amongst the more aggressive environments likely to be encountered. However, it should be noted that strong acids, alkalis, hypochlorite, glycol and alcohol can also reduce the properties of GRP piping components; the effect depending on chemical concentration, ambient temperature and resin type.

If necessary as a preliminary assessment of chemical degradation, ring samples (full thickness 25mm wide) cut from pipe or fittings may be exposed and tested in accordance with ASTM C 581 in both the medium in question and an aqueous solution that is equivalent to that used in the qualification programme. However this test is likely to be inadequate to demonstrate the benefit of resin-rich liners.

The data from manufacturers' tables are based on experience and laboratory tests at atmospheric pressure, published literature, raw material supplier' data etc. Chemical concentrations, wall stresses, type of reinforcement and resin have not always been taken into account. Therefore the tables can only give an indication of the suitability of the piping components to transport the listed chemicals. In addition, mixtures of chemicals may cause unexpectedly more severe situations.

The basic materials of glass fibre and resin react differently to various chemicals, as do the adhesive and elastomeric seals/locking rings.

The elastomeric O-ring must be judged on its chemical resistance separately. Locking strips, used in the elastomeric seal lock joint, will not come in contact with the conveyed media, but might come in contact with a medium on the outside of the piping system.

The tabulated values of the ratio, r , for joints, bends and tees in Table 3.1 are discussed in sections 3.1.4.1, 3.1.4.2 and 3.1.4.3 respectively.

Component		Ratio
Joints		1
Bends and Reducers	Filament Wound	As per equivalent pipe
	Hoop Wound	1
	Hand Lay	1
Tees		1

Table 3.1 – Ratio, r , for Pipe Components.

3.1.4.1 Joints

Generally, joints are limited by axial tensile strength and therefore the allowable load envelope will be of rectangular box form, where $r = 1$.

3.1.4.2 Bends

The response of bends to axial loads is more complex than equivalent loads on straight pipe (more details can be obtained from BS 7159). Application of a bending moment causes ovalisation resulting in both longitudinal and circumferential bending stresses. The ratio of circumferential to longitudinal bending stresses ranges between 2.1 and 2.8 depending on the direction of loading (in plane or out of plane). Thus, for an axial bending stress of 10 MPa, there would be an associated circumferential stress of between 21 and 28 MPa which is in addition to the hoop pressure stress. However, this does not necessarily require a further reduction of pressure rating, as, with the application of f_3 , there is an element of hoop strength capability which may be employed. The magnitude of this ranges between 20 MPa and 33 MPa for an f_3 value determined from an allowable axial stress of 10 MPa. This variation arises due to the effect of the strength ratio r .

As can be seen, the range for allowable and applied stress correspond although in some extreme cases, high applied stress levels will apply where the allowable stress is at the minimum. However, peak stresses are very localised and it is proposed that values for the ratio r for bends should be as per the equivalent straight pipe. Where the components are of hand-laminated construction and therefore are essentially isotropic, r can be taken as unity.

3.1.4.3 Tees

At the intersection point of tee sections, stresses and their direction become complex and cannot easily be related to applied loads. There are no analytical expressions which may be used to calculate stress levels in tee joints, and relationships for stress concentration factors available in piping codes are largely empirical. From recent work (MarinetchNW Programme CP03) where typical tee sections have been loaded in bending and by application of internal pressure, the following conclusions may be drawn:

- maximum stress concentration factors (SCF) due to pressure are of the order of unity and are located in the intersection region. It is therefore this region which governs component performance.
- maximum stress concentration factors due to bending are of the order of unity. Additional stresses due to bending can therefore be added to pressure stresses without enhancement due to a SCF.

When considering the development of a design envelope for tees it is useful to draw an analogy with joints. That is, failure is likely to be dominated by axial 'pull out' at the intersection. As a result, the shape of the design envelope will be of rectangular box form where $r = 1$. The direction of bending stress, say, the 10 MPa specified for qualification, cannot be defined and therefore it must be considered additional to

4 LAYOUT CONSIDERATIONS

The designer should evaluate system design requirements in relation to the properties of proprietary pipe systems available from manufacturers, including but not be limited to:

- pressure rating;
- maximum and minimum rated temperature;
- axial thermal expansion rate;
- design life;
- chemical resistance;
- erosion resistance;
- ultraviolet radiation and weathering resistance;
- bacterial and scaling resistance;
- component dimensions;
- jointing system;
- supporting requirements.

4.1 NOMINAL PRESSURE RATINGS

The nominal pressure rating (NPR), in bar, of components should be one of the following:

1, 2.5, 4, (5), 6, (8), 10, 12, 16, 20, 25, 32, 40

where the ratings expressed in parentheses should be regarded as 'non-preferred'.

4.2 NOMINAL DIMENSIONS

4.2.1 Nominal Diameters

The preferred nominal diameter, in mm, of pipes and fittings as defined in ISO 7370, should be one of the following values:

25, 40, 50, 80, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 900, 1000, 1100, 1200

4.2.2 Bend Radii

The standard minimum bend radius should be 1.5 times the nominal diameter.

3.3 CYCLIC VERSUS STATIC RATINGS

Manufacturers may assign their products either static or cyclic ratings, i.e. LCL_S or LCL_C and NPR_S or NPR_C .

Piping components may be selected for either static or cyclic service based on either an NPR_S or an NPR_C together with the factors given in Table 3.3.

Table 3.3 – Relationship between Static and Cyclic Pressure Ratings

Static	Cyclic
NPR_S	$0.5 \times NPR_S$
$1.5 \times NPR_C$	NPR_C

Note:

Components nominally qualified for static pressures have been tested for 5000 pressure cycles of between 10% and 150% of the NPR or equivalent. Refer to Part 2: "Components and Manufacture".

3.4 DESIGN TEMPERATURE RANGE

The maximum normal operating temperature of the piping system shall not exceed the rated temperature of the GRP components. Acceptable short term excursions above the maximum normal operating temperature (e.g. upon steam cleaning) shall be agreed by the Principal and the Manufacturer.

GRP materials do not normally undergo ductile/brittle transition. Hence, there is no significant abrupt change in mechanical properties at low temperatures. Where appropriate, this shall be confirmed by the Principal in consultation with the Manufacturer.

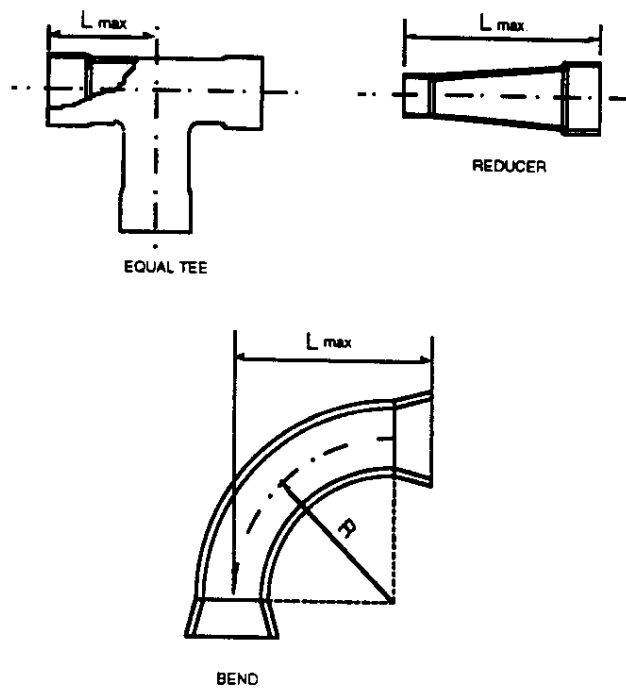


Figure 4.2.3 - Fitting Lengths

Fitting lengths can in practice be reduced if prefabricated spools (i.e. spools fabricated from straight pipe lengths and laminated to form segmental elbows, tees, reducers, etc) are used instead. For further details of this, reference should be made to the Manufacturer.

4.2.3 Fitting lengths

The preferred maximum overall lengths of fittings (bends, tees and reducers) denoted as L_{max} in Figure 3.2.3 shall be in accordance with Table 4.2.3a and 4.2.3b.

Table 4.2.3a - Preferred Maximum Overall Length of Bends and Tees

Nominal pipe size Dia (mm)	Preferred length, L_{max}	
	Bends (mm)	Tees (mm)
25	100	80
40	120	120
50	130	150
80	180	160
100	220	180
150	320	250
200	420	260
250	520	310
300	620	340
350	700	400
400	780	460
450	780	500
500	860	550
600	1030	660
700	1050	700
800	1200	740
900	1290	770
1000	1430	850
1100	1540	900
1200	1660	960

Table 4.2.3b - Preferred Maximum Overall Length of Concentric Reducers

Reduced Dia (mm) \ Max Dia (mm)	40	50	80	100	150	200	250	300	350	400	500	600	700	800	900	1000	1100	1200
25	200	220																
40		225	300															
50			250	350														
80				315	450													
100					380	500												
150						430	650											
200							500	700										
250								550	750									
300									600	800								
350										700	900							
400											830	1030						
500												925	1125					
600													950	1150				
700														975	200			
800															1000	1300		
900																1025	1350	
1000																	1050	1400
1100																		1075

4.6 VULNERABILITY

The designer should give consideration to the risk of abuse during installation and service. Sources of abuse include:

- personnel walking or climbing on piping;
- impact from dropped objects such as scaffold tubing;
- weld spatter from nearby or overhead welding activities.

Small branches (e.g. instrument and venting lines) which are susceptible to shear damage may be designed with reinforcing gussets to reduce vulnerability.

Table 5.2 - Pressure Loss Equivalent Lengths

Fitting Type	Equivalent Pipe Length
90° 1.5D bend	30 x D
60° 1.5D bend	25 x D
45° 1.5D bend	18 x D
Tee, straight	20 x D
Tee, angle	50 x D
45° branch	60 x D
Ball valve	15 x D
Butterfly valve	40 x D
Globe valve	340 x D
Two-way cock	100 x D
Gate valve	15 x D

Frictional loss in pipes is calculated from the following formula:

$$\Delta H = f \frac{v^2 L}{2g R}$$

where:

- ΔH = pressure gradient drop in m
- f = friction factor
- v = fluid velocity in m/s
- g = acceleration due to gravity = 9.81 m/s²
- L = pipe length in m
- R = hydraulic radius = $\frac{D}{4}$ in m for a filled pipe.

The value of the friction factor, f , has been the subject of many theories, experiments and investigations.

The use of the Colebrook-White formula is an applicable method for pressure loss friction factor calculation, but other methods such as Hazen-Williams formula may be used. Data on roughness factors and pressure-loss curves for pipes and fittings should be taken from manufacturer's data (a typical pipe wall roughness factor is 5×10^{-3} mm).

The Colebrook-White method utilises the following equation:

$$\sqrt{\frac{2}{f}} = 6.4 - 2.45 \times \ln \left(\frac{k}{R} + \frac{4.7}{Re \sqrt{f}} \right)$$

where:

- k = absolute pipe wall roughness in mm
- Re = Reynolds number
- \ln = natural logarithm

Pressure losses for fluids other than water can be calculated by multiplying the pressure loss for water with a correction factor based on fluid specific weight and viscosity.

5 HYDRAULIC DESIGN

The aim of hydraulic design is to ensure that GRP piping systems are capable of transporting the specified fluid at the specified rate, pressure and temperature throughout their intended service life.

5.1 LINE SIZING

Selection of nominal pipe diameter depends on the internal diameter required to attain the necessary fluid flow consistent with the calculated pressure gradient in the system.

5.2 FLOW CHARACTERISTICS

Frictionless flow in pipes can be calculated from:

$$Q = A.V$$

$$V = 1.27 \frac{Q}{D^2}$$

$$D = 1.13 \sqrt{\frac{Q}{V}}$$

where:

- Q = mass flow in m³/s
- V = fluid velocity in m/s
- A = internal cross sectional area in m²
- D = internal pipe diameter in m

Knowing the required flow and fluid velocity, the pipe diameter can be calculated before the system pressure gradient is included in the calculation.

The pressure gradient consists of loss due to fluid friction against the pipe wall, together with changes in dimension and direction of the piping.

Fluid velocity, density of fluid, interior surface roughness of pipes and fittings, length of pipes, inside diameter of pipes, as well as resistance from valves and fittings shall be taken into account when estimating pressure losses.

If data on pressure losses in fittings is unavailable, the equivalent lengths expressed as a multiple of pipe nominal diameter given in Table 5.2 may be used.

Shock loading generally induces oscillation in the pipe. Since GRP pipe has a lower axial modulus of elasticity than the equivalent steel pipe, longitudinal oscillations are generally more violent.

The designer should use standard methods to predict whether pressure transients will occur from actuated valves.

Water hammer may be minimised by use of surge tanks or reducing actuated valve closing times if possible. If the GRP system has surge pressures severe enough to move the pipe, then anchoring near the centre of straight runs is recommended in order to restrain axial movements while allowing maximum flexibility.

5.3.3 Erosion

The erosion resistance of GRP piping transporting abrasive fluids are difficult to predict without the relevant field experience or experimental data. Factors affecting erosion rate include:

- fluid velocity;
- particle size, density and shape;
- particulate/fluid ratio;
- piping configuration.

Reference should be made to the Manufacturer if doubts exist on erosion performance.

5.4 VACUUM

GRP pipe and fittings are qualified for external pressure/vacuum resistance as detailed in Part 2: "Components and Manufacture".

The designer shall ensure that, where possible, vacuum conditions can be sustained by the selected component. If this is not possible, consideration should be given to the use of vacuum release valves.

Verification of components for vacuum/external pressure loads is detailed in section 6.6.

5.3 VELOCITY LIMITATIONS

As a general guide fluid velocities greater than those given in Table 5.3 should not be exceeded.

Factors which normally limit velocities in piping systems include:

- unacceptable pressure losses;
- prevention of cavitation at pumps and valves;
- prevention of transient overloads (water hammer);
- reduction of erosion where particulates are present in the fluid;
- reduction of noise;
- reduction of wear in components such as valves.

Table 5.3 - Maximum Flow Velocity

Nominal Diameter (mm)	Maximum velocity of clean fresh water and sea water (m/s)
100 and smaller	5
150	5
200	7
250	7
300	8
350	8
400 and larger	10

5.3.1 Cavitation

Cavitation may be found in any fluid process where low and high pressure areas exist. In the low pressure area, liquids boil forming vapour bubbles, which then move to areas of high pressure where the vapour condenses and the bubbles collapse. The liquid surfaces come together with considerable velocity, sending out severe shock waves through the liquid. The shock waves are radiated equally in all directions, but if the implosion occurs at a pipe surface, half the energy of the shock wave is imparted to the pipe wall. Under repeated implosions severe damage to the pipe wall may occur, resulting in possible erosion and delamination of the pipe wall.

The smooth-wall nature of GRP piping, having advantages of low friction and low erosion, enables the designer to allow for high velocities. However, the danger of high velocities is that it is easier to put the flow into a cavitation mode. The designer should use standard methods to predict the onset of cavitation at likely sites such as control valves. In such cases, the potential for cavitation can generally be avoided by increasing valve size or increasing upstream pressure by relocation of the valve. Other potential locations of cavitation include angles at segmented elbows, tees and reducers, flanges where the gasket has been installed eccentrically and joints where excessive adhesive has been applied.

5.3.2 Water Hammer

A moving column of liquid has a momentum proportional to its weight and velocity. When flow is halted suddenly, such as by fast closing of valves, the momentum is converted into a shock load or high pressure surge. The longer the line and the higher the liquid velocity, the greater the shock load will be.

- flexibility factors;
- the allowable stress(es) for the material.

Where applicable, standard industry approved manual or computer-based methods may be used for determining deflections and stresses within GRP piping systems.

There are two areas of flexibility analysis that specifically require judgement by the design engineer. First, the model of the piping system must be conceived in such a way as to reflect the actual behaviour of the piping system. Many good modelling techniques are common to both isotropic and anisotropic piping systems, although some are unique to anisotropic systems.

The second area that requires judgement is the interpretation of the results obtained from a flexibility analysis. When steel pipe is used there are well defined allowable stress levels for the various grades of steel available. However, for GRP there is a wide range of laminates available and definition of the allowable stress is far more complex. Further details on allowable stress are given in Section 6.6.7.

6.3 MATERIAL PROPERTIES

6.3.1 General

Manufacturers generally attempt to optimise performance of GRP pipes for the 2:1 pressure condition. The material is therefore anisotropic, and hoop moduli tend to be significantly greater than axial moduli.

Accordingly, the important material properties for anisotropic pipe are:

ϵ_a	=	Strain in axial direction
E_a	=	Young's modulus in the axial direction
E_h	=	Young's modulus in the hoop direction
γ_{ha}	=	Poisson's ratio of a strain in the axial direction resulting from a stress in the hoop direction
G	=	Shear modulus
α_a	=	Coefficient of thermal expansion in the axial direction

E_a is used to determine the axial tensile and flexural stiffness in the same manner as the isotropic case.

E_h and γ_{ha} are used together with E_a to produce the proper axial behaviour due to internal pressure:

$$\epsilon_a = \frac{\sigma_a}{E_a} - \gamma_{ha} \frac{\sigma_h}{E_h}$$

Unlike isotropic pipe, the shear modulus is not related to Young's modulus and Poisson's ratio in the conventional manner:

$$G \neq \frac{E}{2(1 + \gamma)}$$

Therefore, G must be input independently of E and γ . α_a is used in a manner identical to that used for isotropic pipe.

6.3.2 Flexibility Factors

Another important area, where anisotropic flexibility analyses differ from isotropic analyses, is in the use of flexibility factors. Because of ovalisation of the cross section during bending, the flexibility of an elbow of tee is greater than that of an equivalent length of straight pipe of the same wall construction and diameter. The ratio of these flexibilities is known as the flexibility factor.

For the determination of flexibility factors, reference should be made to BS 7159..

6 STRUCTURAL DESIGN

The aim of structural design for GRP piping systems is to ensure that they shall perform satisfactorily and sustain all stresses and deformations during construction/installation and throughout their service life.

6.1 ANALYSIS METHODS

Either manual or computer methods may be used for the structural analysis of piping systems. However, the degree of analysis will depend on the following factors:

- a) pipework flexibility;
- b) layout complexity;
- c) simplicity of pipe supports;
- d) pipework diameter;
- e) magnitude of temperature changes;
- f) system criticality;
- g) failure risk assessment.

As the pipe diameter increases, the pipework becomes less flexible and the stress intensification factors at bends and tees increase. It may be necessary, particularly if temperature changes in pipework are large, to make provision for expansion and contraction. Anchor loading should be checked for acceptability.

6.2 ANALYSIS REQUIREMENTS

The designer shall evaluate the total piping system, inclusive of system criticality and risk of failure due to operating/material factors, in order to assess the need for flexibility/stress analysis. It is recommended that a manual flexibility calculation is performed initially to determine whether more formal computer analysis is required.

The following information should be obtained before performing flexibility/stress analysis :

- the operating pressure of the pipe;
- the operating temperature of the pipe;
- mass per unit length of pipe and contents;
- axial and hoop expansion coefficient of pipe material;
- axial and hoop modulus of elasticity of pipe material;
- Poisson's ratio (longitudinal and circumferential);
- pipe diameters and wall thicknesses for all parts of the system;
- routing dimensions and masses of all valves and other in-line items;
- valve types and closure times;
- environmental loadings;
- stress intensity factors (SIFs);

6.5.4 Environmental Loading

The effect of wind, snow and ice loadings shall be taken into account in the design of exposed piping. Piping shall also be designed for earthquake-induced horizontal and vertical forces, where appropriate.

6.5.5 Blast Overpressure

Designers shall consider the blast overpressures determined from the risk analysis.

6.5.6 Encapsulation in Concrete

The designer shall take account of possible mechanical and thermal loads which may be applied to crude oil and ballast water transfer GRP pipe during concrete pouring and setting construction activities of gravity based structures.

6.6 COMPONENT VERIFICATION

6.6.1 Internal Pressure

The nominal pressure rating (NPR) of all pipe and fittings as determined in Part 2: "Components and Manufacture" used in a piping system shall be equal to, or above, the design pressure of the piping system.

6.6.2 External Pressure/Vacuum

Pipe and fittings shall have sufficient stiffness to resist vacuum and/or external pressure loads. The minimum stiffness shall be sufficient to resist a short-term vacuum (e.g. by the operation of an upstream valve) with a safety factor of 1.5.

Piping susceptible to long term vacuum and/or external pressure loads shall have a stiffness sufficient to resist the induced load with a safety factor of 3.0.

External pressure resistance shall be calculated in accordance with Annex A.

6.6.3 Transient Pressure

Transient pressures above the hydrotest pressure may only be accommodated with special consideration.

6.6.4 Cyclic Excitation and Vibration

GRP pipe has a lower absolute stiffness than the equivalent steel pipe, which results in differing dynamic response characteristics when subjected to external forces.

Low amplitude vibrations, can be dampened/absorbed by GRP piping although the designer should ensure that vibration does not cause chafing of supports or overstress in branch lines.

High amplitude vibrations from pumps or other equipment should be isolated from the piping system by flexible connectors.

6.6.5 Fatigue

GRP pipe and fittings are qualified for either static or cyclic pressure use. The relationship between static and cyclic pressure ratings is given in section 3.3.

If the predicted number of pressure cycles exceeds 5000 over the design life, then the designer shall determine the design cyclic severity of the piping system, and ensure appropriate qualified pipe and fittings are used in the design.

Cyclic loading is not necessarily limited to pressure loads. Thermal and other cyclic loads shall therefore be considered when assessing cyclic severity.

6.3.3 Stress Intensification Factors

Because of ovalisation of the cross section during bending, the stresses in a pipe elbow or tee are greater than those in a straight pipe of the same wall construction and diameter under the same bending moment. These ratios are known as stress intensification factors (SIFs).

For the determination of stress intensification factors, reference should be made to BS 7159.

6.4 DESIGN CODES

The American National Standards Institute (ANSI) in conjunction with the American Society of Mechanical Engineers (ASME), has published the American National Standard Code for Pressure Piping. This code has been written to ensure proper use of steel pressure pipe. Unfortunately, much of the code is not relevant to GRP piping.

A standard which provides a much greater depth of information about system design is BS 7159: "Design and Construction of Glass Reinforced Plastics (GRP) Piping Systems for Individual Plants or Sites". Of particular note are recommendations given for flexibility and stress analysis factors. BS 7159 is not immediately applicable for use within the offshore industry (except with respect to stress intensification and flexibility factors) because it was written primarily for the chemical industry for applications up to 10bar and where greater emphasis is placed on corrosion resistance than structural efficiency.

6.5 LOADS

6.5.1 Pressure Loading

Designers shall consider all internal and external pressure and vacuum loads experienced by the piping system during the anticipated service life. Transient pressures such as water hammer and hydrotest overpressures shall also be considered.

6.5.2 Weight Loading

Designers shall consider all dead and live loadings experienced by the piping system during the anticipated service life. Typical dead loadings include:

- piping self weight;
- insulation;
- electric surface heating;
- fire protection;
- other superimposed loads supported by the piping.

Live loadings typically include, but are not limited to, the weight of the transported medium.

6.5.3 Thermal Loading

Thermally induced loads associated with the maximum operating or ambient temperature range shall be allowed for in the design. In addition, the effect of extreme transient temperatures such as adiabatic cooling shall also be considered.

7 OTHER DESIGN ASPECTS

7.1 STATIC ELECTRICITY

Possible static electricity build-up in GRP piping systems and subsequent discharging shall be considered during design. Factors that affect the build-up of static electricity include:

- conductivity of pipe laminate;
- conductivity of transported fluid;
- flow rates;
- turbulence of flow;
- environmental humidity;
- external impingement of non-conducting media, e.g. wind, steam etc;
- interface area between pipe and fluid.

Electrostatic charges can be generated on the inside and outside of GRP pipe or on any insulated metallic components in the line; sparks from subsequent discharging can puncture pipe walls, ignite surrounding explosive atmospheres, or ignite flammable pipe contents if sufficient air is present. Consideration during design should therefore be given to these hazards when GRP piping systems are used to carry fluids capable of generating electrostatic charges (static accumulators) or when using GRP piping systems in hazardous areas (i.e. areas that could in fault conditions, contain an explosive atmosphere).

In practice, fluids with a conductivity of less than 1,000 pico siemens per metre (pS/m) are considered to be non-conductive and therefore capable of generating electrostatic charges. Refined products and distillates fall into this category and piping used to convey these liquids should therefore be electrically conductive. Fluids with a conductivity of greater than 1,000 pS/m are considered to be static non-accumulators, and can therefore be conveyed through pipes not having special conductive properties when located in non-hazardous areas.

Regardless of the fluid being conveyed, the need for GRP piping to be electrically conductive should be considered if the piping passes through a hazardous area (i.e. where there is risk of fire or explosion).

Where conductive piping is required, surface resistivity should not exceed 10^5 ohm and volume resistivity should not exceed 10^3 ohm.m. The resistance to earth from any point in the piping system should not exceed 10^6 ohm.

In addition, metallic fittings and mechanical joints should be individually grounded; for mechanical joints at least one grounding saddle is required for each length of pipe.

Reference should be made to BS 5958, Parts 1 and 2, for further details on controlling the risk of static discharge.

7.2 IMPACT

7.2.1 General

GRP piping is susceptible to impact damage, particularly when empty during installation at impacts as low as 10J. However, the impact damage is usually visible and the associated failure characteristic is usually restricted to weepage, which is likely to become apparent within 24 hours of system pressurization. The energy needed to penetrate a GRP pipe is very high, and can be higher than that needed to penetrate a thin wall steel pipe.

6.6.6 Buckling

Long, vertical runs of piping shall be supported in such a way as to resist column buckling (Euler buckling). It should be noted that GRP piping has a comparatively low axial modulus of elasticity, which will increase any tendency for buckling.

6.6.7 Allowable Stresses

The results of the structural analysis shall be reviewed to ensure that the stresses in the system are within the allowances included for the pressure rating of the relevant component.

The general requirement is that component stresses (axial and hoop) should fall within the allowable stress envelope.

This requirement will be automatically fulfilled when the nominal pressure rating of the component exceeds the design pressure and the calculated axial bending stress, σ_a^b , is less than the allowance assumed, i.e. 10MPa.

When the axial bending stress, σ_a^b , exceeds 10MPa, selection of a higher rated component will be necessary. The axial bending stress capability (in MPa) of a higher rated component can be calculated using the following equation and matched to the corresponding calculated axial bending stress:

$$\sigma_a^b = \sigma_{hs} \times \frac{r}{2} \times (1-r') + (\sigma_a^b)' \times (r')$$

where r' is the ratio of design pressure and pressure rating, σ_{hs} is the allowable hoop stress at the 2:1 condition and $(\sigma_a^b)'$ is the axial bending stress used to establish the pressure rating, i.e. 10MPa.

6.6.8 Allowable Deflections

The results of the structural analysis shall be reviewed to ensure that allowable deflections are not exceeded. The maximum allowable deflection is dependent on drainage slopes, dynamic loading and aesthetic considerations.

In general, where the manufacturer's minimum support spacings are not exceeded, deflections should be within allowable limits. It is recommended that the lesser of 12.5mm or 0.5% of support spacing is taken as the default value.

- Fire protection coatings
- Fire protection of joints and supports
- Retention of pressure and flow
- Interface with metal fixtures
- Formation of steam traps
- Jet fire
- Heat release and Spread of fire
- Smoke emission, Visibility and Toxicity

The methodology for assessing blast and fire performance is given in section 9.0.

7.5.1 Blast

Where components may be exposed to explosion hazards, the effect of blast overpressure, blast wind direction and projectile impacts shall be considered, including the possible effect on support spacing.

7.5.2 Endurance and Wall thickness

If a GRP system is required to perform some function during a fire such as maintain pressure, flow or structural strength then a degree of fire resistance is needed. The minimum time the system must survive and perform its function shall be determined from risk assessment but for most applications is unlikely to be less than 20 minutes.

Non fire protected GRP piping filled with flowing water has good fire endurance when exposed to moderate/severe fire exposure. This in part is because of the ability of the material to produce a sacrificial char layer which helps protect the underlying material. Therefore the design of a non-fire protected GRP pipe system intended to function in a fire should include provision for loss of structural wall thickness. It is recommended that the pipe wall be not less than 5 mm thick.

7.5.3 Fire Protection Coatings

Piping which could be exposed to severe fire exposure may require to be insulated using a fire protection coating. The designer shall consider the following when determining the performance of the fire protection coating.

- the effect of exposure to liquids
- the attachment of the coating and the effect of interfacial liquid entrapment
- the effect of mechanical abuse, impact and vibration
- the effect of fire type
- the effect of long term environmental exposure, eg exposure to UV radiation

7.5.4 Fire Protection of Joints and Supports

Mechanical joints and some designs of adhesive joint will require to be fire protected.

The support system may require to be fire protected to ensure the piping is not subject to additional stresses caused by premature failure of the supports in a fire.

Representative qualification tests for impact are difficult to devise because impact damage is dependent on a number of factors including impactor energy, impactor shape, pipe wall thickness, pipe diameter, support spans and support spacing. Although ASTM D 2444 defines a methodology, the impact energy is only 1.75J and the method is not applicable to large diameters or thick-walled pipe.

Impact damage to GRP piping can generally be minimised by specifying a minimum thickness and by routing piping such that possible damage from personnel or dropped objects is avoided.

7.2.2 Impact Shielding

The risk of impact damage is greater during installation, and the designer shall consider the need for temporary shielding. Permanent impact shielding of GRP piping, for operational purposes, should be considered in the following areas:

- any area where the piping can be stepped on or used for personnel support;
- any area where piping can be damaged by adjacent crane activity e.g. booms, loads, cables, ropes or chains.

Impact shielding, if required, should be designed to protect the piping together with any fire protection coating. The shielding should be mounted at least 50mm from the pipe and in such a manner that loads occurring on the shielding are not transmitted to the pipe. Impact shielding may be in the following forms:

- GRP or metallic sleeve pipe sections at least 100mm larger in diameter than the pipe to be protected should be used, and as a minimum cover the upper 180° of the pipe;
- metallic shielding at least 6mm thick should be used on areas which are susceptible to impact from lifting equipment.

Impact shielding may be omitted if the GRP piping is routed such that other steel pipes or steel structures provide suitable protection against impact.

7.3 ELECTRIC SURFACE HEATING

Electric surface heating may be needed to prevent freezing in cold weather or to maintain flow of viscous fluids.

Heat tracing should be spirally wound onto GRP pipe in order to distribute the heat evenly round the pipe wall. Heat distribution can be improved if aluminium foil is first wrapped around the pipe. Care should be taken that the tracing is not wound too tightly onto the pipework or it may be damaged when the pipe expands.

Electric surface heating must not raise pipe temperature above its rated temperature.

7.4 ACCUMULATION OF SCALE DEPOSITS

GRP pipe, can suffer scale build-up which will degrade its hydraulic performance. Consideration must be given in the design to methods of descaling pipe (e.g. providing means of access) without damaging the pipe either mechanically or chemically.

7.5 FIRE

The performance of any GRP piping system subject to a fire event (to include blast) should always be considered. The factors to be considered in the design of a GRP piping system intended to function in a fire include:

- Blast
- Endurance and wall thickness

8 DETAIL CONSIDERATIONS

The following sections discuss factors that should be considered in the detailing of joints, supports, and penetrations.

It is likely that complex piping layouts will require more space when designed in GRP, due to the dimensions of GRP fittings and joints designs.

When space is limited, consideration should be given to mixed GRP/metallic designs. Vertical pipe runs of large diameter GRP will require extensive metallic supports. For optimum layout design, the use of metallic elbows with a simple duck-foot support is an alternative.

Generally as GRP piping systems are of a proprietary nature, the manufacturer should be identified as early as possible in the design phase in order to facilitate detailing.

8.1 JOINTS

Various types of bonded and mechanical joint are available. These tend to be proprietary in nature but can generally be categorised into the following types:

- adhesive-bonded joints;
- laminated joints;
- elastomeric seal joints (with/without locks);
- flanged joints;
- other mechanical joints;
- metallic/GRP interfaces.

For most offshore applications thrust-resistant types of joints will be required, e.g. adhesive-bonded joint, elastomeric seal lock joint, laminated joint or flanged joint.

However, for well supported and anchored piping non-thrust-resistant systems can be used, e.g. elastomeric seal joint (without locks) or mechanically joined systems.

The designer should take into account of the following factors when selecting the jointing method: criticality (reliability); performance under bending loads; installation environment (ease of inspection); ease of fabrication.

8.1.1 Adhesive-bonded Joints

The adhesive-bonded joint is a rigid type of joint which consists of a slightly conical (tapered) bell end and a machined (cylindrical or tapered) spigot end. Alternatively, the bell and spigot tapers may be threaded. A typical adhesive-bonded joint is shown in Figure 8.1.1.

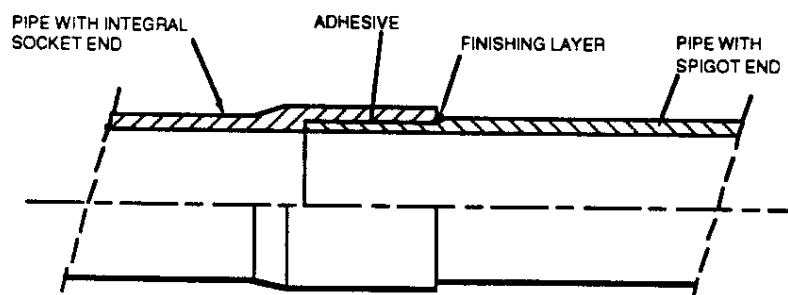


Figure 8.1.1 - Typical Adhesive-bonded Joint

7.5.5 Pressure and Flow Retention

The ability of non-fire protected GRP piping to survive in a fire is also attributed to slow weepage of water through the pipe wall which reduces the surface temperature of the pipe. The designer shall be satisfied that the fluid loss by weepage is will not adversely effect the function of the system.

7.5.6 Interface with Metals Fixtures.

Consideration should be given to applying fire protective coatings to associated metal fixtures (eg. valves, support clamps) which could conduct excessive heat into the GRP.

7.5.7 Steam Traps

Consideration should be given to the possibility of steam traps forming in pipe containing stagnant water which would reduce the conduction of heat away by water.

7.5.8 Jet Fires

Jet fires pose a significant threat to all types of piping systems because of the very high heat flux and erosive conditions they produce. Whilst GRP pipe systems can be designed to withstand jet fires, the lay-out should be designed to route piping away from areas which could be exposed to direct impingement by a jet fire.

7.5.9 Heat Release and Spread of Fire

Consideration should be given to the contribution to the fire inventory and the risk of surface spread of flame to other areas particularly where the pipes are empty and/or are no longer in service. The performance requirements shall take account of the orientation of the piping and the possibility of thermal feedback from nearby reflective surfaces.

7.5.10 Smoke Emission, Visibility and Toxicity

Performance criteria for smoke and toxic emissions will primarily be applied to the use of GRP piping in confined spaces or with limited ventilation and where personnel are at risk. Consideration should be given to the risk of the spread of smoke and toxic emissions to other areas particularly where the pipes are empty and/or are no longer in service.

- loose ring type flanges, with GRP collars adhesive-bonded or laminated to the pipe ends with loose backing flanges in GRP or steel.

Connecting bolts should always be used with washers on both flange faces, and consideration should also be given to the use of backing plates to avoid damage to the GRP on torquing the bolts.

Where possible the use of heavy duty flanges shall be avoided and should not be specified to compensate for the possibility of inadequate quality control during installation.

Allowable bolt torques shall be defined by the Manufacturer.

8.1.5 Other Mechanical Joints

Various proprietary mechanical joints or couplers are available. Reference should be made to the Manufacturer's data for guidance on use.

8.1.6 Metallic/GRP Interfaces

Interfaces with metallic tanks, vessels, equipment or piping should be by flanged (i.e. mechanical) connection.

The making of connections by other means, e.g. overwrapping of metallic pipe with GRP, is not acceptable unless qualified as an appropriate jointing method.

8.2 PENETRATIONS

Penetrations (wall, bulkhead, deck) shall not weaken the division which they penetrate. Penetrations must therefore comply with the same requirements which are specified for the relevant hazardous divisions. The main requirements are to prevent passage of smoke and flames, to maintain structural integrity and to limit the temperature rise on the unexposed side.

Penetrations are usually of a proprietary nature and are subject to type approval by an appropriate authority. Type approval, however, is only valid with the insulation materials as tested. Any change of insulation materials with respect to manufacturer, type, density and thickness will render the type approval invalid.

Limited amounts of combustible materials may be acceptable to the Certifying Authorities as integral parts of penetrations, provided the fire resistance requirements are met.

8.3 SUPPORTS

GRP piping systems may be supported using the same principles as those for metallic piping systems. However, due to the proprietary nature of piping systems, standard size supports will not necessarily match the pipe outside diameters. However, the use of saddles and elastomeric pads may allow the use of standard size supports.

Supports in all cases should have sufficient width to support the piping without causing damage and should be lined with rubber or other suitable soft material.

Clamping forces where applied should be such that crushing of the pipe does not occur. Local crushing could result from a poor fit, and all-round crushing could result from over-tightening.

In all cases, support design should be in accordance with the Manufacturer's guidelines.

Supports shall be located on plain pipe sections rather than at fittings or joints.

Where there are long runs, it is possible to use the low modulus of the material to accommodate axial expansion and eliminate the need for expansion joints provided the system is well anchored and guided.

8.1.2 Laminated Joints

The laminated joint consists of plain-ended pipe and fittings, prepared, aligned and laminated with reinforcing fibres and resin/hardener mixture. Generally these joints will only be used on large diameters.

Laminated joints require a high degree of craftsmanship and their use on site should be minimised. Lamination of pipes for a pipe spool assembly at a prefabrication shop or at a manufacturer's facility is recommended.

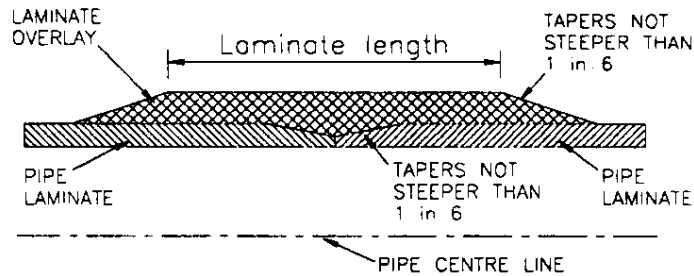


Figure 8.1.2 – Typical Laminated Joint

8.1.3 Elastomeric Sealed Joints

Elastomeric seal joints are made up of a spigot end and a socket end with 'O' or lip-sealing rings. The socket may either be an integrated part of the pipe (single socket), or a separate item (double socket). A double socket is used for joining two pipes both with spigot ends. Joints with two or more 'O' rings may be used. Elastomeric seal joints allow for some axial movement as well as a certain amount of angular deflection. Where a tensile-resistant joint is required, a locking strip can be incorporated as shown in Figure 8.1.3.

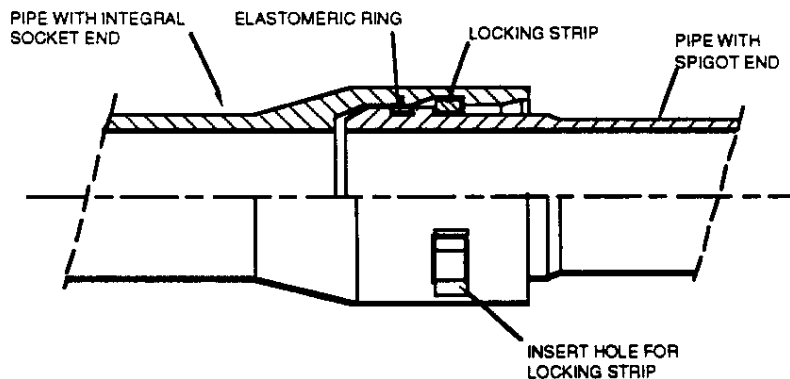


Figure 8.1.3 - Typical Elastomeric Sealed Joint (Locking Type)

8.1.4 Flanged Joints

Flanged joints facilitate connections with steel piping and allow for easy assembly and disassembly of piping systems. The outside diameter and hole spacing of flanges should meet the requirements of either ISO 7005/3 or ANSI B 16.5.

GRP flanges are always flat-faced and accordingly, matching flanges should also be flat-faced.

Two types of flanges are commonly used:

- fixed type flanges, adhesive-bonded or laminated to the pipe ends;

9 FIRE PERFORMANCE

9.1 GENERAL

This section provides guidance on the quantification of appropriate fire test standards for Glass Fibre Reinforced Plastic (GRP) pipework for use on fixed, floating, mobile and subsea offshore oil and gas installations. These standards are based on performance requirements rather than any prescriptive criteria. Use of a performance based selection process ensures that a system will perform in terms of blast loading, fire endurance and in limiting further escalation of fire, smoke and toxicity both during and after a fire event. Where the failure of a piping system has no significant consequence, fire testing may not be required.

The selection methodology of the fire performance requirements is shown schematically in the attached flow sheet (figure 9.1), and is further explained in the following sections of this document. Fire performance is defined as the combination of fire endurance plus fire reaction properties, ie. smoke and toxic emissions, heat release and spread of flame properties. The fire test parameters and the performance standards which can be derived from the specified functional requirements can then be matched to equipment systems, which have been type tested and found to have an acceptable fire endurance and reaction properties under clearly defined fire conditions. Representative system testing in order to "Type Test" manufactured products is considered to be the most practical testing philosophy. Any "type tested" system, whose performance has been verified by an independent third party and which meets or exceeds the performance standards set, would therefore be acceptable for use.

9.2 SYSTEM DEFINITION

9.2.1 Application

The first stage in the selection of fire performance requirements for a GRP piping system is to identify the application and extent of the system in service. The function of the system in the event of a fire event, and if applicable thereafter should be clearly defined.

9.2.2 Criticality

Once the system application has been defined the criticality of the system should be evaluated. A critical system can be defined as any system which must perform a function either during or after a fire, and the loss of which results in personnel hazard or unacceptable facilities damage either directly or indirectly. The criticality can vary for a given application depending on the precise function of that application on a given installation, i.e. a cooling water system may service an item of equipment, the continuing operation of which may be either essential or non-essential to the survival of the facilities and/or personnel, in the event of a fire.

9.2.3 Location

The location or locations in which a system is situated shall be defined, as these will affect the probability of piping being exposed to a potential fire and/or blast hazard.

9.2.3.1 Influence

Location has a major "influence" on the type of fire to which a system will be exposed (see section 9.6). For example firewater piping could be exposed to either jet fire or hydrocarbon pool fire depending on the design of a facility but piping within safe areas is likely to be subject to only a cellulosic fire type.

9.2.3.2 Consequence

Location will determine the "consequence" of non-functional fire reaction performance. This will concern:

- Spread of fire

Supports shall be spaced to avoid sag and/or excessive vibration for the parameters envisaged for the design life of the piping system.

Valves are often equipped with heavy control mechanisms located far from the pipe centre line and may cause large bending and torsional loads. It is therefore recommended that valves are independently supported.

Pipe supports can be categorised into those that **permit movement** and those that **anchor the pipe**.

Consideration should be given to the effective support of fire-protected GRP piping. Supports placed on the outside of fire protection could result in irregular transmitted loads through the coating, which could result in shear/crushing damage and consequent loss of support integrity.

8.3.1 Supports Permitting Pipe Movement

Supports allowing pipe to move with relative freedom include:

- **hangers** which are free to move laterally or longitudinally with the pipe;
- **fixed** supports over which the pipe may slide, allowing longitudinal movement and often lateral movement;
- **guides** which permit longitudinal movement of the pipe but restrain lateral movement.

Hangers are free to move on their hanger rods and allow considerable longitudinal and lateral movement. Hanger types include band, ring, clevis or roller.

Fixed supports permit the pipe to move longitudinally and, in some cases, laterally. An orthodox pipe rack made of steel angle is a typical fixed support permitting both longitudinal and lateral movement. Pipe resting in fixed supports requires abrasion protection in the form of saddles, elastomeric materials or sheet metal.

Guides restrict translational movement but may permit longitudinal and rotational movement. Guides are recommended for lines which are subject to sideloads or uplift. Examples include lines subjected to pressure surges, lines emptied and filled during operation, and lines (especially when empty) which can be lifted or moved by wind or other external loads.

8.3.2 Supports Anchoring Pipe

Anchors restrict movements in all directions and divide the pipe system into individually expanding sections.

Anchor clamps are recommended to be placed between two double 180° saddles, adhesive-bonded to the outer surface of the pipe. The Manufacturer's standard saddles are recommended and shall be bonded using standard procedures.

9.3 CONSEQUENCE OF SYSTEM FAILURE AND/OR SPREAD OF FLAME AND EMISSIONS

There are two separate "consequence" considerations for GRP piping exposed to a fire. These are the consequence of system failure, i.e. loss of service, and the consequence of fire reaction.

An assessment of the consequence of failure of any system is essential prior to the identification of appropriate fire performance requirements. For example in a piping system, it is clear that the consequence of failure of a potable water system and a fire main are very different. The potable water pipework being non-essential is unlikely to require fire endurance properties, whereas the fire main in most cases will. The direct and indirect consequences should be evaluated and if the consequence of failure is unacceptable in terms of personnel safety and asset integrity, other engineering solutions should be evaluated (ie. re-designing, relocating equipment, or reduction of inventory etc.).

There may be a fire reaction consequence within confined areas or for transits through fire rated walls. Concerns as to the heat release, the surface spread of flame to adjacent areas and the release of smoke and toxic emissions should be addressed.

To summarise, the consequence of the failure of a system to maintain its function following exposure to a fire, is determined by the criticality of the service. The consequence of fire reaction depends upon the location of the system.

9.4 PERFORMANCE PARAMETERS

Having established the consequence of failure for a piping system, and/or having identified that there is a consequence of system loss and/or of fire reaction, the relevant performance parameters during and after the fire should now be identified.

9.4.1 Functional Performance parameters

The following properties may be required:

- a) The maximum blast overpressure to which a system may be exposed.
- b) Minimum fluid flow through a piping system for the system to function as needed.
- c) Minimum pressure retention of a fluid in a piping system which is required for the system to function correctly.
- d) Endurance for the system. The minimum time the system must perform at the required level should be identified. Dry endurance time may be defined by a quantitative risk assessment whilst the endurance time under conditions of flowing water may be defined by other considerations e.g. survival time for safe refuge, personnel evacuation, asset protection etc.

9.4.2 Reaction to Fire Performance Parameters

- a) The requirement for smoke visibility and toxicity performance should be identified particularly for piping in enclosed areas.
- b) The requirements for spread of flame should be identified. Consideration should be given to the orientation of the pipe and proximity of reflective surfaces.
- c) The potential for addition to the fuel inventory from the GRP pipework should be identified. This should be quantified in terms of the heat release characteristics of the GRP.
- d) Consideration should also be given to the possible effects of post fire-exposure flaming (i.e. the time required for the material to self-extinguish).

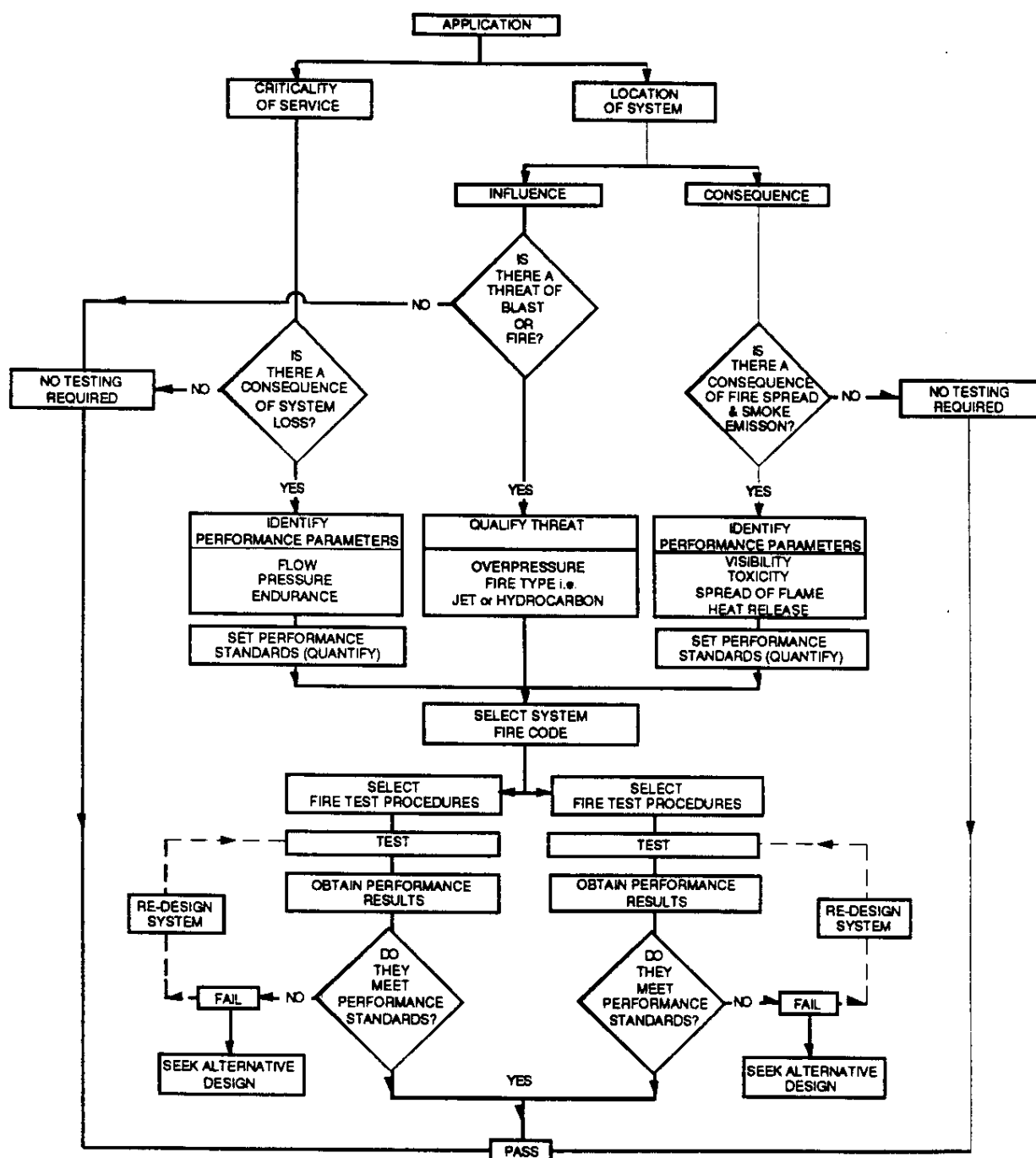


Figure 9.1 - Fire Testing Logic Diagram for GRP Piping

- A = Service**
- = 1 hydrocarbon
 - = 2 empty
 - = 3 critical flowing water initially empty for minimum of 1 minute
 - = 4 critical flowing water initially stagnant for minimum of 1 minute
 - = 5 critical flowing water
 - = 6 other, eg chemical
 - = 9 other non critical water based service
- B = Fire Type**
- = 1 full scale jet fire
 - = 2 medium scale jet fire
 - = 3 hydrocarbon fire (NPD curve)
 - = 4 hydrocarbon fire mitigated by cooling effects of firewater deluge
 - = 5 cellulosic fire
 - = 6 cellulosic fire mitigated by cooling effects of firewater sprinkler system
 - = 9 other less severe fire exposure
- C /xxx = Endurance (minimum survival time of 30 minutes)**
- C**
- = 1 no exchange of media between inside and outside of pipe permitted
 - = 2 function maintained, fluid exchange/loss limited and quantified
 - = 3 function maintained, fluid exchange/loss limited but unquantified
 - = 4 maintain integrity but fluid exchange/loss unlimited
 - = 9 endurance not quantified or required
 - = 0 no test data available
- /xxx**
- = /020 endurance greater than 20 minutes
 - = /060 endurance greater than 60 minutes
 - = /120 endurance greater than 120 minutes
 - = /180 endurance greater than 3 hours etc.
- D = Fire Reaction: Spread of Fire and Heat Release**
- = 1 no spread of fire permitted
 - = 2 spread of fire is limited (SOLAS class 1)
 - = 3 spread of fire is limited (SOLAS class 3)
 - = 4 spread of fire is limited (SOLAS class 3)
 - = 9 spread of fire unlimited or not quantified
 - = 0 no test data available
- E = Fire Reaction: Smoke and Toxicity**
- = 1 representative of needs within a safe area
 - = 2 levels must not exceed 10 minute emergency exposure level
 - = 3 levels must be acceptable within evacuation time
 - = 4 levels are limited
 - = 9 levels unlimited or not quantified
 - = 0 no test data available

9.5 PERFORMANCE STANDARDS

Once the performance parameters have been identified for the critical properties of any system, the performance standards can be quantified. As a minimum, the performance standards should match the functional requirement. Where a safety factor is considered necessary, it is included within the performance standard and documented. This provides an auditable trail, and avoids the possibility for compounding safety factors beyond reasonable levels. The performance standards and all included safety factors should be agreed between the end user, the relevant certifying authorities and the regulatory bodies.

9.6 FIRE THREAT EVALUATION

There are three clear steps to the evaluation of a fire threat.

- a) The location in which any system is used must be clearly defined as this may affect, not only the consequence of failure but also the type, extent and duration of a fire event, as well as the proximity of active and passive fire control equipment.
- b) Having defined the location of the system the fire threat can be qualitatively determined. This will largely be concerned with the pre-fire blast, fuel inventories, the ventilation available and the potential for jet fires which may exist.
- c) The qualitative threat evaluation leads directly to the quantitative evaluation of the threat, to produce estimates of duration and values of blast over-pressure, temperature and/or heat flux and flame erosion/inertia effects which would be experienced during a fire. The quantification of the fire threat should be consistent with that derived in the safety case.

9.7 PIPE SYSTEM FIRE CLASSIFICATION CODE (TYPE TEST ENVELOPES)

The classification code provides a means of identifying the fire performance of pipe in terms of service conditions and severity of fire threat.

The following proposal for such a fire coding system. Note that it has still to be agreed by the appropriate authorities and organisations and is subject to further revision. It is included for guidance purposes and the user of this document should check the availability of an updated and endorsed version.

The Fire Classification Code is designated by a five field number:

A.B.C/xxx-(D.E)

where service function A, fire type B and performance C/xxx, D and E are assigned prescribed levels in decreasing order of severity representative of offshore requirements. The minimum standard (default value 9) is indicative of either unlimited or unquantified performance. A value 0 for a particular performance category C, D or E is indicative of the non-availability of fire test data.

9.8 FIRE TEST PARAMETERS

The fire test parameters are derived from the fire threat evaluation. Having qualitatively identified the fire type a standard test method appropriate for that fire type should be identified and adopted for the purpose of type testing GRP piping.

If more appropriate, the values established from estimates of the heat flux/temperature, erosion/inertia effects and flame velocity may be used to form the basis of the fire test to which the system will be exposed.

The performance standards previously established in 9.5 provide the pass/fail parameters for the tests. In this way the performance based criteria have been clearly identified and have been given an appropriate prescriptive level as a performance requirement.

System testing allows components to be matched with the requirements while meeting or exceeding the performance standards. Further guidance on the factors which must be taken into account in "Type Testing" and suggested minimum performance levels are given in Annex B.

Whilst the number of test scenario's and the different performance requirements may appear daunting to a supplier trying to standardise systems, it is anticipated that 95% of all offshore applications will be covered by a limited number of classification codes. These in time would come to represent typical "Type Test" envelopes.

The five classification codes listed below illustrate potential uses of GRP.
A.B.C/xxx-(D.E) where:

- a) **3.2.2/120-(4.9)** represents a firewater dry deluge system in an open ventilated area which may be exposed to a hydrocarbon jet fire and which may be empty initially but become water-filled very soon after a fire is detected. Spread of fire along the pipes to adjacent areas must be limited
- b) **4.4.3/060-(2.3)** represents piping typical of continuously water filled systems either stagnant or stagnant then flowing, such as critical cooling water supply lines, which are in a deluge protected area and may be exposed to a hydrocarbon pool fire. No spread of fire is permitted away from area subject to fire and smoke and toxicity levels must remain acceptable within the evacuation time.
- c) **9.5.9/000-(1.1)** represent piping within safe areas such as accommodation, safe refuges and control rooms. Typically these systems would be transporting fresh water utility water or sewage. The fire type is cellulosic but in this instance no active fire protection can be relied upon from the sprinkler system. No spread of fire is permitted and smoke and toxicity levels must meet the needs of a safe area.
- d) **1.3.1/120-(4.4)** represents systems containing hydrocarbon which may be exposed to a conventional hydrocarbon pool fire with no protection from the deluge system. No spread of fire is permitted although smoke and toxicity levels may be unlimited. It should be noted that this application is beyond the experience of most fire testing carried out to date.

Note : The classification codes only provide a first level guide to performance. Assigned to each code are details of the performance standards, eg. blast, endurance time, pressure and flow retention, fire spread and smoke/toxicity levels achieved during testing.

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PART 4
FABRICATION AND INSTALLATION

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ANNEX A	CALCULATION OF EXTERNAL COLLAPSE PRESSURE OF GRP PIPES
ANNEX B	TYPE TEST VARIABLES AND SUGGESTED MINIMUM PERFORMANCE LEVELS

2 DELIVERY INSPECTION

2.1 INSPECTION

The quantity, pressure rating, nominal dimensions, and relevant special requirements of all piping components shall be verified for compliance with the purchase order.

Shipments of piping components not complying with the purchase order shall be reported to responsible personnel for corrective actions.

All piping components shall be visually inspected for manufacturing faults, and damage that may have occurred during shipment. 100% of exterior surfaces shall be visually inspected. Internal surfaces shall be visually inspected where accessible. If a separation of the laminate extends through the wall of the material, this will be revealed by a whitening around the damaged area.

All end/face protective devices must be removed to allow inspection of flange faces and inspection of machined or ground male spigots and female bells. End and face protection devices must be re-instated unless immediate installation is planned.

Rejectable defects are listed in Table 2.2. Any piping component that contains one or more rejectable defect shall be rejected. Rejected items must be marked and positively controlled to ensure they are not inadvertently installed.

Adhesive bonding kits shall be inspected to ensure that the kits contain all necessary materials, are not leaking or visibly damaged, and that at least six months remains until the expiration of shelf life.

All fire protection material shall be inspected to ensure that the original packaging is not damaged.

1 SCOPE

This part of the Document Suite of Specifications and Recommended Practices for the use of GRP Piping Offshore gives recommendations for the **fabrication and installation** of GRP piping systems.

Its objective is to ensure that installed piping systems will meet the specified performance requirements. Main users of the document are envisaged to be the Principal and Fabrication/Installation Contractors. It **should be read in conjunction with Part 1: "Philosophy and Scope"**.

The recommendations apply to delivery, inspection, handling, storage, installation, and system pressure testing.

2.3 DOCUMENTATION

2.3.1 Pipe

The following dimensions, with tolerances where applicable, shall be given by the Manufacturer:

- pipe inside and outside diameter;
- minimum total wall thickness;
- liner thickness;
- overall pipe length;
- effective pipe length;
- outside and inside diameter of the end;
- length of joint;
- form of spigot and socket;
- spigot and socket taper angle.

2.3.2 Fittings

The following dimensions, with tolerances where applicable, shall be given by the Manufacturer:

- fitting inside and outside diameter;
- minimum total wall thickness;
- structural wall thickness;
- liner thickness;
- overall fitting length;
- effective fitting length;
- length of joint;
- form of spigot and socket;
- spigot and socket taper angle.

2.3.3 Flanges

The following dimensions, with tolerances where applicable, shall be given by the Manufacturer:

- thickness of flange;
- pressure rating;
- bolt hole circle and diameter.

2.2 DEFECT EVALUATION

Table 2.2 – Visual Defects

Defect Type	Description	Delivery acceptance criteria	Corrective action
Burn	Thermal decomposition evidenced by distortion or discolouration of the laminate surface.	None permitted	Reject
Chip	Small piece broken from edge or surface. If reinforcement fibres are broken, the damage is considered to be a crack.	If there are undamaged fibres exposed over any area; or no fibres are exposed but an area greater than 10mmx10mm lacks resin.	Minor repair
		If there are no fibres exposed, and the area lacking resin is less than 10mmx10mm	Accept
Crack	Actual separation of the laminate, visible on opposite surfaces, and often extending through the wall. Reinforcement fibres are often visible/broken.	None permitted	Reject
Crazing	Fine hairline cracks at or under the surface of the laminate. White areas are not visible as for cracks.	Crack lengths greater than 25.0mm	Minor repair
		Crack lengths less than 25.0mm	Accept
Dry spot	Area of incomplete surface film where the reinforcement has not been wetted by resin.	None permitted	Reject
Fracture	Rupture of the laminate with complete penetration. Majority of fibres broken. Visible as lighter coloured area of interlaminar separation.	None permitted	Reject
Inclusion	Foreign matter wound into the laminate	None permitted	Reject
Pit (pinhole)	Small crater in the surface of the laminate, with its width approximately of the same order of magnitude as its depth.	Diameter greater than 0.8mm, and/or depth greater than 10% of wall thickness	Minor repair
		Diameter less than 0.8mm, and depth less than 10% of wall thickness	Accept
Restriction	Excessive resin, adhesive, foreign matter on the internal wall of pipe/fittings.	None permitted	Remove by careful grinding.
Wear scratch	Shallow mark caused by improper handling, storage and/or transportation. If reinforcement fibres are broken, the damage is considered to be a crack.	If there are undamaged fibres exposed over any area; or no fibres are exposed but an area greater than 10mmx10mm lacks resin.	Minor repair
		If there are no fibres exposed, and the area lacking resin is less than 10mmx10mm	Accept

If doubts concerning the extent of defects occur during inspection, a specialist approved by the Principal may perform a second inspection of the delivered items.

3 HANDLING AND STORAGE

3.1 HANDLING

GRP piping components can be susceptible to mechanical damage from impact, sharp edges, or scratching. Special consideration must therefore be given to protecting components and to ensuring that all personnel involved are given training in the relevant procedures.

End protection of piping components shall remain in place during handling and transport.

3.1.1 Lifting and Transportation

Lifting, loading, unloading, and shipping shall be performed in accordance with the Manufacturer's recommendations.

Under no circumstances shall piping components be thrown or dropped from any height. Furthermore, no chains, wire ropes or clamps shall be used for lifting piping components.

Small diameter pipe can easily be lifted by hand. Short pipe sections up to 3m in length may be lifted with a crane using at least one 100mm wide canvas or nylon sling. Longer pipe sections, up to 6m in length, may be lifted with a 3m spreader bar and two 100mm wide nylon slings. The lifting point or points shall be such that the pipes are well balanced.

Pipes should be transported either packed in a container or strapped onto pallets.

Fittings shall be loaded by hand onto pallets, or into crates or baskets, with inter-component packing material to avoid transportation damage, and shall be strapped down during lifting.

For lifting pipe spools, two or more 100mm wide canvas or suitable plastic slings may be necessary. The lifting points shall be such that the pipe spools are well balanced. The canvas or nylon slings shall not be placed under fittings or pipe connections.

3.1.2 Temporary Supports

Temporary restraining supports shall be attached to complex prefabricated spools prior to lifting, in order to minimise bending strain in the spools.

3.2 STORAGE

Storage of piping components may be required prior to installation. Special precautions designed to avoid possible damage to any item shall be taken. Consideration shall be given to the state of the storage surface (i.e. level and no sharp objects), high winds, temperature and exposure to ultraviolet radiation.

3.2.1 Pipe

Pipe may be stacked for space saving storage as illustrated in Figure 3.2.1, subject to the following requirements:

- Pipe may be stacked in heights up to 1.5m if side supports are provided. Spacer stripping (approximately 50mm x 100mm) should be used both as supports for the pipes and as separators between pipe layers. The strippings should be located directly above each other. Maximum distance between supports shall be 3m and the supports shall be placed at a minimum of 1m from the end of the pipes.
- Pipe with bell ends may be stored with the bell ends in alternate directions to avoid contact and possible damage to the ends. Spacer stripping shall be located clear of the bell ends.
- End protection shall remain in place during storage.

2.3.4 Pipe Spools

The following dimensions, with tolerances where applicable, shall be given by the Manufacturer:

- face to face;
- centre-line to face;
- centre-line to centre-line;
- flange offset;
- flange face alignment.

3.2.6 Fire Protection Materials

All separately delivered fire protection materials shall be delivered at the receiving facility in factory-sealed containers or in crates.

Unless otherwise specified by the fire protection manufacturer, the fire protection material shall be stored in the original packaging at a temperature of less than 30°C.

Storage of fire protection material shall be in accordance with the Materials Safety Data Sheet (MSDS) for the substances in question.

- Spacer stripping thickness must be sufficient to ensure that pipes are not in contact with each other.
- Strapping down of GRP pipe stacks may be necessary to prevent damage during high winds. Suitable tie-downs such as nylon straps or padded metal strapping should be used to secure the stack. Caution should be used to prevent damage when securing the stack.

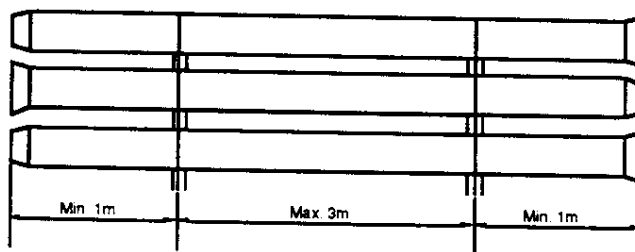
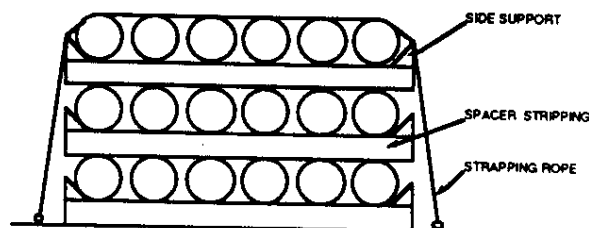


Figure 3.2.1 – Stacking Of Pipes

3.2.2 Fittings

Fittings may be shipped in crates or boxes and may be stored in these crates or boxes provided the package is undamaged and suitable for long-term storage. End protection of fittings and flanges must remain in place during storage.

3.2.3 Pipe Spools

Pipe spools should be packed by the Manufacturer to avoid damage during transportation. If possible, the pipe spools shall be stored with this temporary protection in place. End protection of fittings and flanges must remain in place during storage. Pipe spools shall not be stacked.

3.2.4 Adhesive / Resin systems

Adhesive kits and resin systems shall be stored in the original packaging in accordance with the pipe Manufacturer's recommendations and safety regulations applicable to the storage location.

Storage conditions for the adhesive and resin systems shall be in accordance with the Material Safety Data Sheet (MSDS) for the material in question. Particular attention shall be taken of the recommended storage temperatures, and the requirement to keep certain materials apart for fire safety reasons.

3.2.5 Ancillaries

Ancillary materials (rubber O-rings, flange gaskets, locking strips, reinforcements and lubricants) shall be stored in accordance with the manufacturer's recommendations. Due regard shall be paid to exposure to direct sunlight (UV radiation), chemicals, biological growth and extremes of temperatures.

Where shown on isometric drawings, the fabrication shall include 'cut to fit' lengths and field joints on fabricated pieces to allow for the setting up of pipework accurately on site between fixed points.

The 'cut to fit' dimension shall be 150mm of pipe additional to the length shown on the piping drawings. For hook-up spools the 'cut to fit' dimension shall be a minimum of 250mm in each global direction. 'Cut to fit' lengths shall be left square and plain.

Consideration should be given to provide temporary protection for installed GRP piping where risk of mechanical damage is high. The installer should also consider correct sequencing of fabrication activities to minimise risk of damage.

Higher levels of supervision and inspection should be adopted where it will be difficult to make repairs (eg ballast lines due to be cast in concrete).

4 INSTALLATION METHODS

Installation methods described in this section are recommended practice and are not intended to replace manufacturers' recommendations.

4.1 CUTTING

GRP pipe of nominal diameter up to 100mm may be cut with a hacksaw. For nominal diameters above 100mm an abrasive cutting disc should be used.

Overheating to temperatures above 150°C (i.e. caused by preheating or by the heat developed during cutting/machining and the low thermal conductivity of GRP) is detrimental to GRP material and shall be avoided. Materials which are damaged due to overheating shall be rejected and replaced.

The squareness of the cut shall be checked. Pipe up to 100mm nominal diameter shall be square to within 1.5mm. Cuts on larger pipes shall be square to within 3.0mm.

For adhesive-bonded connections, the pipe end must be machined with a pipe shaver. Each Manufacturer has specialised equipment for shaving spigots. The pipe end shall be shaved to the Manufacturer's recommendations regarding angle, diameter, length and eccentricity.

4.2 SUPPORTS

Where possible, pipework shall be erected on permanent supports designated for that purpose.

During erection of pipework, temporary and/or permanent supports, shall be provided to ensure that no undue stresses are imposed on the pipe.

Temporary supports and assemblies used to facilitate the erection of pipework shall be designed with regard to safety and suitability.

4.3 INSTALLATION

4.3.1 General Requirements

The requirements for the handling of piping components offshore are the same as the requirements defined in section 3.

Before installation, all piping components shall be inspected for damage as described in section 2.

All piping components shall as far as possible be installed so that they are stress-free:

- bending of pipes to achieve changes in direction, or forcing misaligned flanges together by over-torquing bolts is not permitted;
- the Manufacturer's recommendations for bolt torquing sequence, torque increments and maximum bolt torque shall be followed.

Prefabricated pipework shall be fabricated in accordance with fully dimensioned piping isometrics. Overall spool dimensions shall be sized taking the following into consideration:

- site transport and handling equipment limitations;
- installation and erection limitations;
- limitations caused by the necessity to allow a fitting tolerance for installation ('cut to fit' requirements).

4.3.3 Earthing

Pipe and fittings intended for installation in hazardous gas areas, and serving under conditions that will give rise to the build up of static electricity in the piping system, shall be electrically grounded to adjacent steelwork. Piping shall be checked electrically as installation proceeds to ensure that the maximum resistivity to earth is not exceeded at any point. (The upper limit for earthing resistance is 10^6 ohm).

4.4 JOINTING

Various types of joint are available. These tend to be proprietary in nature but can generally be categorised into the following types:

- adhesive-bonded joints, plain or threaded;
- laminated joints;
- elastomer seal joints;
- flanged joints;
- other mechanical joints;
- metallic/GRP interfaces.

All jointing shall be performed in accordance with the Manufacturer's recommendations. The following sections, however, give guidance on the main aspects that need to be considered.

4.4.1 Adhesive-bonded Joints

No person may produce an adhesive-bonded connection unless that person has been instructed in the Manufacturer's bonding procedures and has passed the bonder qualification test described in section 5.1.2. Bonding inspectors shall fulfil the requirements stated in section 5.2.

The adhesive-bonded joint consists of a tapered bell end and a tapered or cylindrical spigot end bonded with an adhesive/hardener mixture. Alternatively, ball and spigot may be taper threaded.

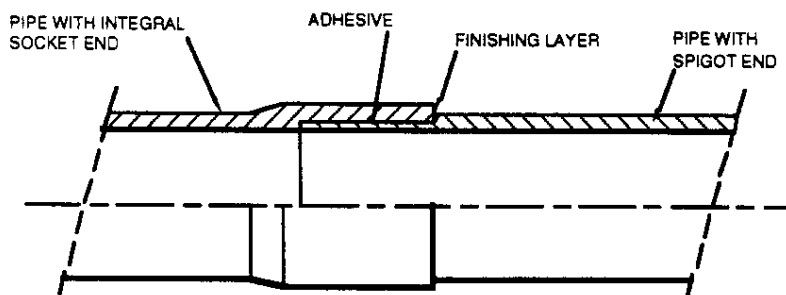


Figure 4.4.1 Adhesive-bonded Joint

4.4.1.1 Preparation

End caps and surface protectors shall be left in place until just prior to surface cleaning.

Manufacturers' recommendations regarding preparation and adhesive application at ambient temperature and humidity shall be followed. A suitable environmentally controlled habitat may be necessary in adverse weather conditions.

Each bonding surface shall be checked visually for ultraviolet degradation prior to cleaning, by lightly sanding the bonding surfaces. UV degradation will be noted by a change in colour of the sanded surface. The appearance of UV degradation shall require refinishing of the surface. Spigots shall be re-shaved. Sanding shall remove all discolouring, but not to the degree that flat spots are made.

4.3.2 Tolerances

Global tolerances shall be within +/- 6mm in all directions if not otherwise shown on the approved drawings.

Dimensional tolerances for finished piping are given in Table 4.3.2.

Table 4.3.2 – Maximum Dimensional Tolerances

ID	Dimension number (see Figure 4.3)					
	1	2	3	4	5	6
25-200	±3mm	±3mm	±0.5°	±3mm	±1mm	±0.5°
250-300	±3mm	±3mm	±0.3°	±3mm	±1mm	±0.5°
350-400	±3mm	±3mm	±0.3°	±3mm	±2mm	±0.5°
450-600	±5mm	±5mm	±0.3°	±3mm	±2mm	±0.5°
700-900	±5mm	±5mm	±0.2°	±3mm	±3mm	±0.5°
1000-1200	±5mm	±5mm	±0.15°	±3mm	±3mm	±0.5°

The dimension numbers are depicted in the accompanying diagram, Figure 4.3.2.

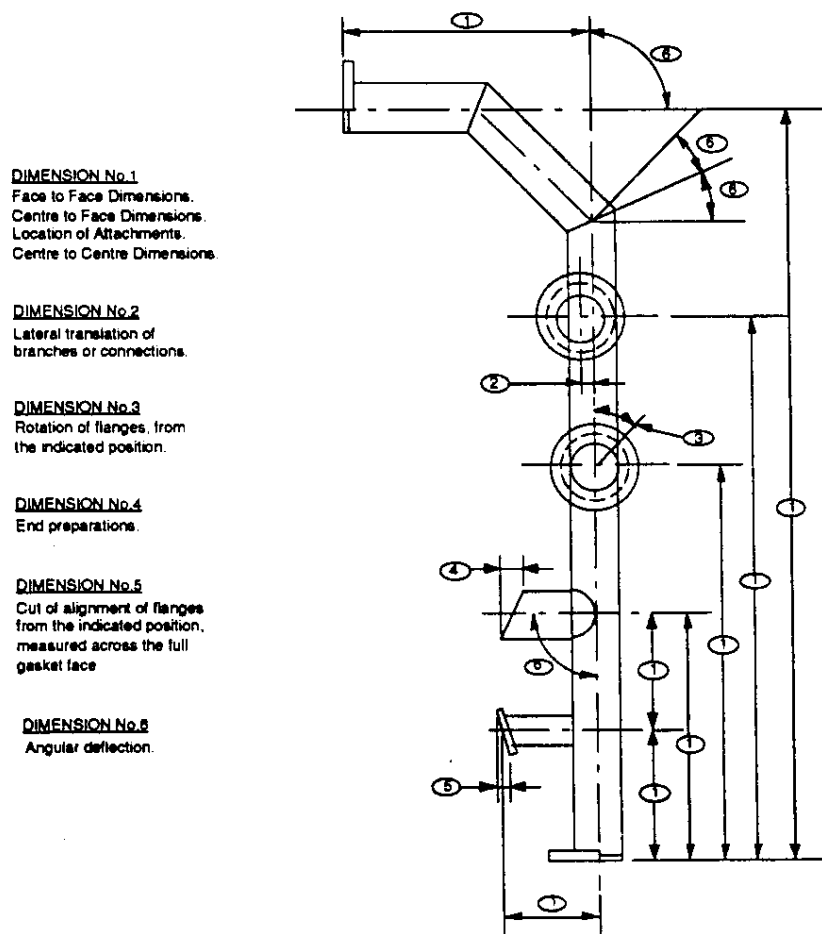


Figure 4.3.2 – Tolerance Dimensions

If ambient temperatures are below 5°C, the heating collars shall be long enough to completely encircle the connection or fitting area to be cured, plus a minimum 50mm overlap. Heating collars shall be wrapped around the connection to be cured so that the collar thermostat is not against the pipe wall.

Heating collars should be insulated. Foil backed fibreglass insulation is typically used. Insulation should overlap the collar by at least 100mm on either side and be tied down onto the pipe at the edges. Pipe ends should be loosely closed with non-sealing devices (typically, Styrofoam plugs are used) to prevent interior cooling in windy conditions.

Flanges may be cured by inserting the heating collar on the inside of the pipe. Excess adhesive shall be wiped from the interior of the pipe prior to inserting the collar. A fibreglass core for the collar may be made from a section of pipe having the same diameter as that being connected.

Adhesive-bonded connections between pipes, fittings, and flanges must not be disturbed, and if necessary, provided with additional bracing to prevent accidental movement until fully cured.

4.4.2 Laminated Joints

The laminated joint consists of plain-ended pipe and fittings, prepared, aligned and laminated with reinforcing fibres and adhesive.

4.4.2.1 Preparation

Before work on a laminated joint is started, all necessary equipment for completing the procedure must be available.

A jig or other holding device should be used to ensure that the pipes are maintained with the joint faces held tightly together without offset. The restraints should be left in place until the joint has fully cured.

When connecting two pipes, the end of the pipes shall be chamfered back to a minimum taper of 1 in 6, as illustrated in Figure 4.4.2.

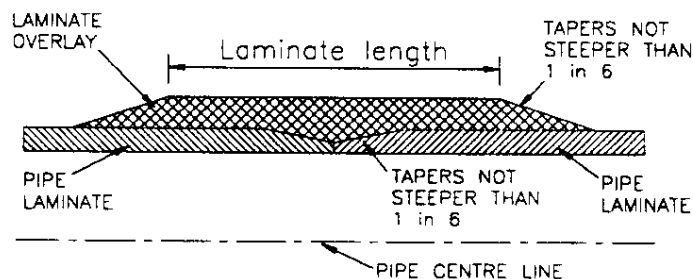


Figure 4.4.2 – Laminated Joint

The outer pipe surface shall be abraded to remove the outer resin-rich surface and expose the reinforcing fibres over an area extending to at least 50mm outside both ends of the laminate as defined in the Manufacturer's technical specifications. The pipe ends should also be abraded.

Bonding surfaces shall be cleaned as recommended by the Manufacturer. The cleaned surfaces should not be touched or be contaminated by oil or moisture prior to bonding. If surfaces become wet or contaminated they must be cleaned, re-ground and made dust-free.

4.4.2.2. Resin Mixing

The resin used shall be of the same type, or compatible with, the resin used in the manufacturing of the pipes.

Bonding surfaces shall be thoroughly cleaned and sanded. The cleaned surfaces should not be touched or contaminated by oil or moisture prior to bonding. If surfaces become wet or contaminated they must be cleaned, re-sanded and made dust free.

4.4.1.2 Adhesive Mixing

Adhesive shall not be used beyond its expiry date. Any leaking or damaged kits shall be safely discarded, according to the Material Safety Data Sheet.

The adhesive components shall be within the temperature range recommended by the Manufacturer before mixing.

The complete contents of the hardener container shall be emptied into the base adhesive. All the adhesive and all the hardener shall be mixed; kits shall never be split. Mixing shall continue until the adhesive mixture has a uniform colour and consistency. The working life (pot life) of the adhesive will depend on the type of adhesive used and mixing temperature. If the adhesive starts to heat up in the mixing can, it has started to cure and must be discarded. If lumps or gels are apparent in the can, the adhesive must be discarded.

4.4.1.3 Assembly

Pipe connections must be aligned as true as possible. Any visually detectable misalignment is not permitted. If recommended by the pipe Manufacturer, a reference mark shall be made on the spigot end of the connection to check for proper insertion and seating after connection is made-up. The distance of the reference mark from the spigot nose shall be specified by the Manufacturer for each pipe diameter and shall include the insertion depth of the spigot in the bell plus 25mm.

Bonding surfaces must have a temperature of at least 20°C and less than 40°C prior to application of adhesive. If preheating is required, separate heating of bell and spigot by electric blanket is recommended. Contamination of the spigot can be avoided by inserting the heating blanket in the pipe bore instead of by external wrapping.

A thin uniform coating of adhesive shall be applied to the bonding surface, taking care to avoid an excessive resin bead on the inside of the pipe which will cause flow disturbance. The bell surfaces shall be coated first. All machined or sanded surfaces shall be coated. Adhesive shall be coated down into the bell past the insertion depth of the spigot. The cut end of the spigot must be coated.

Piping of diameter up to 150mm may be assembled by hand. The spigot shall be inserted as far as possible by hand. A block of wood shall be placed across the free end of the pipe or fitting and the spigot driven into the bell by hammering on the wooded block. Proper insertion of straight spigot connections is verified by measuring the reference mark on the spigot; it should be 25mm from the bell.

Connections with a diameter of 200mm or more may be assembled with a ratchet winch or hydraulic pullers; furthermore, care shall be taken to prevent the connections from being damaged during this operation. Spigots shall be inserted until they bottom against pipe stops and the reference marks are in their fully home position.

Assembly of the adhesive joint up to full insertion should be performed as a single action to avoid entrainment of air into the adhesive. Where the joint has been pulled out again by (say) 80%, the old adhesive shall be wiped off and the bonding procedure repeated.

4.4.1.4 Curing

Heat assisted curing may be required for epoxy adhesive-bonded connections, for which purpose full wrap electric collars shall be used. Heating collars shall be provided or approved for use by the pipe Manufacturer. Heat assisted curing shall be performed immediately after bonding. The curing time and temperature depend on the type of adhesive used. For large assemblies and higher wall thickness pipe, the use of ovens, if available, is preferable to individual heating collars. Accurate temperature control and monitoring is essential.

Joints with elastomer sealing O-rings or lip-sealing rings are made up of a spigot end and a bell end. The bell may either be an integrated part of the pipe (single bell), or a separate item (double bell). A double bell is used for joining two pipes both with spigot ends. Joints with two or more O-rings may be used.

Two types of bell and spigot joints with elastomer seals and O-rings are acceptable:

- tensile resistant type, locked with a locking strip;
- non tensile resistant type, allowing greater axial movement.

The following shall be regarded as minimum requirements for installation:

- the bell and spigot shall both be inspected for damage prior to installation. Damaged parts shall be set aside for evaluation by responsible personnel;
- the surfaces to be connected, including the gasket grooves, shall be clean;
- the seal ring and groove shall be checked for the correct dimensions, in particular the ring cross-section and diameter;
- non-symmetric seals, like lip-seals, shall be checked for correct installation in the grooves;
- clean, non-contaminated lubricant shall be used on both seals and spigot end prior to insertion;
- correct tooling shall be used to enter the spigot into the bell to avoid jamming or damage to the seals. This is particularly important for larger dimensions;
- entry location marks on the spigot (if applicable) shall be checked to ensure correct entry distance;
- pipe sections to be aligned as straight as possible in order to retain the O-rings in their grooves.
- a feeler gauge shall be used to establish good seating of the seals;
- for key lock tensile-resistant joints, a clean and lubricated locking strip (if applicable) shall be inserted in the complete circumference of the locking strip groove, and the locking strip shall have the correct cross-section and length;

4.4.4 Flanged Joints

Two types of flanges are commonly used:

- fixed type flanges, adhesively bonded or laminated to the pipe ends;
- loose ring-type flanges, with GRP collars adhesive-bonded or laminated to the pipe ends with loose backing flanges in GRP or steel.

The Manufacturer's installation instructions regarding flanges shall be followed to ensure good quality joints. The following shall be regarded as minimum requirements:

- bolt thread lubrication shall be according to the Manufacturer's recommendations;
- correct torquing shall be strictly performed using a torque wrench. Over-torquing to compensate for poor alignment of flanges or other discrepancies is not acceptable;
- tightening sequence, torque increments, and maximum torque shall be in accordance with the Manufacturer's recommendations;

The curing agent or hardener shall be mixed with resin, strictly following the recommendation of the Manufacturer regarding weighing, metering, mixing, and temperature. No more resin shall be prepared than can be applied within the pot life of the mixture. Mixing shall continue until the resin mixture has a uniform colour and consistency.

The working life (pot life) will depend on the type of resin and hardener used and mixing temperature. If the resin starts to heat up in the mixing can, it has started to cure and must be discarded. If lumps or gels are apparent in the can, the resin must be discarded.

4.4.2.3 Assembly

The pipe ends shall be positioned together and fixed in the correct position. Bonding surfaces must have a temperature of at least 20°C and less than 40°C prior to application of resin. An electric heating blanket may be used to heat the pipe ends. The chamfered, abraded and cut surfaces shall be covered with a uniform resin or adhesive layer.

Layers of chopped strand mat and/or woven rovings impregnated by resin/hardener mix shall be applied as recommended by the Manufacturer. The Manufacturer's recommendations regarding reinforcing layer wrapping tension shall be followed in order to force out air inclusions, optimise resin impregnation, and ensure correct glass/resin ratio. Wrapping shall proceed, each layer impregnated with resin until the required thickness is obtained. An outer resin-rich layer should be applied.

4.4.2.4 Curing

Heat assisted curing is recommended for all laminated epoxy joints; for which purpose full wrap insulated electric collars shall be used. Heating collars shall be provided or approved for use by the pipe Manufacturer. Heat assisted curing shall be performed immediately after bonding. The curing time and temperature depend on the type of resin used.

Heating collars shall be long enough to completely encircle the joint or fitting area to be cured, plus a minimum 50mm overlap.

The heating collar shall be wrapped around the joint to be cured in such a way that the collar thermostat does not rest against the pipe wall. A protective film (plastic, metal) between the collar and uncured laminate shall be used to prevent the collar from being bonded to the laminate.

If ambient temperatures are below 5°C, the heating collars should be insulated. Foil backed fibreglass insulation is typically used. Insulation should overlap the collar by at least 100mm on either side and be tied down onto the pipe at the edges. Pipe ends should be loosely closed with non-sealing devices (typically, Styrofoam plugs are used) to prevent interior cooling in windy conditions.

Laminated joints must not be moved or otherwise disturbed until fully cured.

4.4.3 Elastomer Sealed Joints

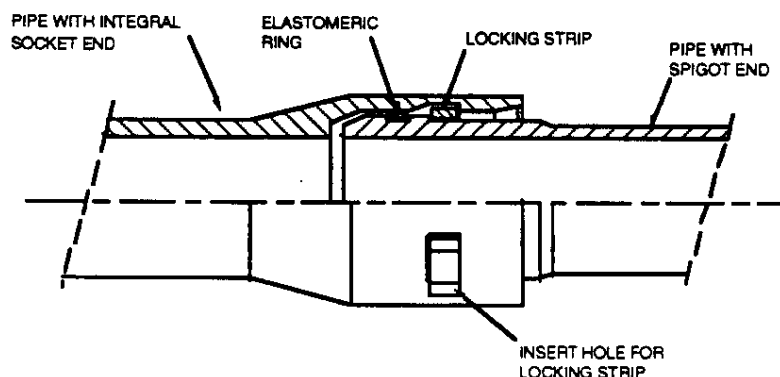


Figure 4.4.3 Elastomer Sealed Joint (Locking Type).

- both the finish and the appearance of the fire protection shall be of the same quality as the sample submitted for approval by the fire insulation Manufacturer and the Principal;
- if the fire protection thickness, appearance, or finish are of inadequate quality, the Principal can require the section to be repaired or replaced.

In fire protection applications where the protection is to be removable for inspection purposes e.g. valves and flanges, the following stipulation applies:

- the fire protection shall be inside or outside a box or other container so as to provide structural integrity, or;
- a complete structural reinforcing mesh integrated in the fire protection material shall be used.

4.6 QUALITY PROGRAMME FOR INSTALLATION

The Contractor shall maintain a high level of inspection to ensure compliance with all requirements of this Specification and shall have a quality management system in accordance with ISO 9000.

The Contractor shall designate one individual, experienced in all aspects of GRP piping field fabrication, to be responsible for quality control throughout the installation of the GRP piping system. This individual shall be certified as an installation leader, and be responsible for maintaining records of all bonds, joint inspections and hydrotests.

Quality control shall be based on the implementation of:

- bonding procedure qualification records;
- requirements by the Principal for inspection of adhesive-bonded joints;
- inspection register for GRP piping joints;
- inspection of finished fabricated pipework for compliance with design drawings to within tolerances as detailed in section 4.3.

For quality assurance and quality control during the installation phase, the Principal shall have the right to inspect the on-going work as well as inspect the Contractor's quality control routines.

Each adhesive-bonded connection shall be permanently marked for identification purposes. A log book containing key values relevant for the bonding process shall be maintained. The key values are:

- date;
- temperature and relative humidity;
- connection identification number;
- curing temperature and time;
- signature of pipe fitter and inspector.

Each field bond between pipes, fittings, or flanges, shall be inspected by an approved Inspector as defined in section 5.2. A log book sheet shall be filled in for each bond. Inspection sheets shall be retained as long as the piping is in service.

- connecting bolts shall be inserted with washers on both sides. Flange faces must be intact, clean and plane;
- correct gaskets for the required service shall be used;
- flanges to be adhesive-bonded square to the axis of the pipe, to within the tolerance as detailed in section 4.3.2 above;
- pipework is not pulled to align mating flanges.

4.4.5 Other Mechanical Joints

Other proprietary mechanical joints may be used on GRP pipes, either for permanent or temporary repair.

Manufacturers' installation instructions for mechanical couplings shall be followed. The main point to be observed is the use of the correct torque applicable to composite pipes when tightening the coupling bolts. Over-torquing of the bolts may result in damage to the GRP piping.

4.4.6 Metallic/GRP Interfaces

Interfaces with metallic systems (tanks, vessels, equipment or piping) shall be by flanged (i.e. mechanical) connection. No alternative methods are permitted unless qualified to procedures given in Part 2: "Components and Manufacturer". Installation of flanges shall be as described in section 4.4.4.

4.5 APPLICATION OF FIRE PROTECTION

All fire protection applied to piping components, whether the work is performed at a location offshore or in a prefabrication shop onshore, shall be subjected to the following requirements.

The fire protection application contractor, if used, shall have a quality management system in accordance with ISO 9000 and shall in addition have written application procedures covering environmental control, application, and inspection aspects, and which are approved by the Principal.

Acceptable methods for applying or covering piping components with fire protection are:

- by conventional hand application;
- by an automated process;
- use of moulded half shells or sections of different shapes and lengths.

Before initiating fire protection work on piping components, the Contractor's personnel intending to apply the fire insulation material shall:

- have received training both in the application method and actual application of the fire protection materials under the instruction of the fire protection Manufacturer, and;
- shall have applied fire protection to a sample pipe and fitting that is approved by the fire insulation Manufacturer and by the Principal.

The Contractor shall use application equipment recommended by the fire protection Manufacturer.

Before fire protection material is applied to any piping components, the surfaces shall be free from moisture, grease or any other contaminants.

After the fire protection material is applied to piping components, the Principal shall inspect the fire protection in order to approve or reject the work. Inspection shall include the following aspects:

- the fire protection thickness shall be randomly measured in a wet or cured state; the thickness shall not be less than the minimum required thickness;

If more than one type of connection, i.e. straight spigot and tapered spigot, are used on the same construction project, the crew must individually qualify on each type of joint. In addition, if the job requires the use of both small diameter pipe, (i.e. less than 200mm) and larger diameter pipe (i.e. greater than 200mm) test connections shall be made from both diameter ranges. Bonding of piping with diameters of 50mm to 150mm shall be qualified using the largest pipe diameter to be installed. Likewise, for piping of 200mm diameter and above, the test connection shall be equal to the largest size to be installed.

The pipe Manufacturer's representative shall grade the bonding personnel on their knowledge and application of the bonding procedure during assembly. When a joint is deemed to have been satisfactorily assembled, it is pressure tested to check the integrity of the joint.

Each test assembly which passes the bonding procedure above shall be subjected to a short-term hydraulic failure pressure test. The STHP of the test component shall be determined by testing at standard laboratory temperature ($23 \pm 2^{\circ}\text{C}$) in accordance with ASTM D1599. The test shall be conducted with freely supported ends such that the full pressure-induced axial load is supported by the test component. The STHP of the test component shall not be less than production control STHP.

The test may be conducted at the job site if equipment is available to conduct the test in accordance with the specification. In particular, the time to failure must be strictly observed, in order to generate reproducible and meaningful results. On-site tests shall be witnessed by the Principal and the Manufacturer's representative. Alternatively, the test assemblies may be shipped to the Manufacturer's laboratory and tested. Testing must be witnessed by the Principal.

5.1.2 Certification

Pipe fitters may be qualified exclusively for the joint type or types covered in the training and examination programme.

Pipe fitters having successfully passed the approved qualification procedure shall be assigned an individual "Bonding Qualification Certificate" provided by the GRP pipe and fittings Manufacturer or accredited organisation recognised by the Manufacturer and the Principal.

To avoid duplication of effort, the Principal may accept a pipe fitter qualification from a previous project, provided the qualification covers bonding of the same range of nominal pipe size, materials and GRP Manufacturer. The Principal shall be provided with, or obtain a copy, of the fitter's qualification test record, showing the name of the previous Principal, name of the fitter, procedure identification, date of successful qualification, and the date that the fitter last used the Manufacturer's procedure on pressure piping.

The Principal reserves the right to require an individual to re-qualify for the bonding procedure at any time and to revoke a GRP pipe fitter's qualification.

5.2 INSPECTOR

5.2.1 Qualifications

GRP piping inspectors shall be experienced in the handling and jointing of GRP piping components, and have received training and passed the relevant pipe fitter tests as described in section 5.1.1. Additionally they will have training and certification relevant to inspection methods and techniques applicable to GRP piping.

5 INSTALLER CERTIFICATION

All pipe, fittings, and related items shall be installed by qualified GRP pipe fitters and thereafter approved by a qualified GRP piping inspector.

5.1 PIPE FITTER

5.1.1 Qualifications

Pipe fitters shall be trained, certified and qualified in the handling and jointing (both mechanical and bonded) of GRP piping components.

5.1.1.1 Handling

All fitters shall have formal training in the handling of GRP piping components. This shall include an understanding of the special considerations relevant to GRP.

5.1.1.2 Jointing

Fitters shall have formal training in both the mechanical and bonded jointing of GRP piping.

With respect to bonded (adhesive and laminated) joints, all personnel shall be given theoretical and practical training followed by a written examination and a practical test. The pipe Manufacturer's recommendation regarding bonding shall be considered during the theoretical and practical training.

For **adhesive-bonded and laminated joints** the theoretical training, practical training, written examination, and practical test should cover the following items as a minimum:

- handling of pipes, fittings, and pipe spools (especially large diameters if applicable);
- inspection of pipes, fittings and pipe spools prior to assembly;
- cutting of pipes;
- establish acceptable environmental conditions (humidity, temperature);
- shaving of pipe ends;
- surface treatment prior to application of adhesive;
- adhesive mixing;
- application and control of amount of adhesive and assembly of the joint, for adhesive-bonded joints;
- application of resin and reinforcing fibre matting for laminated joints;
- localisation of curing/heating device and control of degree of curing;
- quality control procedures;
- health and safety aspects.

For both types of bonded joints, a test assembly shall be fabricated by each of the persons to be qualified as bonders in accordance with the Manufacturer's bonding procedures.

Each test assembly will consist of one GRP pipe to GRP pipe connection. The length of pipe on each side of the connection shall be equal to at least 5 pipe diameters. The ends shall be closed and the assembly shall have a connection for pressure testing purposes.

6 REPAIRS

6.1 DEFECT TYPES

Defect types and corrective action are given in Table 6.1. Details of repair methods for use during the fabrication and installation phase are described in section 6.2.

Table 6.1 – Visual Defects

Defect Type	Description	Fabrication / Installation acceptance criteria	Corrective action
Burn	Thermal decomposition evidenced by distortion or discolouration of the laminate surface.	Distortion and/or extensive discolouration	Replace
		Minor discolouration	Use as is
Chip	Small piece broken from edge or surface. If reinforcement fibres are broken, the damage is considered to be a crack.	If there are undamaged fibres exposed over any area; or no fibres are exposed but an area greater than 10mmx10mm lacks resin.	Minor repair
		If there are no fibres exposed, and the area lacking resin is less than 10mmx10mm	Use as is
Crack	Actual separation of the laminate, visible on opposite surfaces, and often extending through the wall. A continuous crack will be evident by a white area.	None permitted	Replace
Crazing	Fine hairline cracks at or under the surface of the laminate. White areas are not visible as for cracks.	Crack lengths greater than 25.0mm	Minor repair
		Crack lengths less than 25.0mm.	Use as is
Fracture	Rupture of the laminate with complete penetration. Majority of fibres broken. Visible as lighter coloured area of interlaminar separation.	None permitted	Replace
Pit (pinhole)	Small crater in the surface of the laminate, with its width approximately of the same order of magnitude as its depth.	Diameter greater than 0.8mm, and/or depth greater than 10% of wall thickness	Minor repair
		Diameter less than 0.8mm, and depth less than 10% of wall thickness	Use as is
Wear scratch	Shallow mark caused by improper handling, storage and/or transportation. If reinforcement fibres are broken, the damage is considered to be a crack.	If there are undamaged fibres exposed over any area; or no fibres are exposed but an area greater than 10mmx10mm lacks resin.	Minor repair
		If there are no fibres exposed, and the area lacking resin is less than 10mmx10mm	Use as is

5.2.2 Certification

Inspectors may be qualified exclusively for the joint type or types covered in the training and examination programme.

Inspectors having successfully passed the training and examination programme shall be assigned an individual "Inspection Certificate" provided by the GRP pipe and fittings Manufacturer.

The Principal reserves the right to require an individual to re-qualify for the inspection procedure at any time, and to revoke a GRP inspector's qualification.

7 SYSTEM TESTING AND CERTIFICATION

7.1 TESTING REQUIREMENTS

7.1.1 Flushing

On completion of installation, GRP piping systems shall be flushed. The medium used for flushing shall be seawater or freshwater. All lines requiring a pressure test shall be flushed prior to testing. Systems which are open to atmosphere and do not require pressure testing shall be flushed to ensure that the lines are not restricted.

All valves that are not required to be removed for flushing purposes shall be set to the fully open position.

Flushing is most effective when carried out initially from the highest entry point in the new pipework. Flushing water should be admitted into entry points at progressively lower elevations until effluent from the low point drains runs clear. Flushing of pipe systems into tanks and/or vessels is not permitted, unless approved by the Principal.

The main headers, in general, shall be flushed out first and then all branches which connect to any equipment. All necessary precautions shall be taken to ensure that debris is not flushed into associated equipment or dead ends.

All instrument, vent and drain connections shall also be inspected for debris. The flushing and debris checking shall continue until all debris has been removed.

The main headers shall be flushed for 30 minutes and branches for 15 minutes or until clear water is seen, whichever is the longer. Alternatively, temporary strainers can be installed on discharge outlets in order to ascertain when the debris has been removed. When there is no further build-up evident on the strainer mesh, flushing can cease.

On completion of flushing and debris checking, all broken connections shall be made up, with new gaskets to suit the relevant line specifications.

When flushing with fresh water in sub-zero temperatures, precautions shall be taken to avoid freezing of the water in the piping system, i.e. the water must be continually circulating, or glycol antifreeze added, or the system must be drained for the duration of sub-zero temperatures.

7.1.2 Pressure Testing

All closed GRP piping systems, shall be hydrostatically pressure tested after installation.

Systems which are open to atmosphere (e.g. drains) shall as a minimum be subjected to a hydrostatic leak test, and may require full hydrostatic pressure test if they could be subject to system pressure.

7.1.2.1 Preparation

All supports, guides and anchors must be in place prior to pressure testing.

All pipe sections shall be adequately supported and restrained before the start of hydrotesting. Temporary supports shall be added if required.

All joints shall be properly cured in accordance with Manufacturers specifications before pressure testing.

Unless noted otherwise, all valves are to be through-body tested. Piping containing check valves shall have the source of test pressure located on the downstream side. If this is not possible the check valve disc shall be removed or jacked open. Ball gate, plug, and globe valves shall be set in the half-open position before pressure testing commences.

6.2 REPAIR METHODS

6.2.1 Replacement

Pipe sections with major damage should be replaced. All replacement work shall be performed according to the methods and requirements covered in section 4. Pipe fitter qualification requirements for the replacement of piping shall be identical to those for the installation of the original pipework.

The Principal may accept the use of a bonded saddle repair as an option to pipe replacement.

6.2.2 Minor Repairs

Minor repairs to pipe and fittings may be repaired on-site. The damaged outer layer shall be ground, cleaned and resin/hardener mix applied as recommended by the Manufacturer.

8 HEALTH AND SAFETY

In general, all safety precautions set forth by the Manufacturer of pipes and fittings, chemicals etc., shall be adopted. Materials Safety Data Sheets (MSDS) should always be read in advance of commencing work.

8.1 CHEMICAL HAZARDS

Smoking, eating and drinking are prohibited during handling and storage of resin, paste, adhesives or other chemicals.

Special precautions should be taken when working in contact with resins, curing agents, catalysts etc. which may produce irritation if allowed to come into contact with human tissue and may sometimes produce dark spots on clothing. Operators should therefore observe strict personal hygiene at all times with respect to the handling of these products when in the uncured liquid state.

Peroxide curing agents used in the bonding of vinylester and polyester pipework are especially harmful to eyes, even small quantities can cause permanent damage. Eye protection must be worn when handling peroxides. Eye protection when handling other curing agents is recommended.

Skin contact shall be prevented by the use of rubber gloves and barrier creams. Any accidentally contaminated skin areas should be thoroughly washed with soap and water.

In confined spaces, where natural ventilation is poor, the use of oxygen or fresh-air masks is recommended if operators are exposed to noxious gases.

8.2 DUST HAZARDS

During machining of GRP the use of a dust mask and protective clothing is recommended, in order to prevent inhalation of the glass-fibre dust produced and prevent skin irritation. Machining in a well ventilated room or in the open air is advised in order to minimise contact with dust. In the workshop a portable dust extraction unit should be used with the point of extraction as close as possible to the work.

Before carrying out any pressure test, the area of the test shall be roped off and warning signs erected at all adjacent access points. The safety officer shall be informed of the intended test in sufficient time to perform his own inspection if required.

7.1.2.2 Testing

Water shall be admitted at a low point in the system and provision shall be made for bleeding the air at high points (e.g. by loosening of flange connections). Any compressed air in the system may give erroneous results. Removal of air pockets will prevent damage to piping and personnel in the event of an unexpected failure during the pressure test.

The test pressure shall be raised over a period of 30 minutes to 1.5 times the design pressure for the system. Any sudden increase in pressure is to be avoided for GRP pipework.

The pressure decay test shall be conducted for a minimum of one hour. Additional checks shall be carried out after this time has elapsed, by visual inspection of the complete piping system.

Any leaking or weeping shall constitute a defect and the test shall be terminated and a repair effected. The test procedure shall then be repeated.

Over-torquing of flanges to stop leaks is not permitted. Leaking flanges shall be remade with new gaskets and retested. If leakage still occurs, flanges must be replaced.

7.1.2.3 After Completion of Test

After controlled depressurisation, all remaining vent and low point drain valves shall be opened and the system thoroughly drained.

Temporary blinds and other equipment installed for testing shall be removed on completion of the test.

Test pressure gauges shall be removed and any temporary vent and drain facilities installed for testing are to be removed and the tie-in points plugged in accordance with pressure stipulations for that section of pipework.

Gaskets at flanged joints broken for testing shall be renewed.

Transit bars or gags installed shall be removed together with temporary supports, lashings, etc.

Where permanent or temporary strainers have remained in place for the hydrostatic pressure test, they shall be removed and the permanent strainers thoroughly cleaned before re-installing.

7.2 DOCUMENTATION

7.2.1 Flushing Certificate

Upon completion of flushing, a Flushing Certificate delineating the flushing boundary limits shall be endorsed by the Principal. As one flush may extend over more than one pressure or leak test, the flushes shall be numbered separately and cross referenced on applicable test isometric drawings. A copy of the completed Flushing Certificate shall be incorporated into the relevant test packs.

7.2.2 Pressure Test Certificate

Upon completion of successful testing, a Pressure Test Certificate showing the limits of the test shall be endorsed by the Principal and incorporated into the relevant test pack.

PART 5
OPERATION

1 SCOPE

This part of the Document Suite of Specifications and Recommended Practices for the use of GRP Piping Offshore gives recommendations for the operation of GRP piping systems.

Its objective is to ensure that GRP piping systems will continue to meet the specified performance requirements throughout their operational life. Main users of the document are envisaged to be the Principal, IRM (Inspection, Repair and Maintenance) Contractors, Certifying Authorities and Government Agencies. It should be read in conjunction with Part 1 : "Philosophy and Scope".

The recommendations apply to inspection, maintenance, repair and system pressure testing.

2 OPERATORS DOCUMENTATION

The Principal shall be responsible for compilation of design documents and Manufacturer's data for the use of operational personnel. The documentation shall include:

- special considerations for operating a GRP piping system;
- operating and design parameters;
- system drawings;
- approved inspection, repair and hydrotest procedures.

2.1 SPECIAL CONSIDERATIONS FOR GRP PIPING

Documentation shall state the special considerations for operating a GRP piping system highlighting the differences to a conventional metallic system. Such a document shall include a brief description of the following where appropriate:

- mechanical properties;
- chemical resistance limitations;
- temperature limitations;
- health and safety;
- impact damage;
- static electricity;
- erosion limits;
- cavitation effects;
- water-hammer effects;
- fire performance; (see note on p.3)
- repair methods and kits;

2.2 OPERATING AND DESIGN PARAMETERS

The Operator should be in receipt of a document that states the operating and design parameters for the piping system. Such a document should as a minimum include details of the following:

- operating pressure;
- operating temperature;
- operating flow velocity and particular contents;
- design maximum transient pressure;
- design maximum transient temperature;
- design maximum transient flow velocity;

-
- design pressure rating for components;
 - design temperature limits for components;
 - non-system loads.

2.3 SYSTEM DRAWINGS

All relevant as-built drawings shall be available. These shall show as a minimum details of the following:

- pipe nominal diameters;
- pipe wall thicknesses;
- key layout dimensions;
- location of supports/restraints.

Note: The ability of the GRP pipe to survive and continue to function in a fire is in part due to the presence of flowing water inside the pipe. The cooling effect will not be present where a pipe is empty and no longer in service. Such pipe may not meet the original design endurance requirements and could be cause for concern about spread of fire, smoke and toxicity where it penetrates a fire rated wall. In such situations the operator should take precautions to ensure the integrity of the fire rated penetration is maintained in the event of a fire, for example by the removal of the pipe or the addition of fire protection coating.

3.3 INSPECTION TECHNIQUES

Inspection techniques fall into two broad categories:

- visual
- instrumented

Visual inspection is the most effective method for inspecting the GRP piping and can be used to detect the following defects:

- surface scratches severe enough to expose or break the fibres;
- impact damage with associated internal delaminations;
- matrix cracking and damage to flange edges;
- damage due to mechanical or environmental overloading;
- environmental degradation due to exposure to the weather and salt water spray, etc;
- damage due to fire;
- loose or damaged electrical earthing wires.

However, instrumented inspection will be necessary to detect non-surface breaking flaws, such as:

- significant debonding and delamination;
- debonding and other damage in joints.

Several instrumented non-destructive techniques are available (listed below). All of these techniques require further development for use as on-site methods in the offshore industry. The most promising recent developments involve thermography, ultrasonics and acoustic emission.

- ultrasonics;
- acoustic emission;
- vibration monitoring;
- radiography;
- thermal imaging;
- optical techniques.

There are also a number of more specialist techniques that are either under development or are more suited to laboratory uses, which include;

- chemical spectroscopy;
- dye penetration techniques;
- stress coating.

4 REPAIR AND MAINTENANCE

4.1 MAINTENANCE

GRP pipes are generally maintenance free, but the following points should be given attention during inspection.

4.1.1 Scaling

GRP piping systems can suffer scale build-up. Where scaling is predicted to be a problem systems should be checked periodically using ultrasonic thickness measuring equipment or internal visual inspection. Care shall be taken in the use of conventional methods of scale removal (e.g. water-jetting, chemical) and the Manufacturer's recommendations should be followed in all cases.

4.1.2 Marine Growth

Saltwater systems are generally protected from marine growth build-up by electrolytic hypochlorination. The hypochlorite generator system should be periodically checked.

4.1.3 Conductivity

GRP earthed piping systems shall be periodically checked to ensure all earthing leads are functional and that the resistance to earth from any part of the system is not greater than 10^6 ohm.

4.2 DAMAGE/REPAIR EVALUATION

Defects and advised corrective action are given in Table 4.2. Both major and minor repair methods are described in section 4.3.

Table 4.2 - Visual Defects, Evaluation and Repair Methods

Defect Type	Description	Repair and Maintenance Acceptance Criteria	Corrective Action
Burn	Thermal decomposition evidenced by distortion or discolouration of the laminate surface.	Distortion and/or extensive discolouration	Major repair
		Minor discolouration	Use as is
Chalking	Minor breakdown of outer surface due to effects of UV radiation and/or acid rain.	If extensive	Clean, lightly grind, apply UV resistant paint.
Chemical Spill	Minor breakdown of outer surface due to effects of chemical spillage.	If occurring	Clean
Chip	Small piece broken from edge or surface. If reinforcement fibres are broken, the damage is considered to be a crack.	If there are undamaged fibres exposed over any area; or no fibres are exposed but an area greater than 10mmx10mm lacks resin.	Minor repair
		If there are no fibres exposed, and the area lacking resin is less than 10mmx10mm	Use as is
Crack	Actual separation of the laminate, visible on opposite surfaces, and often extending through the wall. A continuous crack will be evident by a white area.	None permitted	Major repair
Crazing	Fine hairline cracks at or under the surface of the laminate. White areas are not visible as for cracks.	Crack lengths greater than 25.0mm.	Minor repair
		Crack lengths less than 25.0mm.	Use as is
Fracture	Rupture of the laminate with complete penetration. Majority of fibres broken. Visible as lighter coloured area of interlaminar separation.	None permitted	Major repair
Pit (Pinhole)	Small crater in the surface of the laminate, with its width approximately of the same order of magnitude as its depth.	Diameter greater than 0.8mm, and/or depth greater than 10% of wall thickness	Minor repair
		Diameter less than 0.8mm, and depth less than 10% of wall thickness	Use as is
Wear Scratch	Shallow mark caused by improper handling, storage and/or transportation. If reinforcement fibres are broken, the damage is considered to be a crack.	If there are undamaged fibres exposed over any area; or no fibres are exposed but an area greater than 10mmx10mm lacks resin.	Minor repair
		If there are no fibres exposed, and the area lacking resin is less than 10mmx10mm.	Use as is
Weld Sparks	Minor breakdown of outer surface due to effects of close proximity welding.	If extensive	Minor repair

4.3 REPAIR METHODS

Repair methods described in this section are recommended practice and are not intended to replace manufacturers' recommendations. When damage occurs or is revealed during an inspection, the appropriate method of correction or repair shall be decided. The repair method will depend on the extent of the damage, the level of criticality of the piping system and the availability of spare parts and/or repair facilities.

Major repairs as described in Table 4.2 shall be repaired by one of the following methods:

- permanent replacement;
- temporary laminated joint prior to permanent replacement;
- temporary clamps or saddles prior to permanent replacement.

Minor repairs as described in Table 4.2 shall be permanently repaired on site.

In all cases where GRP piping systems are used on offshore installations an Emergency Offshore Repair Kit shall be available as described in section 4.3.5.

4.3.1 Permanent Replacement

It is recommended that damaged sections are replaced, if pipes and fittings are available. Replacement of damaged piping sections with new piping sections shall be considered as a new installation and be performed according to the methods and requirements covered in Part 4: "Fabrication and Installation". Requirements for pipe fitter and inspector qualifications for replacement of piping shall be identical to the requirements for installing original piping.

The Principal may accept the use of an adhesive - bonded saddle repair as an option to pipe replacement.

Pre-assemblies or prefabricated pipe spools are recommended for easier installation. Because of the material's low weight, pipe sections may be moved or lifted into place with relative ease.

4.3.2 Laminated Joints

Laminated joint repair techniques may be used as an emergency repair method if a pipe suffers major failure or leakage and no other replacement or repair techniques are available.

Laminated joint techniques may be used either to patch over a damaged area or to connect two pipes together after the damaged area has been removed and replaced with a new pipe section. Damaged areas up to a length equal to one diameter may be repaired according to this method.

Before this type of repair work starts, the pipe system must be empty and the pipe surface must be dry.

4.3.2.1 Environmental Controls

A laminated joint or laminated patch repair must be performed under environmentally controlled conditions. The specific requirements are:

- the surfaces to be bonded should be at temperatures between 20°C and 40°C;
- the relative air humidity at the bonding site should be 75% or less. (A working shelter may be necessary in order to obtain such an environment).

4.3.2.2 Preparations

Before work on a laminated joint is started, all necessary equipment for completing the procedure must be available.

A jig or other device should be used to ensure that the pipes are maintained with the joint faces held tightly together without offset. The restraints should be left in place until the joint has fully cured.

When connecting two pipes, the end of the pipes shall be chamfered back to a minimum taper of 1 in 6, as illustrated in Figure 4.3.1.

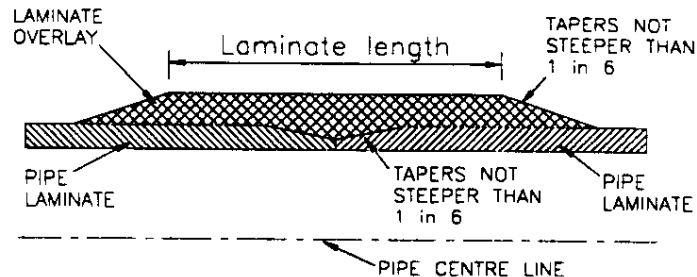


Figure 4.3.1 - Laminated Joint

The outer pipe surface shall be abraded to remove the outer resin-rich surface and expose the reinforcing fibres over an area equal to at least 50mm outside both ends of the laminate as defined in the Manufacturers technical specifications. The pipe ends should also be abraded.

Bonding surfaces shall be thoroughly cleaned as recommended by the Manufacturer. The cleaned surfaces should not be touched, or be contaminated by oil or moisture prior to bonding. If surfaces become wet or contaminated they must be cleaned, re-ground and made dust free.

4.3.2.3 Resin Mixing

The resin used shall be of the same type, or compatible with, the resin used in the manufacturing of the pipes.

Curing agent or hardener shall be mixed with resin, strictly following the recommendation of the Manufacturer regarding weighing, metering, mixing, and temperature. No more resin shall be prepared than can be used within the pot life of the mixture. Mixing shall take place until the resin mixture has a uniform colour and consistency.

The working life (pot life) will depend on the type of resin and hardener used and mixing temperature. If the resin starts to heat up in the mixing can, it has started to cure and must be discarded. If lumps or gels are apparent in the can, the resin must be discarded.

4.3.2.4 Assembly

The pipe ends shall be fixed together in the correct position. The temperature of the surfaces which shall be bonded to each other should be at least 20°C and less than 40°C prior to application of resin. An electric heating blanket may be used to heat the pipe ends. The chamfered, abraded and cut surfaces shall be covered with a uniform resin layer.

Layers of chopped strand mat and/or woven rovings impregnated by resin/hardener mix shall be applied as recommended by the Manufacturer. The Manufacturer's recommendations regarding reinforcing layer wrapping tension shall be followed in order to force out air inclusions, optimise resin impregnation and ensure correct glass/resin ratio. Wrapping shall proceed, each layer impregnated with resin until the required thickness is obtained. An outer resin-rich layer shall be applied.

4.3.2.5 Curing

Heat assisted curing is recommended for all laminated epoxy joints; for which purpose full wrap electric collars may be used. Heating collars should be provided or approved for use by the pipe Manufacturer.

Heat assisted curing shall be performed immediately after bonding. The curing time and temperature depends on the type of resin used.

Heating collars shall be long enough to completely encircle the joint or fitting area to be cured, plus a minimum 50mm overlap.

The heating collar shall be wrapped around the joint to be cured in such a way that the collar thermostat does not rest against the pipe wall. A thin protective film (plastic, metal) shall be used between the collar and uncured laminate to prevent the collars from being bonded to the laminate.

Laminated joints must not be moved or otherwise disturbed until fully cured.

4.3.3 Clamps and Saddles

As a general rule, mechanical clamps or saddles shall only be used if the pipe suffers minor leakages or weepings. However, depending on service criticality and safety aspects, mechanical clamps may be used for major damage. The clamps or saddles shall cover the entire damaged area.

A mechanical clamp with rubber sealing may be used on a wet pipe and without de-pressurising the system. Before a mechanical clamp is used, the pipe and clamp diameter shall be checked to verify the clamp usage. The outer diameters of GRP pipes might vary from one Manufacturer to another. Due to the flexibility of the GRP pipe, care must be exercised when tightening a mechanical clamp; over-torquing may cause crushing damage to the pipe wall.

For an adhesive-bonded GRP saddle, the damaged area shall be abraded, cleaned, and dried to ensure good bonding. The method of bonding saddles is similar to the method used for adhesive-bonded joints and shall be performed according to the recommendations contained in Part 4: "Fabrication and Installation".

4.3.4 Minor Repairs

Minor repairs to pipe and fittings may be repaired on site. The damaged outer layer shall be ground, cleaned and resin/hardener mix applied as recommended by the Manufacturer.

4.3.5 Emergency Offshore Repair Kit

In addition to a practical assortment of spare pipes and fittings, a kit containing necessary equipment to perform repair of GRP pipes is recommended to be stored on the offshore installation. Suitable repair kits may be available from the Manufacturer. Recommended kit contents are:

4.3.5.1 Adhesive-bonded Joints

- instructions;
- measuring tape, sliding gauge, pipe marker;
- temperature and relative humidity measurement instruments;
- light strap winch and pipe clamps;
- right-angled grinding tool with cutting and coarse-grinding discs;
- pipe shaver;
- adhesive kits;
- heating collar;

-
- solvent cleaner, cleaning rags;
 - gloves, eye protection and dust mask.

4.3.5.2 Laminated Joints

- instructions for butt and strap method;
- measuring tape, sliding gauge, pipe marker;
- temperature and relative humidity instruments;
- right-angled grinding tool with cutting and coarse-grinding discs;
- flexible support disc and grinding disc;
- resin, hardener, glass reinforcement, mat and woven roving;
- heating collar;
- solvent cleaner, cleaning rags;
- gloves, eye protection and dust mask.

4.4 QUALITY PROGRAMME FOR REPAIR AND MAINTENANCE

The Contractor shall have a quality management system according to ISO 9000 and shall maintain a high level of inspection for all repair and maintenance work to ensure compliance with all requirements of this specification.

For quality assurance and quality control during the operating phase the Principal shall have the right to inspect the on-going work as well as inspect the contractor's quality control routines.

4.4.1 Repair

The Contractor shall designate one individual, experienced in all aspects of GRP piping field fabrication, to be responsible for quality control throughout the repair of the GRP piping system. This individual shall be certified as an installation leader and be responsible for maintaining records for all repairs, inspections and hydrotests.

Each repair shall be permanently marked for identification purposes. A log book containing key values relevant for the repair process shall be maintained. The key values are:

- date;
- temperature and relative humidity;
- connection or repair identification number;
- curing temperature and time;
- signature of pipe fitter and inspector.

Each field bond between pipes, fittings, or flanges, shall be inspected by an approved inspector as defined in section 6.2. A log book sheet shall be filled in for each bond. Inspection sheets shall be retained as long as the piping is in service.

4.4.2 Maintenance

The Contractor shall maintain records of all maintenance work. These records should incorporate:

- date;
- temperature and relative humidity;
- location;
- details of maintenance work;
- signature of pipe fitter.

5 MODIFICATIONS AND TIE-INS

Modifications and tie-ins shall be considered as a new installation and be performed according to recommendations contained in Part 4: "Fabrication and Installation".

6 FITTER AND INSPECTOR CERTIFICATION

All repairs shall be carried out by qualified GRP pipe fitters and thereafter approved by a qualified GRP pipe inspector.

6.1 PIPE FITTER

6.1.1 Qualifications

All personnel involved with adhesive-bonding or laminated jointing of pipes shall be given theoretical and practical training, followed by a written examination and a practical test.

The Manufacturer's recommendations regarding laminated joining practice shall be acknowledged during the theoretical and practical training.

For laminated joints the theoretical training, practical training, written examination, and practical test should cover the following items as a minimum:

- handling of pipes, fittings, and pipe spools;
- inspection of pipes, fittings, and pipe spools prior to assembly;
- cutting of pipes;
- establishing acceptable environmental conditions (humidity, temperature);
- bevelling of pipe ends;
- surface treatment prior to application of resin;
- resin mixing;
- application of resin and reinforcing fibre mats;
- localisation of curing/heating device and control of degree of curing;
- quality control procedures;
- health and safety aspects.

A test assembly shall be fabricated by each of the persons to be qualified as bonders in accordance with the Manufacturers bonding procedures.

Each test assembly will consist of one GRP pipe to GRP pipe connection. The length of pipe on each side of the connection shall be equal to at least five pipe diameters. The ends shall be closed and the assembly shall have a connection for pressure testing purposes.

If more than one type of connection, i.e. straight spigot and tapered spigot, are used on the same construction project, the crew must individually qualify on each type of joint. In addition, if the job requires the use of both small diameter pipe (<200mm) and larger diameter pipe (>200mm) test connections shall be made from both diameter ranges. Bonding of piping with diameters of 50mm to 150mm diameter shall be qualified using the largest pipe diameter to be installed. Likewise, for piping 200mm in diameter and above, the test connection shall be equal to the largest size to be installed.

The pipe Manufacturer's representative will grade the bonding personnel on their knowledge and application of the bonding procedure as the candidates fabricate each test assembly.

Each test assembly which passes the bonding procedure above will be subjected to a short-term hydraulic failure pressure test. Pipe ends shall be closed and have connection for pressure testing. The STHP of the test component shall be determined by testing at Standard Laboratory Temperature ($23 \pm 2^{\circ}\text{C}$) in

accordance with ASTM D1599. The test shall be conducted with freely supported ends such that full pressure induced axial load is supported by the test component. The STHP of the test component shall not be less than the production quality control.

The test can be conducted at the job site if equipment is available to conduct the test in accordance with the specification. In particular, the time to failure must be strictly adhered to in order to generate reproducible and meaningful results. On-site tests shall be witnessed by the Principal and Manufacturer representatives. Alternatively, the test samples can be shipped to the Manufacturer's laboratory and tested. Testing must be witnessed by the Principal.

6.1.2 Certification

Pipe fitters may be qualified exclusively for the joint type or types covered in the training and examination programme.

Pipe fitters having successfully passed the Principal approved qualification procedure shall be assigned an individual Bonding Qualification Certificate provided by the GRP pipe and fittings Manufacturer.

The Principal reserves the right to require an individual to re-qualify for the bonding procedure at any time and to revoke a GRP pipe fitter's qualification.

6.2 INSPECTOR

6.2.1 Qualifications

Inspectors of operational GRP piping repairs shall have experience with GRP bonding practices, and have previously received training and passed the relevant pipefitter tests as described in section 6.1.1. Additionally, they will have received training and examination relevant to inspection methods and techniques applicable to GRP piping.

6.2.2 Certification

Inspectors may be qualified exclusively for the joint type or types covered in the training and examination programme.

Inspectors having successfully passed the training and examination programme shall be assigned an individual Inspection Certificate provided by the Manufacturer.

The Principal reserves the right to require an individual to re-qualify for the inspection procedure at any time, and to revoke a GRP inspector's qualification.

7 TESTING AND RE-CERTIFICATION

7.1 TESTING REQUIREMENTS

If repair, replacements or modification of the piping in the piping system have been made, the section containing the repaired or replaced piping shall be re-certified by performing a pressure test.

For practical reasons, the repaired section should be isolated by closing the nearest valves both upstream and downstream from the repair site.

7.1.1 Preparation

All supports, guides, and anchors must be in place prior to pressure testing. All adhesive-bonded joints and all laminated joints must be fully cured prior to pressure testing.

Before carrying out any pressure test, the area of the test shall be roped off and warning signs erected at all access points. The safety officer shall be informed of the intended test in sufficient time to perform his own inspection if required.

7.1.2 Testing

Water shall be admitted at a low point in the system and provision shall be made for bleeding the air at high points (eg by loosening of flange connections). Any compressed air in the system may give erroneous results. Removal of air pockets will prevent damage to piping and personnel in the event of an unexpected failure during the pressure test.

The test pressure shall be raised over a period of 30 minutes to 1.5 times the design pressure for the system. Any sudden increase in pressure is to be avoided for GRP pipework.

The pressure decay test shall be conducted for a minimum of one hour. Additional checks shall be carried out after this time period has elapsed, by visual inspection of the repaired pipework.

Any leaking or weeping shall constitute a defect and the test shall be terminated and a repair effected. The test procedure shall then be repeated.

Over-torquing of flanges to stop leaks is not permitted. Flanges shall be remade with new gaskets and retested. If leakage still occurs, flanges must be replaced.

7.1.3 After Completion of Test

After depressurisation, all vents and low point drain valves shall be opened and the system thoroughly drained.

Temporary blinds and other equipment installed for testing shall be removed on completion of the test.

Test pressure gauges shall be removed and any temporary vents and drains installed for testing are to be plugged.

Gaskets at flanged joints broken for testing shall be renewed.

Transit bars or gags installed shall be removed together with temporary supports, lashings, etc.

7.2 DOCUMENTATION

Upon completion of successful testing a Pressure Test Certificate showing limits of the test shall be endorsed by the Principal or his representative and incorporated into a test pack.

8 DECOMMISSIONING

8.1 DISMANTLING

Contractors should be aware of all relevant health and safety requirements prior to the start of dismantling. All piping systems should be de-pressurised and drained .

Dismantling should generally be the reverse of installation with piping systems being disconnected at joints. At non-mechanical joints dismantling should be performed by cutting. In no circumstances should burning equipment be used.

Attention should also be paid to avoiding damage to adjacent GRP piping which is to remain in service, and should be protected if necessary.

8.2 DISPOSAL

All redundant components should be packaged and transported to shore for disposal.

Components should be disposed of in a responsible environmentally friendly manner. Components should not be incinerated in the open atmosphere.

9 HEALTH AND SAFETY

In general, all safety precautions set forth by the Manufacturer of pipes and fittings, chemicals, etc, shall be adopted. Manufacturer's Materials Safety Data Sheets (MSDS) should always be read in advance of commencing work.

9.1 CHEMICAL HAZARDS

Smoking, eating and drinking is prohibited during handling and storage of resin, paste, adhesives or other chemicals.

Special precautions should be taken when working in contact with resins, curing agents, catalysts, etc, which may produce irritation if allowed to come into contact with human tissue and may sometimes produce dark spots on clothing. Operators should therefore observe strict personal hygiene at all times with respect to the handling of these products when in the uncured liquid state.

Skin contact shall be prevented by the use of rubber gloves and barrier creams. Any accidentally contaminated skin areas should be thoroughly washed with soap and water.

In confined spaces, where natural ventilation is poor, the use of oxygen or fresh air masks is recommended if operators are exposed to noxious gases.

9.2 DUST HAZARDS

During machining of GRP the use of a dust mask and protective clothing is recommended, in order to prevent inhalation of the glass-fibre dust produced and prevent skin irritation. Machining, grinding or sawing in a well ventilated room or in the open air is advised in order to minimise contact with dust. In the workshop a portable dust extraction unit should be used with the point of extraction as close as possible to the work.