MANUAL

GRP PIPELINES AND PIPING SYSTEMS (AMENDMENTS/SUPPLEMENTS TO UKOOA DOCUMENTS)

DEP 31.40.10.19-Gen.

December 1998
(DEP Circular 60/99 has been incorporated)

DESIGN AND ENGINEERING PRACTICE

PREFACE

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Shell International Oil Products B.V. (SIOP)
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Shell International Exploration and Production B.V. (SIEP)
and
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The Hague, The Netherlands,

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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PART A INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the use of GRP for pipeline and piping systems both onshore and offshore.

This DEP is based on the "Guidelines for Fibre Reinforced Plastics Use Offshore" dated April 1994 and "Specification and Recommended Practice for the Use of GRP Piping Offshore" dated March 1994, both published by UKOOA.

Part B of this DEP amends, supplements or replaces various sections of the "UKOOA Guidelines".

Parts C, D, E, F and G of this DEP amend, supplement or replace various sections of Parts 1 to 5 respectively of the "UKOOA Specification and Recommended Practice".

This DEP incorporates the applicable contents of the following DEPs, which are herewith withdrawn:

- DEP 31.40.10.31-Gen. "Glass fibre reinforced plastic pipes and fittings".
- DEP 31.38.70.24-Gen. "Design and installation of glass fibre reinforced epoxy and polyester piping".
- DEP 31.38.70.37-Gen. "Requirements for glass fibre reinforced epoxy and polyester pipes and fittings".

GRP vessels and tanks are excluded from the scope of this DEP.

NOTE: This DEP has been developed with the participation of several major GRP piping manufacturers, all of whom have confirmed their ability to comply with the requirements.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers nominated by them (i.e. the distribution code is "F", as described in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Principal and/or the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

General and Technical Definitions are provided in the "Specification and Recommended Practices for the Use of GRP Piping Offshore: Part 1 - Philosophy and Scope" Section 4 as amended/supplemented by Part C of this DEP.

Throughout the UKOOA documents whenever the term **piping** is used it shall be replaced by **pipelines and piping** unless otherwise indicated.

Throughout the UKOOA documents whenever the term **offshore** is used it shall be replaced by **onshore and offshore** unless otherwise indicated.

1.4 CROSS-REFERENCES

The section numbering used in Part B of this DEP corresponds with that used in the

UKOOA "Guidelines". The section numbering in Parts C to G corresponds with that used in Parts 1 to 5 respectively of the UKOOA "Specification and Recommended Practice". Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced in this DEP are listed in (Part H).

PART B AMENDMENTS/SUPPLEMENTS TO THE UKOOA "GUIDELINES FOR FIBRE REINFORCED PLASTICS USE OFFSHORE"

1. SCOPE

1.1 *Replace this section with:*

This document identifies as a minimum the factors that have to be addressed when engineering Fibre Reinforced Plastic (FRP) materials for onshore pipelines and piping systems in oil and gas production, in petrochemical plants and for use on fixed floating, mobile and subsea offshore oil and gas installations.

2. PURPOSE

2.2 *Replace this section with:*

It is intended that the Guidance be applicable to all uses of GRP materials on all onshore and offshore installations, for example pipelines and piping systems.

3. PHILOSOPHY

3.3 *Replace the last sentence with:*

Where current legislation limits the use of GRP components and systems, the use of this code affords a means by which the use of these materials can be accepted.

4. COMPONENT/SYSTEM PERFORMANCE FACTORS

4.1 MECHANICAL LOADS

Add to the list of loads to be considered (2nd sentence):

Surge.

Add new paragraph:

Consideration shall also be given to loads arising during installation and construction.

4.1.1 Pressure, internal

Replace the first part of the second sentence with the following:

Transient pressures (for example surge pressures, water hammer etc.)

4.1.2 Pressure, external

Replace the last part of the sentence with the following:

vacuum conditions, forces from hydrostatic head of liquids or soil loads.

Add the following new sections:

4.1.7 Soil loads and soil settlement

For buried systems account shall be taken of potential loads caused by soil loads and settlement.

4.1.8 Connection to metallic systems

Loads on the GRP system caused by the metallic system shall be taken into account.

4.2 DEGRADATION FACTORS

4.2.1 Creep

In this section heading and text, replace the word "creep" *by* "ageing".

4.2.6 Chemical resistance

Replace the first part of the first sentence with the following:

The material shall be compatible, over the full design temperature range, with the fluid being carried ....

Add the following new paragraph:

The maximum allowable operating temperatures for different fluids/chemicals are given in (Appendix V).

The Manufacturer shall supply a chemical resistance list for the specific material (resin and curing system) showing the highest known service temperature that the pipe and its component variants have been subjected to and the service life that has been achieved under those conditions. Alternatively, the chemical resistance list shall state whether the material has been laboratory tested (according to ASTM C 581) and shall state the life expectancy in intended actual service.

4.2.8 Environmental factors

In the third line, after "oil", *add the word:*

condensate,

6. COMPONENT/SYSTEM DESIGN

6.1 DESIGN CONSIDERATIONS

Add to list of factors the following:

Soil loads and settlement.

6.1.4 Location and routing

Add the following new paragraph:

In the case of buried systems the likelihood of third-party damage shall be considered. Additionally, the requirement for special precautions to avoid damage at road (wheel loads), water (e.g. canal), rail-track, pipeline and cable crossings shall be taken into account. Connections to any above-ground sections of the system shall be given special attention.

Add the following new section:

6.1.10 Soil loads and settlement

For pipelines and piping sections that are buried or in direct contact with the soil, the design shall take into account the soil/pipe interaction, including soil loads exerted on the pipe by the soil cover, differential soil settlement, subsidence, landslides etc. In the case of special structures, e.g. thrust blocks and/or widely varying soil properties, or in situations where substantial permanent soil displacements are expected, a detailed soil mechanics and pipe/soil interaction analysis should be carried out.

For pipelines laid beneath the water table, buoyancy shall be included in the analysis.

Add the following new section:

6.1.11 Supports

For supports the design shall take into account the functionality of the support design. It shall also include the influence of temporary loads and reaction forces.

9. INSTALLATION AND TESTING

Add new section:

9.4 Acceptance testing shall be preceded by the following:

- inspection of the as-installed GRP system by a qualified inspector and comparison with the detailed design documentation;
- review of the fabrication/installation quality control documentation.

11. HEALTH, SAFETY AND ENVIRONMENT

11.2 *Replace this section with the following:*

All procedures should comply with the relevant national legislation.

APPENDIX II GRP PERFORMANCE PARAMETERS (STRUCTURES/ PIPING)

Replace Table headed "GRP Performance Parameters - Piping" *with the following:*

GRP Performance Parameters - Piping (4.2)

Performance	**Service**												
Parameter	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
Pressure - internal	Y	Y	Y	Y	Y	Y	P	P	Y	Y	Y	Y	Y
Pressure - external	Y	Y	N	Y	P	Y	N	N	Y	Y	Y	Y	Y
Impact (1)	P	P	P	P	P	P	P	P	P	P	P	P	P
Thermal loads	N	Y	N	Y	Y	Y	N	N	P	Y	Y	Y	Y
Blast overpressure	P	Y	N	Y	Y	Y	N	N	Y	P	Y	Y	Y
Ageing	P	Y	P	P	Y	Y	P	P	P	P	Y	Y	Y
Bending loads	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Axial loads	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Buckling	P	P	P	Y	Y	Y	P	P	P	Y	Y	Y	Y
Water hammer	Y	Y	P	Y	Y	P	N	N	P	Y	Y	Y	Y
Fatigue	Y	Y	N	Y	N	P	N	N	Y	N	Y	Y	Y
Erosion	Y	Y	N	Y	P	Y	N	N	N	P	Y	Y	Y
Cavitation	Y	Y	N	Y	P	Y	N	N	P	Y	Y	Y	Y
Abrasion	P	P	P	P	P	P	P	P	P	P	P	P	P
Temperature	P	Y	N	P	P	Y	P	P	P	N	Y	Y	Y
Chemical resistance	Y	Y	Y(2)	P	P	Y	Y	Y	Y	P	Y	Y	Y
Permeation	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Environment	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fire - endurance	P	Y	N	Y	Y	Y	N	N	P	P	Y	Y	Y
Fire - heat release	Y	Y	Y	P	P	Y	Y	Y	Y	P	Y	Y	Y
Surface spread of flame	P	P	Y	P	P	P	P	P	P	P	Y	Y	Y
Smoke - visibility	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Smoke - toxicity	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Electrical conductivity	Y	Y	P	Y	Y	Y	P	P	P	Y	Y	Y	Y
Ground movement	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

The above Table is only a guide. Performance parameters should be determined for all applications on a case-by-case basis.

NOTES:

(a) Service water
(b) Cooling fluids
(c) Potable water
(d) Firewater - wet systems
(e) Firewater - dry systems
(f) Produced water
(g) Grey water (non-hazardous waste)
(h) Non-hazardous drains
(i) Chemicals
(j) Ballast water
(k) Emulsions
(l) Oil
(m) Gas

Y = Yes

N = No

P = Possible

(1) Impact to be considered if location/ routing does not preclude impact.

(2) May require certification of local health authority (e.g. Water Research Council certification)

Add the following new Table:

GRP Performance Parameters - Pipeline System (4.2)

Performance	**Service**												
Parameter	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
Pressure - internal	Y	Y	Y	Y	Y	Y	P	P	Y	Y	Y	Y	Y
Pressure - external	Y	Y	N	Y	P	Y	N	N	Y	Y	Y	Y	Y
Impact (1)	P	P	P	P	P	P	P	P	P	P	P	P	P
Thermal loads	N	Y	N	Y	Y	Y	N	N	P	Y	Y	Y	Y
Blast overpressure	N	N	N	N	N	N	N	N	N	N	N	N	N
Ageing	P	Y	P	P	Y	Y	P	P	P	P	Y	Y	Y
Bending loads	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Axial loads	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Buckling	P	P	P	Y	Y	Y	P	P	P	Y	Y	Y	Y
Water hammer	Y	Y	P	Y	Y	P	N	N	P	Y	Y	Y	Y
Fatigue	Y	Y	N	Y	N	P	N	N	Y	N	Y	Y	Y
Erosion	Y	Y	N	Y	P	Y	N	N	N	P	Y	Y	Y
Cavitation	Y	Y	N	Y	P	Y	N	N	P	Y	Y	Y	Y
Abrasion	P	P	P	P	P	P	P	P	P	P	P	P	P
Temperature	P	Y	N	P	P	Y	P	P	P	N	Y	Y	Y
Chemical resistance	Y	Y	Y(2)	P	P	Y	Y	Y	Y	P	Y	Y	Y
Permeation	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Environment	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fire - endurance	N	N	N	N	N	N	N	N	N	N	N	N	N
Fire - heat release	N	N	N	N	N	N	N	N	N	N	N	N	N
Surface spread of flame	N	N	N	N	N	N	N	N	N	N	N	N	N
Smoke - visibility	N	N	N	N	N	N	N	N	N	N	N	N	N
Smoke - toxicity	N	N	N	N	N	N	N	N	N	N	N	N	N
Electrical conductivity	Y	Y	P	Y	Y	Y	P	P	P	Y	Y	Y	Y
Ground movement	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

The above Table is only a guide. Performance parameters should be determined for all applications on a case-by-case basis.

NOTES:

(a) Service water
(b) Cooling fluids
(c) Potable water
(d) Firewater - wet systems
(e) Firewater - dry systems
(f) Produced water
(g) Grey water (non-hazardous waste)
(h) Non-hazardous drains
(i) Chemical
(j) Ballast water
(k) Emulsions
(l) Oil
(m) Gas

Y = Yes

N = No

P = Possible

(1) Third party damage

(2) May require certification of local health authority (e.g. Water Research Council certification).

APPENDIX IV GLOSSARY

Add the following:

Hydrocarbon fire

Flame resulting from the combustion of gas or oil.

Add new Appendix V:

APPENDIX V CHEMICAL RESISTANCE OF GRP PIPING SYSTEMS

The following recommended maximum temperatures are given for the sole purpose of a quick check and should only be used for guidance purposes. The allowable limits for the actual system are a function of both the chosen resin system and the curing agent. The chemical resistance data supplied by the Manufacturer should be based on experience from industry or from testing in the laboratory, in accordance with ASTM C 581.

	Maximum recommended temperature, °C		
Fluid / chemical	**GRE (glass/Epoxy)** For Tg (see note)	**GRVE (glass/Vinylester)** Tg > 120 °C	GRUP (glass/Polyester) **Tg > 95 °C**
Water (fresh, sea, cooling, fire mains)	100	80	60
Water, chlorinated < 100 ppm	100	80	50
Acetic acid, <10%	80	80	NR
Acetic acid, 10 - 50%	40	80	NR
Acetic acid, 50 - 75%	25	65	NR
Acetic acid, > 75%	NR	NR	NR
Acetone, 5 - 10%	60	30	NR
Acetone, 10 - 25%	25	NR	NR
Air	110	90	70
Alcohol, methyl, < 10%	65	50	NR
Alcohol, methyl, > 10%	40	35	NR
Alkyl chloride	25	25	NR
Benzene	50	NR	NR
Butane gas	60	35	NR
CO_2 gas	110	90	NR
Citric acid	90	80	NR
Condensate	95	80	NR
Gas, natural	90	90	NR
Gasoline	65	65	NR
Glycol, ethylene	90	90	NR
Heptane	60	60	NR
Hexane	60	60	NR
HCL, 0 - 37%	90	80	NR
Jet Fuel (kerosine)	100	70	NR
Oil, Crude	110	90	NR
Petrol; sour, refined -108 octane	60	60	NR
Sodium hydroxide, < 50%	90	75	NR
Sodium hypochlorite, < 18%	25	60	NR
Toluene	50	NR	NR
Xylene	60	NR	NR

NR = Not Recommended

NOTE: Epoxy resin systems should be hot cured. The minimum Tg depending on the type of hardener used should be for:

Anhydride: 115 °C;
Aliphatic amine : 115 °C;
Cyclo-aliphatic amine ; 140 °C;
Aromatic amine ; 140 °C.

PART C AMENDMENTS/SUPPLEMENTS TO THE UKOOA "SPECIFICATIONS AND RECOMMENDED PRACTICE FOR THE USE OF GRP PIPING OFFSHORE: PART 1 - PHILOSOPHY & SCOPE"

1. INTRODUCTION

1.3 DOCUMENT SUITE PURPOSE

Insert after "installation" *the word* "operation"

2. SCOPE

Replace the entire section with the following:

2.1 APPLICATIONS

This DEP is generally applicable to:

- Onshore pipeline and piping systems and offshore piping systems for non-hydrocarbon applications.
- Onshore pipelines transporting oil and associated gas.
- Pipeline and piping systems for chemicals.

Typical potential applications for the use of GRP include:

Alkyl chloride
Ballast water
Boiler feed water
Brine
Condensate (water and gas)
Cooling water
CO_2
Drains (non-hazardous)
Emulsions (oil/water)
Inert gas
Injection water
Fire water (ring main & wet or dry deluge)
Formation water
Fuel
Fresh water
Gas (methane etc.)
Glycol
HCl
Hydrogen chloride gas
Jet-A fuel
Mogas
Oil
Oil plus associated gas
Potable water
Process water
Produced water
Sea water
Service water
Sewer (grey water)
Sewer (red water)
Shallow gas
Sodium hypochlorite
Sodium hydroxide
Unstabilised oil
Vents
Waste water
Water disposal

This DEP is applicable in the pressure-diameter range indicated by (Figure C.2.1), which represents a compromise between the current application experience envelope of GRP pipelines and piping systems and commercial availability.

The maximum allowable temperature for GRP with Epoxy Resin is 110 °C.

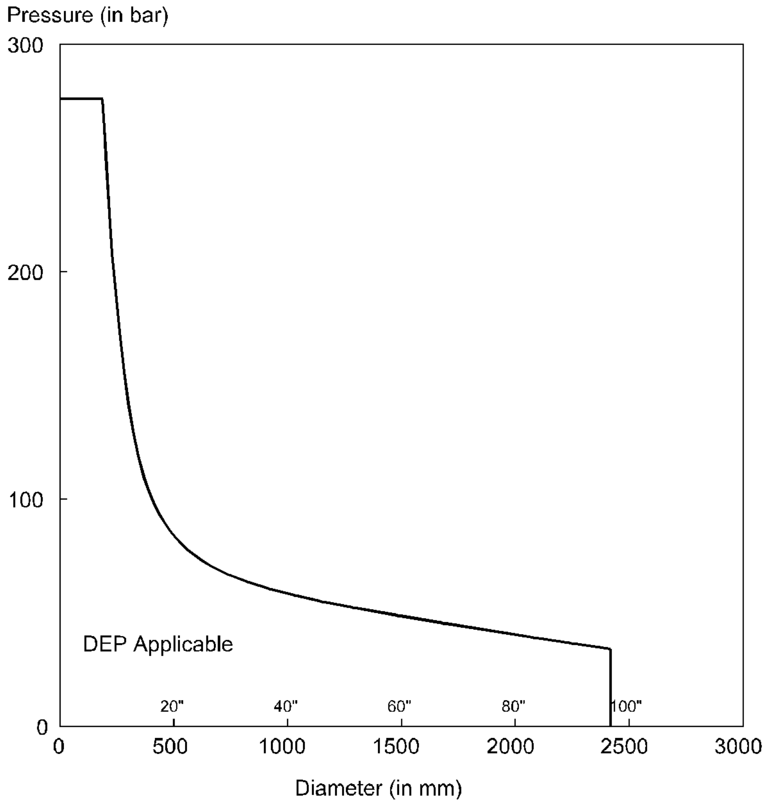
The maximum allowable temperature for GRP with Vinylester is 90 °C

The maximum allowable temperature for GRP with Polyester is 70 °C.

The maximum operating temperature for a GRP pipeline or piping system may, however, be considerably lower, depending on the aggressiveness of the specific fluid and its concentration and the specific curing agent.

The minimum recommended temperature for GRP regardless of the resin system is minus 35 °C although lower temperatures may be considered.

Figure C.2.1 Current experience envelope of pressure/diameter range of GRP pipes and piping systems



The DEP covers all the main components that form part of a GRP pipeline and piping system with the exception of valves and instrumentation.

It is anticipated that the application of GRP will expand further to areas such as:

- onshore and offshore piping systems for hydrocarbon liquids;
- onshore pipeline systems for gas transport; and
- offshore pipelines.

Application outside (Figure C.2.1) to higher pressures or larger diameters is permitted subject to satisfactory qualification.

All these new applications are not specifically excluded from this DEP. However, in these cases an assessment should be made whether additional specifications and requirements are necessary. Such an assessment should show that safety and risk to personnel, the facilities and the environment will not be compromised by the application of a GRP pipeline or piping system.

2.2 QUALITY ASSURANCE OBJECTIVES AND INSPECTION STRATEGIES

2.2.1 General

2.2.1.1 Quality assurance and inspection objectives

As with all materials, defects in GRP can be generated during different stages of the manufacturing process from raw materials to finished components, during installation and commissioning or during operation. The purpose of quality assurance and inspection activities prior to commissioning is to:

- identify deviations from specifications or functional requirements as early as possible;
- form a basis for corrective action.

During operations, the role of inspection is to:

- assure technical integrity during operation;
- form a basis for maintenance evaluation/planning, including fitness-for-purpose evaluation; and
- contribute to the improvement of current and future designs and of inspection strategies (2.2.1.2).

2.2.1.2 Quality assurance and inspection strategies

a) Current strategies - strengths and limitations

Traditionally, most GRP piping applications have been inspected visually and the quality assessed by pressure testing prior to commissioning. Once commissioned no further inspection has been performed. This approach has generally functioned well and it is anticipated it will remain. Some difficulties with this approach have been noted when GRP has been applied offshore. The following sections attempt to address the current limitations associated with inspection of GRP pipe and piping systems:

- over-reliance on system pressure testing has occasionally been a contributing factor in inadequate quality control of the system during various stages of manufacture, material receipt on site and installation;
- visual inspection criteria have been overly subjective (i.e. photographic standards for piping applications have not been readily available); and
- pressure testing often occurs at a late stage in construction which may limit access and make any necessary repairs difficult and costly.

b) Verification activities

The following routine quality assurance/control measures are intended to help in ensuring that GRP piping systems are installed without problems.

c) Responsibility for quality assurance and inspection strategy

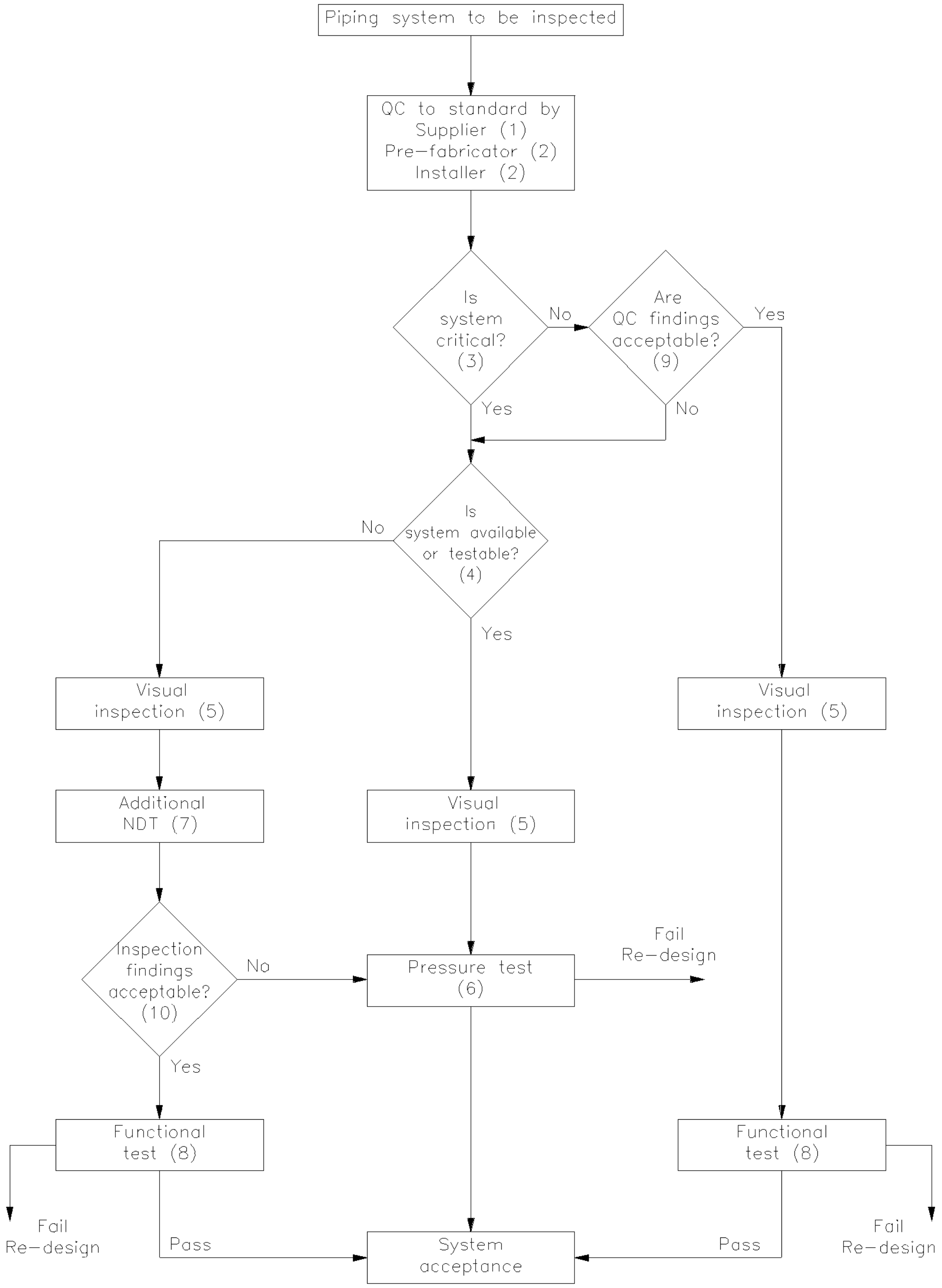
The Principal shall develop a quality assurance and inspection strategy particular to his own needs and applications. This strategy shall be documented and communicated to the qualified inspector and NDT personnel responsible for the equipment and system.

d) Suggested quality assurance and inspection strategies

A suggested inspection strategy for GRP piping systems, which considers system criticality and availability/accessibility, is illustrated in (Figure C.2.2). This should be used as the basis for developing an appropriate specific strategy. The limitations noted above are addressed by:

- highlighting key quality control activities;
- emphasising visual inspection in accordance with NORSOK M-622 Annex A;
- identifying the (limited) circumstances when system design pressure testing may be replaced with various combinations of additional NDT and functional testing at operating pressure.

Figure C.2.2 Suggested inspection strategy for GRP piping systems



NOTES:

(1) Includes mill hydrostatic pressure testing at a frequency defined in (Section D.4.3.1). 100% visual inspection should be performed.

(2) Certified personnel shall be appointed for fabrication and installation. 100% visual inspection should be performed.

(3) System is critical if failure can result in:
- injury to personnel;
- operational shut-down with unacceptable economic consequences (examples: fire water delivery system, some cooling water systems).
System is non-critical if:
- acceptable functionality is maintained even if most likely failure modes occur;
- operating pressure is much lower than system design pressure (see Part D, Section D.4.3.1) (examples: open drains, some cooling water systems).

(4) System is ready and available for testing if it is:
- physically accessible;
- not prohibitively expensive to prepare for pressure testing (i.e. blinding off joints, blocking deluge nozzles etc.).

(5) Visual inspection shall be performed on 100% of system in accordance with (Appendix D.1).

(6) Full system in-field hydrotest in accordance with UKOOA Part 4 Section 7 as amended by (Part F, Section 7).

(7) Other NDT methods applied as appropriate.
NDT to be performed on at least:
- 10% of joints < 250 mm diameter;
- 25% of joints ≥ 250 mm diameter;
- all field joints.

(8) Pressure testing as per UKOOA Part 2 Section 4.3.1 to be replaced by a leak test at 1.5 times the system design pressure.

(9) Supplier and prefabrication testing frequencies may be reduced for non-critical systems, however at least 5% of all testable components shall be tested. QC findings are acceptable if there is no risk that system safety or function will be compromised.

(10) Inspection QC findings are acceptable if there is no risk that system safety or function will be compromised.

2.2.1.3 Defect types - what to inspect for?

Defects can occur in either the GRP material or in the mechanical and/or adhesive-bonded joints that make up the piping system. Joint defects, including defects in prefabricated pipe spools, are more likely to occur than defects in the GRP material, provided QA procedures are followed during manufacture, handling and delivery. Manufacturing processes for fittings are typically more complicated and less automated than those used to produce pipes. Therefore, manufacturing related defects tend to be more prevalent in fittings.

Defects corresponding to specific stages in the manufacture and operation of GRP piping systems are given in various Tables throughout this DEP, where cause and consequence are listed in tabular form along with appropriate acceptance criteria.

2.2.1.4 When to inspect?

GRP piping systems are often used in systems that are not safety-critical and which may be classified as ANSI/ASME B 31.3 Category D systems requiring no inspection. However, these systems can be crucial in maintaining uninterrupted production. Therefore, the choice of when to inspect is largely an economic question. The probability and consequences of system failure must warrant the added cost of inspection. Some representative inspection times are included in the Annexes of NORSOK M-622 to help evaluate the economic trade-offs and determine when to inspect. (These times are elapsed times for inspections carried out in controlled conditions).

Economic and risk considerations will not only determine whether a GRP system is inspected at all, but also whether it should be periodically inspected while in service. A suggested, reasonable balance between costs and benefits of inspections is that both non-critical and critical piping systems should at least be visually inspected within 1-2 years after start of service. Following this the frequency of inspection should be according to the developed strategy.

2.2.1.5 Acceptance criteria

Acceptance criteria are specified in the relevant sections of this DEP.

4. DEFINITIONS

4.2 TECHNICAL

Add the following pressure definitions:

Definitions of pressures	
STHP	Short term hydrostatic (burst) pressure (bar gauge) determined in accordance with ASTM D 1599, with free ends at SLT (Standard Laboratory Temperature).
$LTHP_S$	Long term (static) hydrostatic (extrapolated) pressure (bar gauge) determined in accordance with ASTM D 2992 Procedure B, with free ends at 65 °C or higher based on a 20 year life.
$LTHP_C$	Long term (cyclic) hydrostatic (extrapolated) pressure (bar gauge) determined in accordance with ASTM D 2992 Procedure A, with free ends at 65 °C or higher based on an equivalent 20 year life.
NPR_S	(Nominal) pressure rating (static) based on internal pressure loading.
NPR_C	(Nominal) pressure rating (cyclic) based on internal pressure loading.
System design pressure	The maximum positive internal pressure difference (i.e. minus external pressure) to be experienced by the pipe or piping system. Note, the system design pressure will usually be less than the nominal pressure rating.
Operating pressure	The normal or anticipated standard internal pressure difference (i.e. minus external pressure) to be experienced by the pipe or piping system.

Delete the following definitions:

CPR:

design pressure:

fitting:

LTHP:

LTHS:

piping:

pressure rating:

SPR:

STHP:

Add the following new definitions:

E-glass: Glass fibre, normally used to reinforce GRP pipes, consisting mainly of SiO_2, Al_2O_3 and MgO.

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

fittings: Pressure-tight fluid containing components with a geometry different from straight pipe (e.g. flanges, tees, elbows, reducers etc.).

hand lay-up: A process for fabricating a composite structure in which discontinuous reinforcements (woven mats, chopped strand mats) are impregnated with a matrix material and are manually applied on a mandrel.

in-field hydrostatic test Short term hydrotest after installation, used as a leak test. Defined as 1.5 times the system design pressure.

mill hydrostatic test: Short term hydrotest at the mill (or factory), used as a quality control check. Defined as 1.5 times the nominal pressure rating.

phenolic: A class of polymer resins made from phenol and formaldehyde, and cured by air drying or heat baking. Chemical resistance can be futher increased via heat and catalyst treatment.

pipeline system: Pipe with components subject to the same design conditions and typically used to transport fluids between wells and field facilities, field facilities and processing plants, processing plants and storage facilities.

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

piping (system): Pipe with components subject to the same design conditions and typically used within a processing facility. The piping system also includes pipe supports, but does not include support structures.

R-glass: Glass fibre having a better chemical stability than E-glass in high pH environments.

S-glass: Glass fibre having a higher strength than E-glass and considerably more expensive than E-glass.

5. ABBREVIATIONS

Add the following abbreviations:

HSE Health and Safety Executive (U.K.)

NPD Norwegian Petroleum Directorate

PART D AMENDMENTS/SUPPLEMENTS TO THE UKOOA "SPECIFICATIONS AND RECOMMENDED PRACTICE FOR THE USE OF GRP PIPING OFFSHORE: PART 2 - COMPONENTS & MANUFACTURE"

Replace Section 1 with the following:

1. INTRODUCTION

1.1 SCOPE

This part of the Document Suite of Specifications and Recommended Practices for GRP Pipelines and Piping Systems is a **purchase specification.** It defines requirements relevant to the qualification and manufacture of all GRP pipes and piping components.

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 cover qualification procedures, preferred dimensions, quality programmes, component marking, handling, storage, transportation and documentation.

1.2 PERFORMANCE REQUIREMENTS

This document defines the testing programmes which have to be carried out by the Manufacturer in order to establish the performance of GRP components. It covers:

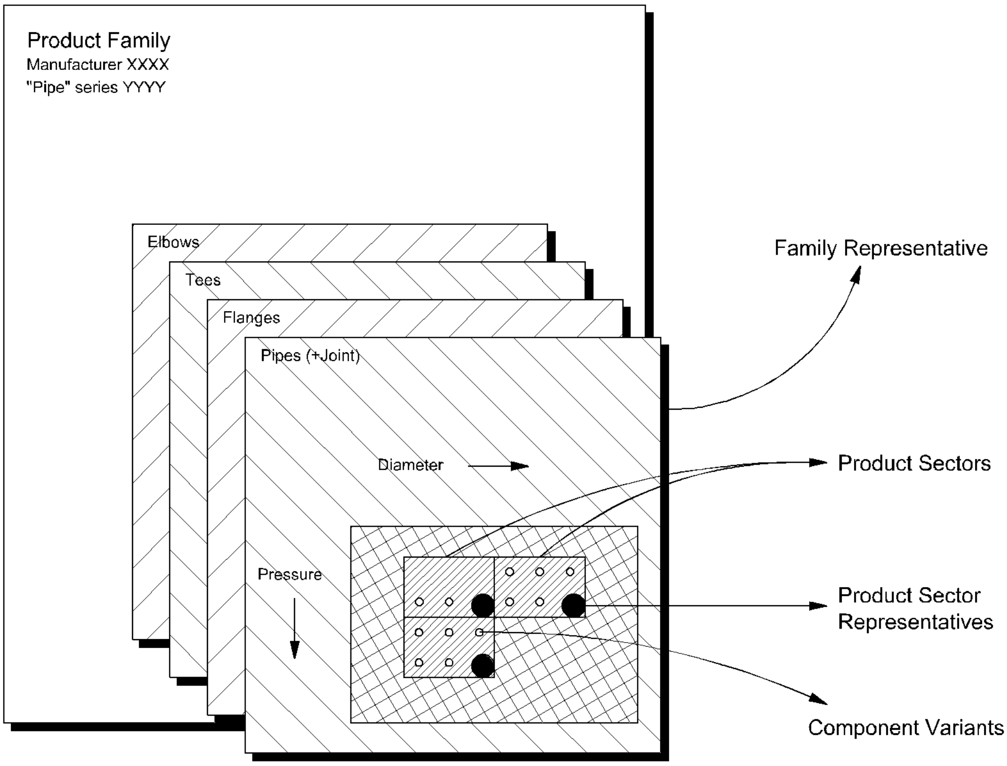
- qualification;
- quality control; and
- testing to generate data necessary for system design.

By carrying out the qualification and quality control testing programmes, the rating of the GRP components or the basis for such rating is established.

The testing programmes have been set up in order to balance the need for technical rigour against the total test burden, taking into account that a product family consists of many different components, i.e. pipes, tees, bends, flanges and reducers with a range of specific diameters and pressure ratings.

In order to keep the total test burden within acceptable limits but at the same time to control the use of test data beyond their limits of applicability, the concept of a product family and its sub-divisions is used in the next sections. The breakdown of a product family into its sub-divisions is shown in (Figure D.1.2a).

Figure D.1.2A Breakdown of a product family into family representatives, product sectors, component variants and product sector representatives



As shown schematically in (Figure D.1.2a), a **product family** defines a range of pipes, fittings and joints manufactured by the same Manufacturer, using the same method and having the same constituent materials.

The **family representative** is the component (normally pipe plus joint) that is taken to be representative of that particular product family.

A **product sector** is a sub-division of a product family (e.g. 50 to 150 mm dia. pipe less than 40 bar) that groups pipes (plus joints) and fittings into specific diameter and pressure ranges.

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

The **product sector representative** (e.g. 150 mm, 40 bar pipe) for a product sector is the component variant taken to be representative of that sector and upon which the basic qualification testing is performed.

This DEP defines three main types of tests for the qualification of GRP pipes and fittings in (nominally static) service:

- Regression tests (ASTM D 2992 Procedure B)
  These are the most rigorous tests which require a total testing time of 10 000 hours or more, and the generation of 18 failure points in order to establish the regression ("ageing") curve. Regression testing is used to determine the long-term performance of a product family. The assumption is that ageing depends on e.g. resin, curing agent, glass type, and sizing and geometry of the reinforcement, but does not depend on e.g. diameter and pressure rating. Following this reasoning, this type of testing will be restricted to family representatives.

  In this DEP default regression line data are given for Epoxy, Polyester and Vinylester pipe systems. These were obtained by fitting a conservative regression line to available industry test data. If the Manufacturer has no regression data available, the default values can be used, within their limits of applicability. However, when Manufacturers have carried out regression tests on their own products, they are encouraged to use these (probably less) conservative data.

- Survival tests (1 000 hour tests; ASTM D 1598)
  Survival tests are carried out in order to compare the long-term performance of other components with that of the family representative. The regression line of the family representative is used to determine the minimum failure pressure of the sector representatives, when tested for 1 000 hours. When the sector representatives are actually tested and survive for more then 1 000 hours at the relevant pressures, the quality is assumed to be at least as good as for the components used in the regression testing, and therefore the products are assumed to be qualified.

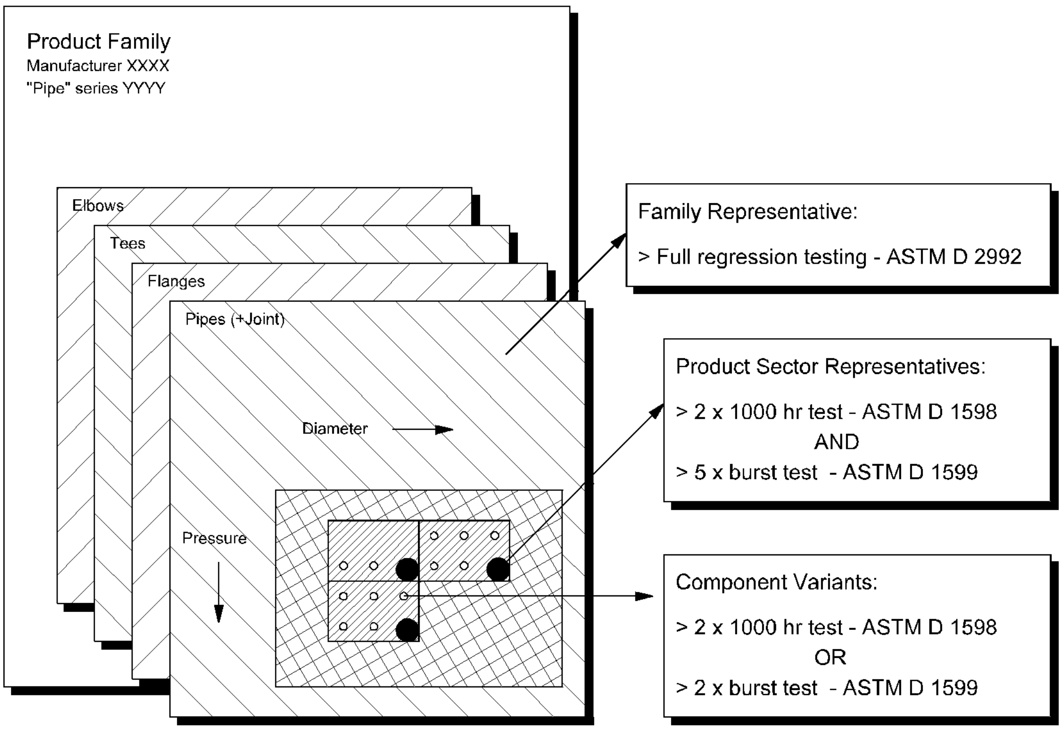
- Burst tests (ASTM D 1599)
  Component variants are qualified, in general, by burst testing although 1 000 hour survival testing is also possible. The burst test results of component variants are compared with the burst test data of components which have been tested for 1 000 hours in order to establish whether the component variants have qualified. (Figure D.1.2b) shows a typical set of testing requirements.

  It is also permissible (but not preferable) to qualify a product line by burst tests only. This can be done by introducing a relatively large safety factor between the burst pressure and the rating, which is necessitated by the wide scatter generally present in burst test data. When the appropriate safety factors are applied this qualification option results in a reliable but conservative criterion.

  The burst tests also are carried out to generate a baseline for quality control tests during manufacturing.

NOTE: GRP systems in fully cyclic service have similar testing requirements to those in static service (see Section D.2.1.2). The main difference, however, is that the qualification tests are carried out for a number of pressure cycles (see Section 2.1.3 of part D for details).

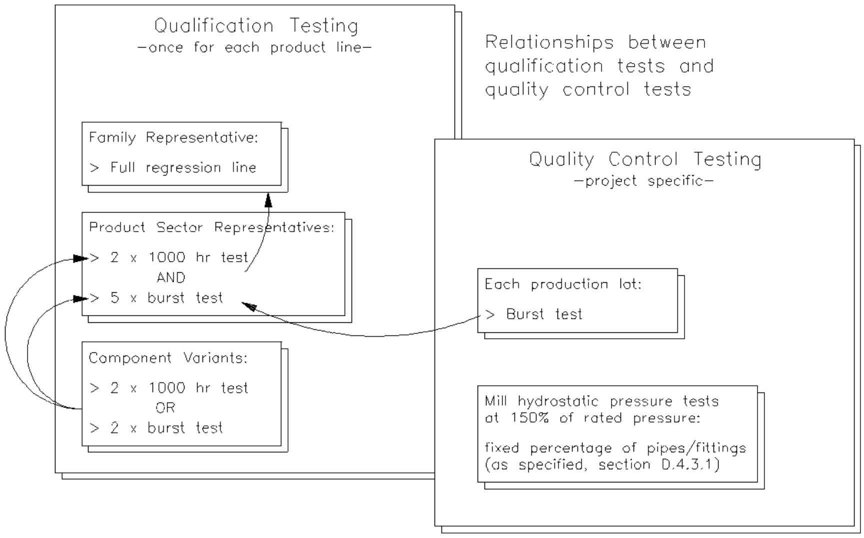
FIGURE D.1.2B Typical qualification test requirements



Qualification tests have to be carried out once during the life cycle of a product line. Quality control tests have to be carried out for each project. This specification explains in detail when and how the quality control tests are carried out. The main tests, shown schematically in (Figure D.1.2c), are as follows:

- Burst tests.
  The results of these tests are compared with the baseline data from the qualification programme.
- Mill hydrostatic pressure tests
  These are carried out on a percentage of the pipes and fittings produced (as specified in Section 4.3.1 of Part D).

Figure D.1.2C Relationship between the qualification and quality control tests



2. QUALIFICATION PROGRAMME

Add the following three paragraphs to the beginning of the introductory text of this section:

Manufacturers assign all components a nominal pressure rating (NPR), the rating given in the Manufacturers' brochures. This rating involves assumptions about the relationship between certain qualification tests, LTHP, LCL, design life, operating temperature, transported fluids and safety factor(s) as well as certain pipeline or piping system design factors. The Manufacturer should always state the basis for the quoted NPR.

The rating methodology varies between Manufacturers as the NPRs are often based on different assumptions and test methods. The NPRs quoted by the Manufacturers, therefore, do not always allow an objective comparison between different products and it is not always clear whether the products will meet the specified performance.

The objective of Section 2 is to arrive at a uniform rating methodology for GRP pipes and piping systems based on a set of widely accepted (and applied) ASTM tests for GRP products.

2.1 PRESSURE RATING QUALIFICATION

2.1.1 General

2.1.1.1 Pressure rating terminology

Replace the first paragraph with the following:

The **LTHP is the long-term hydrostatic (failure) pressure** determined in accordance with ASTM D 2992 at 65 °C or higher and corresponds to the design life. Least square regression curve fitting should be used to determine the LTHP.

Delete the third paragraph.

In the fourth paragraph replace $LTHP_S$ *by* LTHP.

Delete the sixth paragraph.

In the seventh paragraph replace NPR_S and NPR_C *by* $LTHP_S$ and $LTHP_C$ *respectively*.

Delete eighth paragraph, equation (2) and ninth paragraph.

Add at end of section:

The Nominal Pressure Rating (NPR) is defined as:

$NPR = f_2 * LCL$

2.1.1.3 Component definitions

Replace this section with the following:

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

Examples of product sectors are shown in (Table D.2.1.1.3). The product sector representative of a particular product sector in a particular product family is the variant which has the largest nominal diameter and highest pressure rating in that product sector, e.g. a 250 mm, 40 bar bend would be the representative bend in product sector "A".

If a product family does not include variants (e.g. fittings) with nominal diameters and pressure ratings which coincide with the product sector range boundaries, then the product sector representative is identified by selecting first on nominal diameter then on pressure rating.

Table D.2.1.1.3 Examples of product sectors

	Pressure Range (bar)			
Diameter (mm)	**0 to 40**	**40 to 80**	**80 to 150**	**≥ 150**
25 to 250	A	H	N	S
250 to 400	B	I	O	T
400 to 600	C	J	P	
600 to 800	D	K	Q	
800 to 1 200	E	L	R	
1 200 to 2 400	F	M		
> 2 400	G			

2.1.1.4 Standard service conditions

Replace sub-section a) with the following:

a) the standard service life for qualification purposes shall be 20 years.

Add to sub-section c) the following sentence:

In order to minimize the amount of testing a minimum test temperature of 65 °C is recommended for the regression tests and the 1 000 hour survival tests.

2.1.2 Static pressure ratings

Replace entire section with the following:

Static pressure ratings for pipes (plus joints) and fittings shall be qualified in accordance with (sections 2.1.2.1 to 2.1.2.3). An overview of the qualification test requirements for GRP pipes (plus joints) and fittings is given in (Table D.2.1.2). (Section 2.1.2.3) summarises how the LCL_S (the basis for the pressure rating at a specific temperature and for a given design life) is determined from the test results.

Table D.2.1.2 Summary of qualification requirements for pipes (plus joints) and fittings

	Section 2.1.2.1	**Section 2.1.2.2**
Family Representative	- Full Regression Test at 65 °C or design temperature if higher (ASTM D 2992 – Procedure B) or: - Conservative Gradient	
Product Sector Representative	- 2 x 1 000 hr survival test at 65 °C or design temperature if higher (ASTM D 1598) and: - 5x burst tests at SLT (ASTM D 1599)	
Component Variants	- 2x burst test at SLT (ASTM D 1599) or: - 2 x 1 000 hr survival test at 65 °C or design temperature if higher (ASTM D 1598)	- 2x burst test at SLT (ASTM D 1599)

NOTES:

1. SLT is Standard Laboratory Temperature
2. The references to standards in the above table indicate the test procedure and not the number of tests

2.1.2.1 Pipe (plus Joints) and fittings: medium term survival tests

This qualifying procedure permits qualification of the LCL_S of the Product Sector Representative 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 Product Sector Representative's performance is equal, or superior, to the Product Family Representative i.e. that the slope of the regression line for the Product Sector Representative 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, on a product with a diameter of 50 mm or larger. It is recommended that the test procedure outlined in ASTM D 2992 - Procedure B to generate the regression curve for the family representative is performed by a recognised third party.

Two replicate samples of the Product Sector Representative shall be selected at random and pressure tested according to test method ASTM D 1598 (as amended in section 2.1.2.3) at 65 °C or design temperature if higher. The test duration shall be 1 000 hours. The applied pressure shall not be less than the predicted lower confidence limit for the Product Sector Representative at 1 000 hours.

(Figure D.2.1.2.1) presents graphically how to calculate the test pressure for the 1 000 hour test using the regression line for the Product Family Representative.

In the absence of data for the Product Family Representative a conservative gradient may be used. The test pressure at 1 000 hours shall be calculated, based on the proposed pressure rating using the following procedure:

Determine the proposed LCL_S from the pressure rating, using equation (2.1)

$$LCL_S = \frac{\text{pressure rating}}{f_2} \qquad \text{(equation 2.1)}$$

It is assumed that the LCL_S is based on a 20 year design life.

The default gradients given in (Table D.2.1.2.1) are applicable based on a regression line defined by equation (2.2);

log(pressure) = A - [G * log(hours)] (equation 2.2)

Table D.2.1.2.1 Default gradients (for design temperatures up to 65 °C)

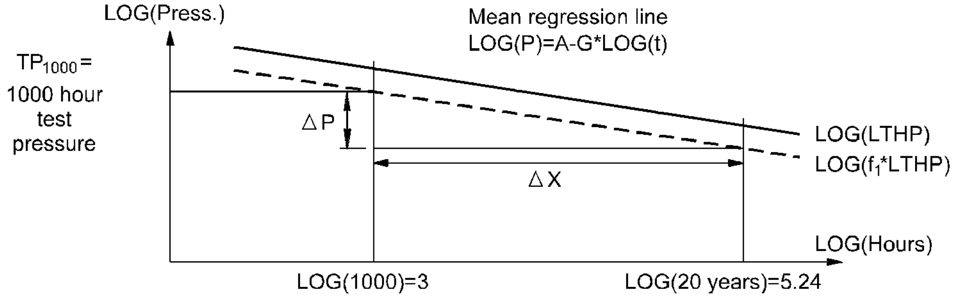
Manufacturing method	Default gradient, G (for Epoxy)	Default gradient, G (for Vinyl Ester and Polyester)
Filament wound components	0.075	0.1
Hand lay-up components	0.1	0.125

The 1 000 hour test pressure shall be determined from equation (2.3)

Test pressure = $LCL_S * 10^{2.24G}$ (equation 2.3)

The following Figure D.2.1.2.1a explains graphically the calculation procedure for the 1 000 hour test pressure.

Figure D.2.1.2.1a Calculation procedure for the 1 000 hour test pressure



$LOG(TP_{1000}) = \Delta P + LOG(f_1{*}LTHP)$

or

$TP_{1000} = f_1{*}LTHP{*}10^{\Delta P}$

$\Delta P = G{*}\Delta X$

$= G{*}(LOG(20\ years)-LOG(1000\ hours))$

$= 2.24{*}G$

$TP_{1000} = f_1{*}LTHP{*}10^{2.24{*}G}$

The procedure outlined in ASTM D 2992 Procedure B should used for data point generation and for calculating the regression curve and the 95% lower confidence limit interval.

In addition, the STHP of the Product Sector Representative shall be determined by testing five replicate samples in accordance with ASTM D 1599. The STHP of the Product Sector Representative shall be taken as the mean burst strength minus one standard deviation of the five tested 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 satisfies one of the following criteria, based on either short term burst data or 1 000 hour tests. It is preferable to qualify component variants from 1 000 hour tests.

The inequality for LCL_S from short term tests is given by;

$$(LCL_S)_{CV} \geq (LCL_S)_{PSR}$$

where $$(LCL_S)_{CV} = (LCL_S)_{PSR} \frac{STHP_{CV}}{STHP_{PSR}} \frac{10^{G}}{10^{G_{CV}}}$$

The inequality for LCL_S from 1 000 hour tests is given by:

$$(LCL_S)_{CV} \geq (LCL_S)_{PSR}$$

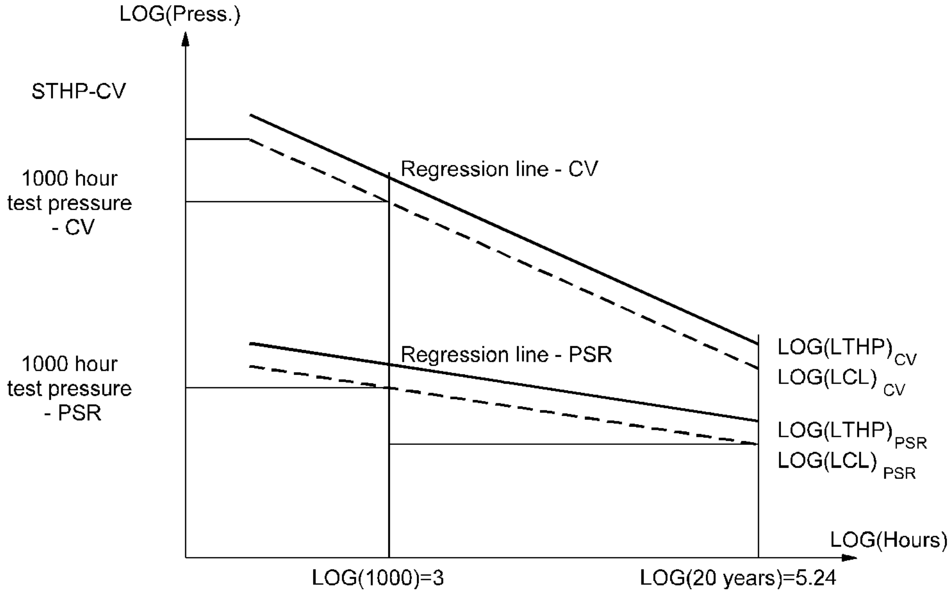
where $$(LCL_S)_S = \left(LCL_S\right)_{PSR} \frac{(Test\ Pressure_{100hour})_{CV}}{(Test\ Pressure_{1000hour})_{PSR}} \frac{10^{G}}{10^{G_{cv}}}$$

where CV = Component Variant, PSR = Product Sector Representative and G = Regression gradient for the PSR (i.e. pipe) and G_{cv} is the regression gradient for the component.

For the component, the default gradients are given in (Table D.2.1.2.1) for hand lay-up components.

(Figure 2.1.2.1b) schematically describes the procedure for determining the test pressures for fittings, either short term or 1 000 hours, based on the above criterion. In practice test pressures for fittings will be higher than for pipes.

FIGURE D.2.1.2.1b Calculation procedure for test pressures for fittings



The STHP of the Component Variant shall be 85% of 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.

If a larger set of values is available for the Component Variant (i.e. more than 8), then the STHP shall be determined as the mean value minus one standard deviation.

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

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).

Product Sector Representatives and/or Component Variants that have been subjected to a 1 000 hour survival test shall not be used as part of a GRP pipeline or piping system.

2.1.2.2 Pipe (plus joints) and fittings: short-term burst tests

If a gradient for the regression line is available, either measured or a default value, then qualification following the procedures specified in (Section 2.1.2.1) should always be used. For low-pressure (less than 8 bar design pressure) water service applications, where a gradient for the regression line is not available, the following qualification procedure based on the short-term burst tests may be applied.

This procedure permits qualification of a Component Variant's LCL_S based on its STHP. The option makes a conservative estimate of LCL_S based on the Component Variant's measured STHP and an empirical derating factor, Z_S. The STHP of the Component Variant shall be 85% of the lower of two replicate samples tested at SLT in accordance with ASTM D 1599.

NOTE: In this option the Component Variant's STHP for quality control purposes (section 4.3.3) shall be taken as the equivalent of the mean STHP of the Product Sector Representative.

The LCL_S shall satisfy the following criterion:

$$(LCL_S)_{COMPONENT\ VARIANTS} \leq \frac{f_1 x\ (STHP)_{COMPONENT\ VARIANT}}{Z_s}$$

where f_1 = 0.85

Values of Z_S shall be taken from (Table D.2.1.2.2).

Table D.2.1.2.2 Values for empirical factor Z_S (up to 65 °C only)

Manufacturing method	Epoxy	Polyester, Vinyl ester
Filament wound: fittings and 55° filament wound pipe	2.5	3
Full or partial hand-lay: all components	3	4

NOTE: The values quoted in the above (Table D.2.1.2.2) are based on tests on pipes and joints. It is assumed that these values are also applicable to fittings.

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).

2.1.2.3 Basis for the pressure rating

The qualification tests are carried out to determine the LCL_S (or LTHP) of all Component Variants. By applying two part factors f_1 and f_2 the rating is determined. (Table D.2.1.2.3) summarises how the LCL_S of the components is determined from the qualification test results.

Table D.2.1.2.3 Determination of the LCL_S from the various tests

	Long/medium term tests	Short term tests
Family Representative	$LCL_S = f_1 x\ LTHP_S$ LTHPS and f1 are determined according to ASTM D 2992 - Procedure B	
Product Sector Representative	$LCL_S = \frac{(\text{Test Pressure})_{1\,000\ \text{hours}}}{10^{2.24G}}$ where G is the regression gradient of the family representative	
Component Variants	$(LCL_S)_{CV} = (LCL_S)_{PSR} \frac{STHP_{CV}}{STHP_{PSR}} \frac{10^G}{10^{G_{CV}}}$ or $(LCL_S)_{CV} = (LCL_S)_{PSR} \frac{(\text{Test Pressure}_{1000})_{CV}}{(\text{Test Pressure}_{1000})_{PSR}} \frac{10^G}{10^{G_{CV}}}$	$LCL_S = \frac{f_1 * STHP_{CV}}{Z_S}$ where Z_S is an empirical factor defined in (Table D.2.1.2.2).

NOTE: For the Product Sector Representative the expression of 2.24 times the gradient is derived from the $LTHP_S$, which is the difference in logarithmic terms between 20 years and 1 000 hours.

2.1.3 Cyclic pressure ratings

Replace the entire section with the following:

Cyclic pressure ratings for pipes (plus joints) and fittings shall be qualified in accordance with (sections 2.1.3.1 to 2.1.3.3). An overview of the qualification test requirements for GRP pipes (plus joints) and fittings is given in (Table D.2.1.3). Section (2.1.3.2) summarises how the LCL_C (the basis for the pressure rating at a specific temperature and for a given design number of cycles) is determined from the test results.

Table D.2.1.3 Qualification test requirements for pipes (plus joints) and fittings

Family Representative	- Full Regression Test at 65 °C or design temperature if higher (ASTM D 2992 - Procedure A) or: Conservative Gradient
Product Sector Representative	- 2x 600 000 cycles survival test at 65 °C or design temperature if higher (ASTM D 2143) and: - 5x burst tests at SLT (ASTM D 1599)
Component variants	- 2x burst test at SLT (ASTM D 1599)

NOTE: The references to standards in the above (Table D.2.1.3) indicate the test procedure and not the number of tests.

The frequency of cyclic testing should be between 5 cycles per minute and 25 cycles per minute. The frequency shall not be greater than 25 cycles per minute, but can be lower than 5 cycles per minute by agreement between the Principal and the Manufacturer.

The default testing frequency is assumed to be 10 cycles per minute.

600 000 cycles is the number of cycles resulting from a test frequency of 10 cycles per minute and a test duration of 1 000 hours.

2.1.3.1 Pipe (plus joints) and fittings: medium-term tests

The qualification of the LCL_C of the sector representative is based on a medium-term survival test. The test pressure is based on the regression line derived from the test data following ASTM D 2992 Procedure A for the Family Representative. The objective of this procedure is to demonstrate that the Product Sector Representative's performance is equal, or superior, to the Family Representative i.e. that the slope of the regression line for the Product Representative Product is not steeper than that for the Family Representative. The $LTHP_C$ of the Family Representative shall be determined in accordance with ASTM D 2992 Procedure A, on a product with a diameter of 50 mm or larger. It is recommended that the test procedure outlined in ASTM D 2992 - Procedure A to generate the regression curve for the family representative be performed by a recognised third party.

Note: ASTM D 2992 Procedure A assumes a testing frequency of 25 cycles per minute. Because the default frequency in this DEP is 10 cycles per minute, Section 6.2.3 of ASTM 2992 – Procedure A should be amended so that data points are generated for the following number of cycles. Data collected according to the number of cycles defined in ASTM D 2992 are still valid.

Table D.2.1.3.1 Test points for regression curve

Cycles to failure	Failure points
400 to 4 000	at least 3
4 000 to 40 000	at least 3
40 000 to 400 000	at least 3
400 000 to 4 000 000	at least 3
up to 6 000 000	at least 1
Total	**at least 18**

Two replicate samples of the Product Sector Representative shall be selected at random and pressure-tested according to test method ASTM D 2143 at 65 °C or design temperature if higher. The test duration shall be 600 000 cycles. This number of cycles is chosen to represent a practical limit to the number of cycles that can be reached within a test period of 1 month. The applied pressure shall not be less than the predicted lower confidence limit for the Product Sector Representative product at 600 000 cycles.

(Figure D.2.3.1) presents graphically how to calculate the test pressure for the 600 000 cycles test using the regression line for the Product Family Representative.

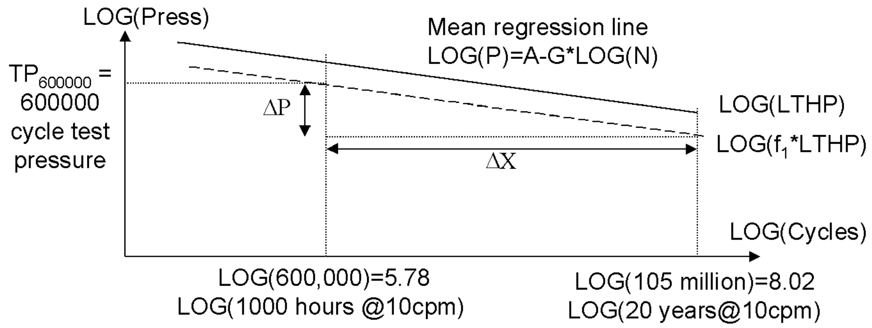
In the absence of fully cyclic data for the Product Family Representative, the $LTHP_C$ shall be derived from the $LTHP_s$ as follows:

$$LTHP_C = \frac{LTHP_S}{4} \qquad \text{(equation 2.4)}$$

NOTE: Components for cyclic service may be qualified from static qualification data. Components for static service shall not be qualified from cyclic qualification data.

The following Figure D.2.1.3.1a explains graphically the calculation procedure for the 600 000 cycles test pressure.

Figure D.2.1.3.1a Calculation procedure for the 100 000 cycle test pressure



$LOG(TP_{600000}) = \Delta P + LOG(f_1{*}LTHP)$
or
$TP_{600000} = f_1{*}LTHP{*}10^{\Delta P}$

$\Delta P = G{*}\Delta X$
$= G{*}(LOG(20\ years@10cpm)-LOG(600000\ cycles))$
$= 2.24{*}G$

$TP_{600000} = f_1{*}LTHP{*}10^{2.24{*}G}$

The statistical procedure outlined in ASTM 2992 - Procedure A should used for data point generation and for calculating the regression curve and the 95% lower confidence limit interval.

$$(LCL_{CV})_{CV} \geq (LCL_C)_{PSR}$$

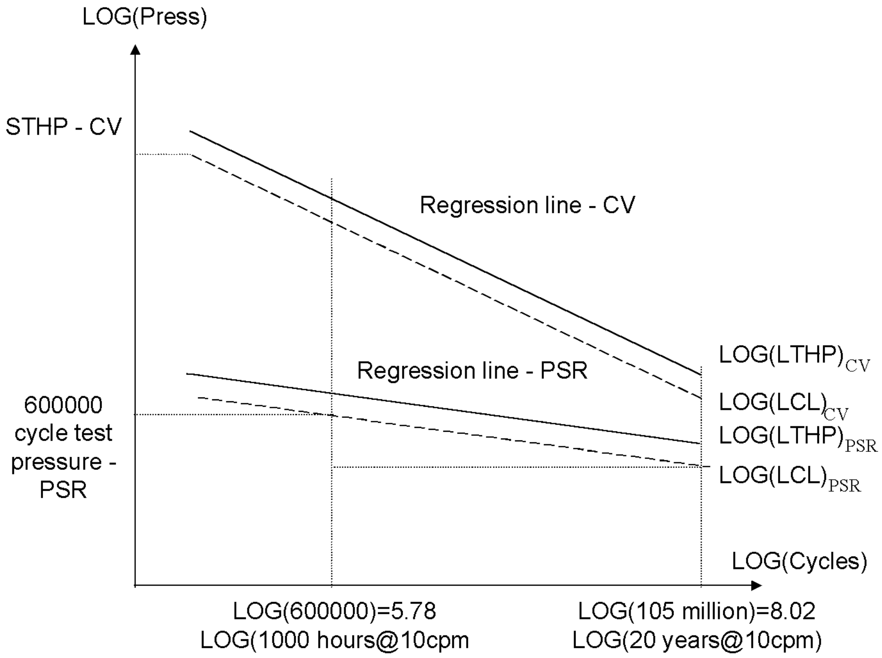
$$\text{where } (LCL_C)_{CV} = (LCL_C)_{PSR} \frac{STHP_{CV}}{STHP_{PSR}} \frac{10^G}{10^{G_{CV}}}$$

where CV = Component Variant and PSR = Product Sector Representative

and G = Regression gradient for the PSR (i.e. pipe) and G_{CV} is the regression gradient for the component.

For the pipe (plus joint), the default gradient G is 0.12, assuming a filament wound construction. For the component, the default gradient G_{CV} is defined as 1.5G. These default gradients are only valid for Epoxy systems at temperatures lower than 65 °C.

Figure 2.1.3.1b Schematic description of the short term test pressure for fittings



The STHP of the Component Variant shall be 85% of 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).

If a larger set of values is availablefor the component variant (i.e. more than 8), then the STHP shall be determined as the mean value minus one standard deviation.

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

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.

2.1.3.2 Basis for the pressure rating

The qualification tests are carried out to determine the LCL_C (or $LTHP_C$) of all Component Variants. By applying two part factors f_1 and f_2 the rating is determined. (Table D.2.1.3.2) summarises how the LCL_C of the components is determined from the qualification test results.

Table D.2.1.3.2 Determination of the LCLc from the various tests

Family Representative	$LCL_C = f_1 LTHP_C$ $LTHP_C$ and f_1 are determined according to ASTM D 2992 - Procedure A
Product Sector Representative	$LCL_C = \frac{(\text{Test Pressure})_{600{,}000\text{cycles}}}{10^{2.24G}}$ where G is the regression gradient of the family representative
Component Variants	$(LCL_C)_{CV} = (LCL_C)_{PSR} \frac{STHP_{CV}}{STHP_{PSR}} \frac{10^G}{10^{G_{CV}}}$

NOTE: For the Product Sector Representative the expression of 2.24 times the gradient is derived from the $LTHP_C$, which is the difference in logarithmic terms between 105 million cycles (20 years, 10cpm) and 600 000 cycles.

2.1.3.3 Cyclic/static service

This section addresses service conditions that can be considered to be neither static nor fully cyclic. It defines the LTHP in terms of either $LTHP_s$ or $LTHP_c$ or both of them as a function of the amplitude of the internal pressure cycle, R.

R is defined as:

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

where P_{min} and P_{max} are the minimum and maximum of the pressure cycle. If the number of cycles is less than 7 000 then the service shall be considered static.

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

(Table D.2.1.3.3) defines the LTHP for the full range of service from static to fully cyclic as a function of R:

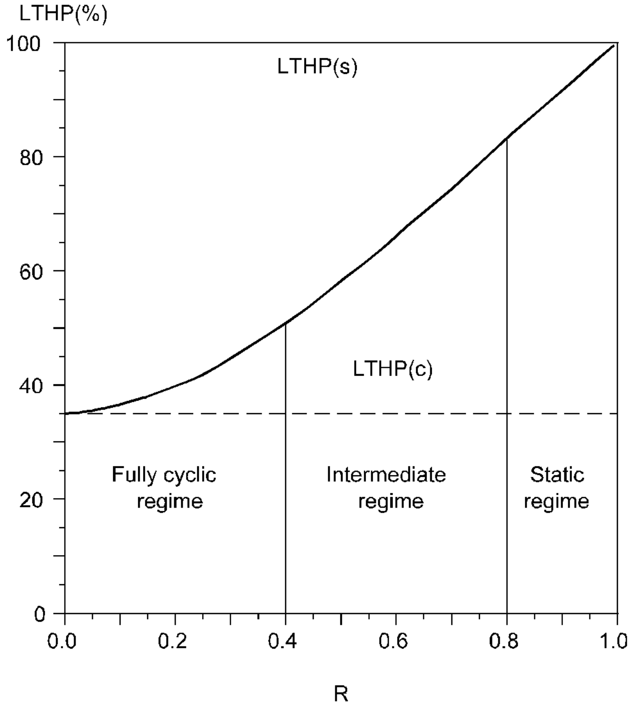
Table D.2.1.3.3 Determination of the LTHP as a function of R

$0 < R < 0.4$	Fully cyclic regime	$LTHP = LTHP_c$
$0.4 < R < 0.8$	Intermediate regime	$LTHP = (LTHP_c^2(1-R^2) + LTHP_s^2 R^2)^{1/2}$
$0.8 < R < 1$	Static regime	$LTHP = LTHP_s$

The scaling rules defined in Table D.2.1.3.3 are derived from an assessment of crack driving forces in fibre reinforced composite materials. Having generated the LTHP, the corresponding LCL and NPR are derived in an identical manner according to either the static or fully cyclic procedures (Section 2.1.2 or 2.1.3).

(Figure D.2.1.3.3) displays graphically the three regimes defined in (Table D.2.1.3.3).

Figure D.2.1.3.3 Determination of LTHP as a function of R



2.1.4 External pressure/vacuum resistance

Add the following paragraph:

Pipes and fittings shall have a collapse (differential) pressure, P_c, of at least 1.5 times the short-term and at least 3 times the long-term maximum design external over-pressure, which shall be specified by the Principal in the invitation to tender.

2.1.5 Requalification

Replace Table 2.1.5 with the following Table:

Table D.2.1.5 Changes in component design requiring requalification

	Minor change	Major change
Reinforcement	- reinforcement manufacturing process - reinforcement composition	- reinforcement finish (sizing) - filament diameter - tow tex - type of fibre
Resin and Adhesive	- curing system supplier - curing temperature - curing schedule	- resin/adhesive grade - curing system type
Internal Surface	- composition - curing schedule/temperature - thickness	
Design		- geometry, dimensions winding angle (> ± 5%) - reinforcement weight weight fraction (> ± 3%)
Manufacture		- change of manufacturing plant

In the third paragraph, replace the term **representative product** *by* **Product Sector Representative.**

2.1.6 Component data for production quality control baseline

2.1.6.2 Glass content

Add the following:

Unless otherwise agreed in writing by the Principal, the glass content by weight shall be as shown in (Table D.2.1.6.2):

Table D.2.1.6.2 Glass content

Pipe / fitting type	Glass content, by weight
Filament wound Pipe	70% - 82%
Filament wound Fittings	65% - 75%
Hand-lay up Fittings	50% - 65%

NOTE: The percentage glass content refers to the reinforced wall thickness.

2.1.7 Minimum thickness

Replace with the following:

In order to provide sufficient robustness during handling and installation of a pipeline or piping system, the minimum total wall thickness, t_{min}, of all components shall be defined as;

For $D_i \geq 100$ mm (4 inches) $t_{min} \geq 3$ mm

For $D_i < 100$ mm (4 inches) $t_{min} \geq 0.025 * D_i$

where D_i is the inner wall diameter (mm).

For offshore piping systems, the Principal and Manufacturer may agree to increase the minimum total wall thickness to 5 mm, where resistance to impact and fire may be critical.

The minimum wall thickness of the pipe at the joint, i.e. at the location of the O-ring or locking strip groove shall be at least the minimum thickness as used for the qualified pipe body.

Depending on location, the system design pressure and other design factors may significantly increase the required wall thickness.

Add the following new section:

2.1.9 Adhesive/resin for bonded/laminated joints

The adhesive to be used in the field shall be the same as that used in the qualification tests. The adhesive shall have suitable properties for field assembly and shall fulfil the following requirements:

- the adhesive shall have a suitable viscosity for application at site temperature as defined in the specifications. The viscosity should not be above 0.4 kPa.s at 23 °C with a shear rate of 10 rotations per second (absolute viscosity data) to ensure ease of application;
- the fracture elongation of the cured adhesive in joints shall not be less than that of the resin used in the piping system, i.e. the shear strength of the adhesive (at the design temperature) shall be at least that of the pipe wall;
- the glass transition temperature (T_g) of the cured adhesive shall be determined by DSC according to Annex C, by measurement of samples taken from joints of components used in qualification testing.The in-field cured adhesive shall have a Tg of of at least that measured during the qualification tests; and
- alternatively, for Polyester and Vinylester based products, the residual styrene monomer content for joints in components used in qualification testing may be determined. The measurement shall be performed according to ISO 4901.

NOTE: The supplier shall record the test procedures used to determine the adhesive/resin properties.

Add the following new section:

2.1.10 Component data for pre-fabrication, fabrication and installation quality control baseline

The Manufacturer shall generate, from the qualification programme, baseline values including acceptance criteria for the fabrication and installation quality control programme.

This shall include measurement of the degree of cure and glass content.

The degree of cure shall be determined by DSC in accordance with Annex C or by residual styrene content measurement in accordance with ISO 4901 for the adhesive used in bonded joints (refer to Section 2.1.9.).

Add the following new section:

2.1.11 Additional qualification requirements for gas applications/service and where specified by the Principal

To demonstrate the gas tightness of the GRE pipe system during qualification, a single gas test is required. The test configuration shall be 2 connected pipes, with a test pressure between 5 and 10 bar. Compressed air or nitrogen may be used as the test medium. The test duration shall be a minimum of 15 minutes. The acceptance criterion is that no gas shall leak from the joint or pipe wall. Any escaping gas can be detected with the aid of soapy water or similar foaming mixture.

If the test is unsuccessful, the Principal and the Manufacturer shall discuss and agree the future course of the qualification testing and pipe manufacture.

After a successful test, microstructures taken from the wall of the female end of the pipe or connector shall be prepared. The number and location of samples shall be agreed between the Principal and the Manufacturer. A minimum of 4 locations is recommended. Reference microstructures shall be defined by agreement between the Principal and the Manufacturer.

2.2 OPTIONAL QUALIFICATION REQUIREMENTS

2.2.3 Impact resistance

Replace this section with the following:

For GRE systems, the impact resistance may be determined using the following formula, however the Manufacturer may propose an alternative calculation procedure subject to agreement with the Principal.

$$KE = \frac{17}{1000} t^2 R_{av}$$

where

KE = the energy of impact (J)
t = the reinforced wall thickness (mm)
R_{av} = the average pipe radius (mm)

The purpose of this calculation is to ensure that the wall thickness of an empty GRE pipe is at least sufficient to withstand a 5 Joule impact, without any visible laminate damage. If the total wall thickness required to withstand this impact is less than the minimum specified wall thickness as defined in (Section 2.1.7), then the minimum specified value shall be used.

For Vinylester and Polyester glass reinforced systems there is insufficient test data available to generate an empirical formula. The Manufacturer shall therefore demonstrate that the pipe is capable of withstanding a 5 Joule impact without any visible laminate damage.

NOTE: 5 joules typically represents the equivalent impact energy of a dropped hand tool.

2.2.4 Low temperature

Replace this section with the following:

For service temperatures of -35 °C and below, the user should consider the need for additional testing at the design temperature. Both qualification as well as additional mechanical tests should be considered. The point of concern is that at temperatures lower than -35 °C, internal residual stresses could be large enough to reduce the safe operating envelope of the piping system.

NOTE: The temperature of the filled pipe system shall always be higher than the freezing temperature of the fluid in the pipeline.

Add new section:

2.2.6 Limited cyclic qualification testing

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

The experimental basis of the testing shall be ASTM D 2143 except that the provisions of this Manual 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 and 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).

The cycling rate should be between 5 and 25 cycles per minute. Where this frequency cannot be maintained then a slower rate can be used by agreement between the Principal and the Manufacturer. Each test pressure cycle shall range between not more than 10% and not less than 150% of the NPR_S.

A failure within 5 000 pressure cycles is unacceptable and disqualifies the component.

Add new section:

2.3.1 Pipe system fire classification code (type test envelopes)

Replace entire section with the following:

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 is 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 whether an updated and endorsed version is available.

The Fire Classification Code is designated by a five field number: **1.2.3/xxx-(4.5)** where:

1	=	fluid or fluid state;
2	=	fire type;
3/xxx	=	integrity/duration;
4	=	fire reaction: spread of fire and heat release;
5	=	fire reaction: smoke and toxicity.

The minimum standard (default value **Z**) is indicative of either unlimited or unquantified performance. A value **Z** for a particular performance category **3**, **4** or **5** is indicative of the non-availability of fire test data.

1	**=**	**Fluid or fluid state**
	= A	flammable gas
	= B	hydrocarbon or other flammable liquid
	= C	chemical service (consult corrosion guide)
	= D	empty
	= E	initially empty for minimum of 5 minutes followed by flowing water
	= F	initially empty for minimum of 1 minute followed by flowing water
	= G	stagnant water
	= H	initially stagnant water for a minimum of 5 minutes followed by flowing water
	= I	initially stagnant water for a minimum of 1 minute followed by flowing water
	= J	flowing water
	= Z	other non-critical water based service
2	**=**	**Fire Type (heat flux in kW/m^2)**
	= A	full scale jet fire (>400)
	= B	medium scale jet fire (300 to 400) [SWRI, Sintef]
	= C	large hydrocarbon pool fire (158±8) [ASTM E1529-93]
	= D	impinging flame (113.6) [ASTM F 1173-95 and IMO A.753(18)]
	= E	hydrocarbon fire [NPD]
	= F	hydrocarbon fire mitigated by cooling effects of firewater sprinkler system {hold at 650 °C after 5 minutes}
	= G	cellulosic fire [BS 476 Part 20]
	= H	cellulosic fire mitigated by cooling effects of firewater sprinkler system {hold at 650°C after 5 minutes}
	= Z	other less severe fire exposure
3/xxx	**=**	**Integrity/Duration** **Integrity**
3	**= A**	complete integrity maintained, capable of resumed service after fire
	= B	no leakage at rated pressure during or after fire
	= C	no leakage within 15 minutes at rated pressure when cooled after fire
	= D	leakage less than 0.2 litres/min at rated pressure when cooled after a fire
	= **E**	leakage less than 2% of rated flow at rated pressure when cooled after fire

	= F	leakage less than 10% of rated flow when cooled after a fire
	= O	no structural collapse, unlimited leakage allowed
	= Z	no requirements
		Duration
/XXX	**= /020**	endurance greater than 20 minutes
	= /030	endurance greater than 30 minutes
	= /060	endurance greater than 60 minutes
	= /120	endurance greater than 2 hours
	= /180	endurance greater than 3 hours
4	**=**	**Fire Reaction: Spread of Fire and Heat Release**
	= A	no spread of fire permitted
	= B	spread of fire is limited (SOLAS class 1)
	= C	spread of fire is limited (SOLAS class 3)
	= D	spread of fire is limited (SOLAS class 3)
	= E	spread of fire unlimited or not quantified
	= **Z**	no test data available
5	**=**	**Fire Reaction: Smoke and Toxicity**
	= A	representative of needs within a safe area
	= B	levels must not exceed 10 minute emergency exposure level
	= C	levels must be acceptable within evacuation time
	= D	levels are limited
	= E	levels unlimited or not quantified
	= Z	no test data available

Whilst the number of test scenarios 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 the code for GRP.

a) **F.B.D/120-(D.Z)** 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) **I.F.E/060-(B.C)** 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 an area subject to fire, and smoke and toxicity levels must remain acceptable within the evacuation time.

c) **Z.G.Z/000-(A.A)** represents 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) **B.E.A/120-(D.D)** represents systems containing hydrocarbons 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, e.g. blast, endurance time, pressure and flow retention, fire spread and smoke/toxicity levels achieved during testing.

2.4 COMPONENT PROPERTIES FOR SYSTEM DESIGN

Delete m).

3. PREFERRED PRESSURE RATINGS AND DIMENSIONS

3.1 NOMINAL PRESSURE RATINGS

Add to the list of nominal pressure ratings the following:

55, 70, 85, 100, 135, 170, 205, 240, 275

3.2 DIMENSIONS

3.2.1 Nominal diameters

Add to the list of nominal diameters the following:

1 400, 1 600, 1 800, 2 000, 2 400

3.2.4 Support spacing

Add the following new section:

Pipes should be capable of spanning at least the distances specified in Table D.3.2.4, when carrying a fluid with a specific gravity of 1.

Table D.3.2.4 Guidance span length

Nominal diameter (mm)	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 and above	6.0

The values quoted in Table D.3.2.4 should be considered as desired or preliminary values used for the initial layout design. During detailed design these values should be reassessed and discussed with the Design Contractor.

For guidance the following empirical formulae, based on pipe beam bending theory, are presented for determining the span length. For the purposes of the formulae, it is assumed that the pipe is full of fluid. Spans are assumed to be simply supported and are based on the minimum span length determined from 3 criteria. These criteria are:

1) The absolute centre deflection shall not exceed w_{max}

2) The ratio of absolute centre deflection to span length, L, shall be $w_{max}/L = 0.005$

3) Axial bending stresses shall not exceed $\sigma_{ax,max}$

The span length, L (mm), based on a maximum centre deflection, w_{max} (mm), criterion, is given by:

$$L = \sqrt[4]{w_{max} \frac{384RtE_{ax}}{5(2\frac{t}{R}\rho_p + \rho_p)g}}$$

where R = Average pipe radius (mm)

L	=	Span length (mm)
t	=	Reinforced wall thickness (mm)
E_{ax}	=	Axial modulus (N/mm^2)
ρp	=	Density of pipe (kg/mm^3)
ρw	=	Density of water (kg/mm^3)
g	=	Gravity (mm/s^2)

Assuming a maximum centre deflection of 12.5 mm, average properties for the pipe and water as the internal fluid, then a simplified form of the above equation is:

$$L = \sqrt[4]{Rt}$$

The span length, L (mm), based on a maximum axial bending stress criterion, $\sigma_{ax,max}$ (N/mm^2), is given by:

$$L = \sqrt{\frac{(1-\nu_{ha}\nu_{ah})}{(1+\nu_{ha}\nu_{ah})} \frac{8t}{(2\frac{t}{R}\rho_p + \rho_p)g} \sigma_{ax,max}}$$

where

ν_{ha} = Poisson's ratio, axial to hoop strain resulting from a stress in the hoop direction

ν_{ah} = Poisson's ratio, hoop to axial strain resulting from a stress in the axial direction

Assuming an allowable axial stress of 10 MPa, average properties for the pipe and water as the internal fluid, then a simplified form of the above equation is:

$$L = 2.33\sqrt{t}$$

The pipe support should not be at the same location as the pipe coupling or joint. The preferred distance between support and coupling or joint is 25% of total support distance.

3.2.5 Threaded end connections

Threaded end connections shall meet the requirements of API Specification 15 HR unless otherwise agreed between the Principal and the Manufacturer.

4. QUALITY PROGRAMME FOR MANUFACTURE

4.3 QUALITY CONTROL TESTS

Replace the second sentence with the following:

A pipe lot should consist of 100 pipes or a fraction thereof for one pipe size, wall thickness or grade in continuous production, unless otherwise agreed between the Principal and the Manufacturer.

For fittings, the number of tests to be performed shall be decided by agreement between the Manufacturer and the Principal.

4.3.1 Hydrostatic mill test

In the first sentence replace "10%" *by* "a fixed percentage, as described below".

Add after the second sentence the following:

For every fiftieth joint, the test pressure shall be maintained for a minimum of ten minutes.

Add after the first paragraph the following:

The fixed percentage of hydrotest samples shall be determined as follows:

For NPR > 32 bar, then fixed percentage = 100%.

For NPR ≤ 32 bar and hoop stress (based on NPR) < $\sigma_{h,max}$, then fixed percentage = 5%.

For NPR ≤ 32 bar and hoop stress (based on NPR) > $\sigma_{h,max}$, then fixed percentage = 100%.

Table D.4.3.1 Maximum hoop stress levels, $\sigma_{h,max}$

Resin	$\sigma_{h,max}$ (MPa)
Epoxy	65
Vinyl ester	55
Polyester	55

NOTE: The values in Table D.4.3.1 are based on glass fibre reinforced systems with a glass volume fraction of 55% and winding angle of approximately 55°. For other resin systems, pipe geometry and lay-up, the fixed percentage can be 5% if the Manufacturer demonstrates to the Principal's satisfaction that the hoop stress (based on NPR) is less than 40% of the LCL.

Replace last paragraph with the following:

In the event of failure, re-tests on two additional components shall be performed. If both of the re-tests are successful, then the lot shall be accepted. If one or both of the re-tests fail, then the lot shall be rejected.

Add new paragraph to end of section as follows:

For hydrostatic mill testing of fittings and spool pieces, the frequency of hydrotesting shall be 100% where possible. For spool pieces that cannot be tested in the mill/factory, a hydrotest at the fabrication yard should be performed.

The length of pipe needed to remove the influence of end-fittings when testing spool pieces shall not be less then 3 times the internal diameter of the pipe. For pipes and fittings where the diameter, D, to wall thickness, t, ratio is greater than 10, then shorter pipe lengths than 3 times the internal diameter may be used. The length of pipe shall be determined from

$$L = 2 * \sqrt{\frac{tD}{2}}$$

When it is impossible to test the spool, it should be agreed between the Principal and the Manufacturer that yearly production QA audits and procedures can be used as sufficient evidence of acceptable quality control.

4.3.3 Short-time failure pressure

Delete entire section and replace with:

The STHP, determined in accordance with ASTM D 1599 at SLT (Standard Laboratory Temperature), of at least one sample per production lot shall be determined. If the STHP is less than 85% of the STHP (as defined in section D.2.1.2.1) established during qualification, then the production lot shall be rejected, subject to re-testing. Section D.4.3.8 DSC tests in accordance with Annex C (original UKOOA document) shall be performed on all test samples.

Replace entire Section 4.3.5 with the following:

4.3.5 Inspection

4.3.5.1 Scope

This section summarises NDE methods that are suitable for detecting defects that could occur during the manufacture of pipes, bends, tees and other components. Probable defects have been derived from experience from both onshore and offshore GRP piping projects. Where warranted, other defect types should be considered e.g. where unusual installation conditions apply or where the consequences of failure are unacceptable.

4.3.5.2 Probable defects, NDE methods and acceptance criteria

NDE methods recommended for use in detecting defects most likely to occur during the manufacture of GRP piping systems are given below along with recommended acceptance criteria. Possible causes and recommended corrective actions are also included.

Defects that could potentially occur during manufacture are listed in (Table D.4.3.5.1). Visible defects along with acceptance criteria and corrective action are listed in (Appendix D.1), (Table 1.1).

The Principal shall be notified of all repairs. By agreement between the Principal and the Manufacturer, a hydrostatic mill test in accordance with (Section 4.3.1) on all minor repaired items shall be performed.

4.3.7 Resistivity

Add to end of paragraph the following:

The resitivity can also be determined by the procedure in Appendix D.2

Add the following new section:

4.3.9 Thread dimensions

Threads shall be gauged in accordance with API 5B. The minimum frequency of gauging shall be once per lot. For moulded threads the first article from a new mould shall also be checked.

Add the following new section:

4.3.10 Additional quality control tests for gas applications/service and where specified by the Principal

After full curing and before hydrotesting, pipes and fittings shall be air-tested. The air test procedure is described in (Section 2.1.11). It is the aim to air-test approximately 10% of produced pipes. An air test schedule and frequency shall be agreed between the Principal and the Manufacturer.

It is recommended to air-test 100% of the first production lot. If all pipes pass this air test, the test frequency for the second lot may be reduced to 50%, for the third lot to 10% and for subsequent lots 5%. If any pipe fails the air test, all other pipes produced in the same lot and all pipes in the subsequent lot should be 100% air-tested. If there are no further failures, the testing frequency may be reduced to 50% and so on for subsequent lots. If further failures do occur, the Principal and the Manufacturer shall discuss the future course of testing and pipe production, including the requirement for additional testing of earlier lots of pipe not subjected to 100% testing.

Furthermore, if failures have occurred, it is recommended to take microstructures from the cut-offs of produced pipes in order to assist the discussion between the Principal and Manufacturer. The number of microstructures should be agreed between the Principal and the Manufacturer, but it is recommended to make microstructures from at least 5% of cut-offs from the first production lot, reducing to 1% for subsequent lots assuming no pipes fail the air test. The microstructures made from the produced pipes should be compared with the reference microstructures as a further control on the quality of the produced pipes.

Table D.4.3.5.1 General description of defects that potentially could occur during manufacture

MANUFACTURING DEFECTS	CAUSE(S)	CONSEQUENCE(S)	RECOMMENDED NDT METHOD(S)	CRITERIA	CORRECTIVE ACTION
1) Incorrect dimensions	- incorrect design input -spool design drawings not correctly verified - incorrect manufacture	- joint cannot be sealed - laminate overstressed if joint pulled up	- measurement to verify documented dimensions - ultrasonics (wall thickness)	- in accordance with UKOOA Part 2 Section 2.1.8	- replace
2) Visible (major and minor) defects	- QA procedures not followed	- weepage or failure if major defect - typically none for minor defects	- visual inspection, with internal light source where appropriate	- in accordance with Appendix D.1 Table 1.1	- replace per Appendix D.1 Table 1.1 (major defect) - repair per Appendix D.1 Table 1.1 (minor defect)
3) Incorrect: - lamination (e.g. wrong lay-up) - filament winding (e.g. incorrect fibre orientation)	- QA procedures not followed - incorrect raw materials used	- weepage - joint or pipe failure if strength not adequate	- visual inspection, with light source inside pipe where appropriate, followed by: - radiography	- in accordance with agreed Manufacturer's specifications	- replace (or repair - only if agreed by supplier and client)
4) Inadequate product design	- supplier's product design does not comply with project requirements	- failure of under-designed components (e.g. flanges, etc.)	- pressure test	- in accordance to agreed project requirements	- replace
5) Inadequate curing of the resin	- incorrect formulation - out of date components - incorrect curing cycle - excessive ambient humidity	- poor laminate quality	- DSC (Epoxy systems) (from samples cut from pipe ends) - Barcol hardness - Styrene content (Vinylester & Polyester systems)	- in accordance with agreed Resin supplier's specification	- replace (major defect) - post-cure (minor defect)
6) Impact, wear or abrasive damage	- incorrect transport - incorrect handling	- weepage or pipe failure	- visual inspection, with light source inside pipe	- in accordance with Appendix D.1 Table 1.1	- replace (major defect) - repair (minor defect)

6. HANDLING, STORAGE AND TRANSPORTATION

6.1 HANDLING

Add the following:

For pipe and components supplied with threaded ends, the Manufacturer shall apply external and internal closed end thread protectors to protect the ends and all exposed threads of the pipe, coupling and fittings from damage under normal handling and transportation. For internal end thread connections, the end protectors shall also protect the end face and the outer surface of the bell-end to prevent chipping and impact damage. Thread protectors shall exclude foreign matter such as dirt from the ends and threads. Protector material shall be plastic and contain no compounds capable of damaging the thread or making the protectors adhere to the threads.

6.1.1 Lifting and transportation

Replace first sentence with the following:

Lifting, loading, unloading and transportation shall be performed in accordance with procedures agreed between the Principal and the Manufacturer.

Add to the fourth paragraph the following sentence:

See also (6.2) for additional packing/storage requirements.

6.2 STORAGE

6.2.1 Pipe

Replace third paragraph with the following:

Pipes with bell-ends shall be stored with the bell-ends in alternate directions to avoid contact with and damage to the ends, mating surfaces or threads. Wooden or plastic spacers shall be used and shall be of sufficient size and strength to prevent contact between pipes. Spacers shall be located clear of the bell-ends.

It is recommended that all pipes and fittings be supplied complete with end protection (both inside and outside) of the pipe wall and shall be transported either packed in a container or strapped onto pallets, suitable for site storage for up to two years.

Small diameter pipes may be transported inside larger diameter pipes, assuming that spacers are used and that the spacers are of sufficient size and strength to prevent contact between the pipes.

7. DOCUMENTATION

7.4 INSTALLATION DOCUMENTATION

Add the following:

- instructions for the field repair of damage to pipe and fittings, where this is permitted in accordance with (Table D.4.3.5.1).

7.5 PUBLISHED VALUES

7.5.2 Dimensions

7.5.2.1 Pipes

In sub-section c) replace "structural" *by* "reinforced".

Add the following new sub-section:

k) thread dimensions.

7.5.2.2 Fittings

In sub-section c) replace "structural" *by* "reinforced".

Add the following new sub-section:

k) tee centre line to branch face length.

7.5.2.3 Flanges

Add the following new items:

d) flange inside diameter.

e) effective length

f) overall length

g) joint configuration

Add new section:

7.5.2.5 Inquiry sheet

The following data sheet should be provided to Manufacturers at the project inquiry stage:

DATA SHEET

1. Principal/Agent		
	Principal	**Agent**
Company		
Contact		
Telephone		
Telefax		
E-mail		

2. Project	
Project Name	
Location	
Type of system	
Fluid composition	
Special Operations	

3. Service conditions	
Design pressure (bar)	
Service cyclicity	
Above ground or buried system?	
Design external pressure (bar)	
Maximum fluid temperature (°C)	
Minimum fluid temperature (°C)	
Maximum ambient temperature (°C)	
Minimum ambient temperature (°C)	

4. Additional items	
Is Manufacturer's supervision of installation required?	
Is potable water health certification required?	
If "Yes" above, specify applicable health authorities	
For Epoxy, are cure agent relaxations applicable?	
Are resin-rich internal liners required?	
Conductivity required?	
Fire performance to be addressed?	

5. Authority					
Name		**Signature**		**Date**	

Add new section:

7.5.2.6 Static qualification summary forms

The following data sheets shall be completed by the Manufacturer for acceptance of qualification for static service.

SPR QUALIFICATION SUMMARY FORM

1. Manufacturer			
Name		Tel. No.	
Location		Fax. No.	
		E-mail	

2. General description			
Component type		Manuf. designation	
Nom. Dia. (mm)		Joint type	

3. Qualified pressure rating				
$LTHP_S$ =		(bar) at Rated Temperature of		(°C)
LCL_S =		(bar) at Rated Temperature of		(°C)
NPR_S =		(bar) at Rated Temperature of		(°C)

4. Process of manufacture of qualified component				
Manufacturing process(es)				
Manufacturing Process(es)	Title			
	Version no.		Issue date :	

5. Materials		
	Reinforced wall	Liner (if applicable)
Glass manufacturer		
Glass type		
Resin manufacturer		
Resin type		
Curing agent (if any)		
Additives (specify)		

6. General properties and dimensions			
The following data is required for all component types			
Nominal unit weight (kg)			
Min. reinforced wall thickness (mm)			
Mean T_g (DSC) of qualified prototypes (°C)			
Mean glass content of qualified prototypes (wt. %)			
Property	Temperature (°C)		
	0	23	Rated
Hoop tensile modulus (MPa)			
Axial tensile modulus (MPa)			
Poisson ratio for axial tensile load (ν_{12})			
Poisson ratio for hoop tensile load (ν_{21})			
Coefficient of axial thermal expansion (1/°C)			
Coefficient of radial thermal expansion (1/°C)			
Axial tensile strength (MPa)			
Collapse pressure (bar)			

7. Potable water health certification		
Is health authority certification required?		If "yes", attach copies

8. Authority					
Name		Signature		Date	

SPR QUALIFACTION TEST DETAILS FORM

1. Qualified component			
Component type		SPR (bar)	
Nominal diameter (mm)		Rated temperature (°C)	
Joint type		Manufacturer	
Product sector		Manuf. designation	

2. 1 000 hour test pressure calculation			
2.1. Calculation based on representative product regression curve data			
Type		LTHP (bar)	
Nominal diameter (mm)		Gradient, G	
Min. test pressure (bar) (per DEP) (= f_1*LTHP*10 $^{2.24*G}$)			
2.2 Calculation based on default gradient			
Proposed SPR (bar)		Default gradient G	
Min. test pressure (bar) (per DEP) (=SPR/f_2*10 $^{2.24*G}$)			

3. 1 000 hour test results							
Test sample data			T_{g1} (DSC) (°C)	Glass content (% wt.)	Test conditions		Survival time (hours)
No.	Date of manf.	Prod. Lot			Temp (°C)	Pressure (bar)	
1							
2							
Mean							

4. STHP (ASTM D-1599) test results for QC baseline							
Test sample data			T_{g1} (DSC) (°C)	Glass content (% wt.)	Test Temp (°C)	Failure description	
No.	Date of manf.	Prod. Lot				Type/ position	STHP (bar)
1							
2							
3							
4							
5							
Mean							

5. Qualification report			
Title			
Date		Ref. No.	

6. Authority					
Name		**Signature**		**Date**	

Add new section:

7.5.2.7 Cyclic qualification summary forms

The following data sheets shall be completed by the Manufacturer for acceptance of qualification for static service.

CPR QUALIFICATION SUMMARY FORM

1. Manufacturer			
Name		Tel. No.	
Location		Fax. No.	
		E-mail	

2. General description			
Component type		Manuf. designation	
Nom. Dia. (mm)		Joint type	

3 Qualified pressure rating				
$LTHP_C$ =		(bar) at Rated Temperature of		(°C)
LCL_C =		(bar) at Rated Temperature of		(°C)
NPR_C =		(bar) at Rated Temperature of		(°C)

4. Process of manufacture of qualified component			
Manufacturing process(es)			
Manufacturing Process(es)	Title		
	Version no.		Issue date :

5. Materials		
	Reinforced wall	Liner (if applicable)
Glass manufacturer		
Glass type		
Resin manufacturer		
Resin type		
Curing agent (if any)		
Additives (specify)		

6. General properties and dimensions			
The following data is required for all component types			
Nominal unit weight (kg)			
Min. reinforced wall thickness (mm)			
Mean T_g (DSC) of qualified prototypes (°C)			
Mean glass content of qualified prototypes (wt. %)			
Property	Temperature (°C)		
	0	23	Rated
Hoop tensile modulus (MPa)			
Axial tensile modulus (MPa)			
Poisson ratio for axial tensile load (ν_{12})			
Poisson ratio for hoop tensile load (ν_{21})			
Coefficient of axial thermal expansion (1/°C)			
Coefficient of radial thermal expansion (1/°C)			
Axial tensile strength (MPa)			
Collapse pressure (bar)			

7. Potable water health certification		
Is health authority certification required ?		If "yes", attach copies

8. Authority					
Name		Signature		Date	

CPR QUALIFACTION TEST DETAILS FORM

1. Qualified component

Component type		CPR (bar)	
Nominal diameter (mm)		Rated temperature (°C)	
Joint type		Manufacturer	
Product sector		Manuf. designation	

2. 600 000 cycle test pressure calculation

2.1. Calculation based on representative product regression curve data

Type		LTHP (bar)	
Nominal diameter (mm)		Gradient, G	
Min. test pressure (bar) (per DEP) (= f_1*LTHP*10 $^{3.42*G}$)			

3. 600 000 cycle test results

Test sample data			T_{g1} (DSC) (°C)	Glass content (% wt.)	Test conditions		Survival time (hours)
No.	Date of manf.	Prod. Lot			Temp (°C)	Pressure (bar)	
1							
2							
Mean							

4. STHP (ASTM D-1599) test results for QC baseline

Test sample data			T_{g1} (DSC) (°C)	Glass content (% wt.)	Test Temp (°C)	Failure description	
No.	Date of manf.	Prod. Lot				Type/ position	STHP (bar)
1							
2							
3							
4							
5							
Mean							

5. Qualification report

Title			
Date		Ref. No.	

6. Authority

Name		Signature		Date	

ANNEX A INQUIRY SHEET

Delete this Annex.

APPENDIX D.1 DEFECTS

Table 1.1 General description of visible defects, acceptance criteria and corrective action

DEFECT TYPE	PHOTO Ref. (see NOTE 4)	DESCRIPTION	CRITERIA	CORRECTIVE ACTION MANUFaCTURE	CORRECTIVE ACTION INSTALLATION	CORRECTIVE ACTION OPERATION
GRP MATERIAL/ ADHESIVE BONDS						
Burn		- Thermal decomposition evidenced by distortion or discoloration of the laminate surface	- Distortion and/or burn deeper than surface resin layer - Minor discoloration limited to surface resin layer, no extent limit	- Reject (major defect) - Repair (minor repair)	- Reject - Accept	- Major repair - Accept
Chalking		- Minor breakdown of outer surface due to UV radiation or acid rain	- Depth limited to surface resin layer, surface area unlimited	- Not applicable	- Not applicable	- Accept
Chemical attack of fibres (corrosion)	A5	- Absence of internal surface resin layer	- None permitted	- Reject	- Reject	- Major repair
Chemical spill		- Minor breakdown of outer surface due to chemical	- If occurring	- Clean, accept	- Clean, accept	- Clean, accept
Chip	A18	- Small piece broken from edge or surface. If reinforcing 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 10 mm x 10 mm lacks resin - If there are no fibres exposed and the area lacking resin is less than 10 mm x 10 mm	- Minor repair - Accept	- Minor repair - Accept	- Minor repair - Accept
Crack	A8 A17 A14 A15 A16	- Actual separation of the laminate, visible on opposite surfaces, extending through the wall. A continuous crack may be evident by a white area.	- Max. depth equal to or less than resin layer - Max. depth greater than resin layer - Crack located in flange, thread root; depth greater than resin layer but less than 20% of flange step or thread height - Other, i.e. max. depth of crack greater than one ply thickness	- Minor repair - Reject - Reject - Reject	- Minor repair - Reject - Reject - Reject	- Accept - Major repair - Major repair - Major repair
Crazing		- fine hairline cracks at or under surface of the laminate - White areas	- max. crack length greater than 25 mm - Max. length dimension greater than 25 mm	- Minor repair - Minor repair	- Minor repair - Minor repair	- Minor repair - Minor repair
Cut roving		- Broken or cut outer rovings due to scraping, scuffing or manufacturing process	- Maximum 3 per pipe with area less than 25 mm x 25 mm. Maximum depth such that the wall thickness is not reduced below minimum	- Accept	- Accept	- Accept

DEFECT TYPE	PHOTO Ref. (see NOTE 4)	DESCRIPTION	CRITERIA	CORRECTIVE ACTION MANUFaCTURE	CORRECTIVE ACTION INSTALLATION	CORRECTIVE ACTION OPERATION
Delamination (internal)	A1 A8 A10	- "Bright solid" area in laminate due to lack of bond between resin and fibres. Separation of the layers (plies) within laminate	- None permitted	- Reject	- Reject	- Accept, but monitoring required
Dry spot		- Area of incomplete surface film where the reinforcement has not been wetted by resin, bare, exposed fibres	- None permitted	- Reject	- Reject	- Major repair
Fracture	A11 A12	- Rupture of the laminate with complete penetration. Majority of fibres broken. Visible as lighter coloured area of interlaminar separation	- None permitted	- Reject	- Reject	- Major repair
Impact damage	A3 A8	- Light area with or without broken fibres	- Circular or ellipsoidal "bright solid" areas (greater than 10 mm in diameter), none permitted - Ring areas, less than 10 mm in diameter	- Reject - Major repair	- Reject - Minor repair	- Accept, monitoring required - Accept, monitoring required
Inadequate bond (e.g. kissing)	A7	- Touching faces, no adhesive	- Debond area greater than 30% of total bond area - Axial length of the debond area greater than 20% of total axial bond length	- Not applicable	- Reject	- Major repair
Inclusion		- Foreign matter wound into laminate	- None permitted	- Reject	- Reject	- Major repair
Lack of adhesive	A6	- Unbonded area of joint face	- Debond area greater than 30% of total bond area - Axial length of the debond area greater than 20% of total axial bond length	- Not applicable	- Reject	- Major repair
Lack of fibres	A9	- Too high resin/fibre ratio	- None permitted	- Reject	- Reject	- Major repair

DEFECT TYPE	PHOTO Ref. (see NOTE 4)	DESCRIPTION	CRITERIA	CORRECTIVE ACTION MANUFaCTURE	CORRECTIVE ACTION INSTALLATION	CORRECTIVE ACTION OPERATION
Pit (pinhole)		- Small crater in the inner surface of the laminate, with its width (max. diameter) similar to or smaller than its depth	- Diameter greater than 0.8 mm and/or depth higher than 20% of wall thickness and/or damaged fibres. - Diameter greater than 0.8 mm and/or depth between 10% and 20% of wall thickness and/or damaged fibres. - Diameter less than 0.8 mm and depth less than 10% of wall thickness and no damaged fibres.	- Reject - Reject - Reject	- Major repair - Minor repair - Accept	- Major repair - Minor repair - Accept
Restriction (excess adhesive)	A4	- Excessive resin, adhesive, foreign matter on the internal wall of pipe/fitting causing restriction	- No flow obstruction > 5% of inner diameter	- Remove by careful grinding	- If access: Remove by careful grinding - If no access: Reject/Major repair	- If access: Remove by careful grinding - If no access: Reject/Major repair
Uneven wall thickness after grinding of adhesive joint surface	A2		- Allowable eccentricity 0.002*ID > 0.3 mm	- Not applicable	- Major repair	- Not applicable
Wear scratch		- Shallow mark caused by improper handling, storage and/or transportation. If reinforcement fibres are broken then damage is considered a crack	- If there are undamaged fibres exposed over any area, or no fibres are exposed but an area equal to or greater than 10 mm x 10 mm lacks resin - If there are no fibres exposed and the area lacking resin is less than 10 mm x 10 mm	- Minor repair - Minor repair	- Minor repair - Minor repair	- Minor repair - Accept
Weeping	A13	- Liquid penetrating, seeping through wall	- None permitted	- Reject	- Reject	- Major repair
Weld sparks		- Minor breakdown of outer surface due to effects of close proximity welding	- Same as for "Wear scratch"	- Minor repair	- Minor repair	- Accept
THREADED JOINTS						
Tears, cuts, grinds, shoulders, or any other imperfections		- continuity of the threads broken	- none within the minimum length of full crest threads (Lc) from the end of pipe	- Reject	- Reject	- N/A
Air bubbles		- Small bubbles at crest of threads	- Max. length 3 mm, one per thread - Max. length 1.5 mm, ten per thread	- Accept	- Accept	- Not applicable

DEFECT TYPE	PHOTO Ref. (see NOTE 4)	DESCRIPTION	CRITERIA	CORRECTIVE ACTION MANUFaCTURE	CORRECTIVE ACTION INSTALLATION	CORRECTIVE ACTION OPERATION
Chips		- Areas where over 10% of thread height is removed	- Max. 10 mm long, one permitted per thread outside the Lc area. - None permitted in the Lc area	- Accept - Reject	- Accept - Reject	- Not applicable
Cracks		- In direction of pipe axis - In radial pipe direction	- None permitted - None permitted that extend from teeth root into the first ply of the pipe wall	- Reject - Reject	- Reject - Reject	- Not applicable
Flat thread		- Area where top of thread is broken or ground off	- Max. 10 mm long, one permitted per thread outside the Lc area, not to exceed 10% of the thread height. - None permitted in the Lc area	- Accept - Reject	- Accept - Reject	- Not applicable
Finish		- Finish cut end	- Sharp edges, exposed fibres, protrusions and/or impact areas are not permitted	- Reject	- Reject	- Not applicable
Squareness		- Angle perpendicular to thread axis	- Variations in end exceeding 1.5 mm are not permitted	- Reject	- Reject	- Not applicable

NOTES:

1. Acceptance criteria are based on experience from sea-water service. More conservative criteria may be specified for other more onerous services.
2. Major repair is defined as:-
   Permanent replacement
   Temporary laminated joint prior to permanent replacement
   Temporary clamps or saddles prior to permanent replacement.
3. Minor repair is on-site repair by grinding, cleaning and application of resin/hardener as recommended by the Manufacturer.
4. Photographs showing defect examples and numbering are contained in Annex A of NORSOK M-622.
5. For pipe body defects, reject is defined as replace. For female joint ends, reject is defined as replace. For male joint ends, reject is defined as either replace or remove and re-thread.

Specification of threading, gauging and thread inspection for all threaded joints shall be according to API 5B, fourteenth edition, August 1996. However, for non-standard API threaded connections, the dimensions and tolerances of the thread shall be according to the specifications of the Manufacturer, for that qualified product. Other specifications shall again conform to API 5B, fourteenth edition, August 1996.

Add new Appendix:

APPENDIX D.2 ELECTRICAL CONDUCTIVITY TEST PROCEDURE

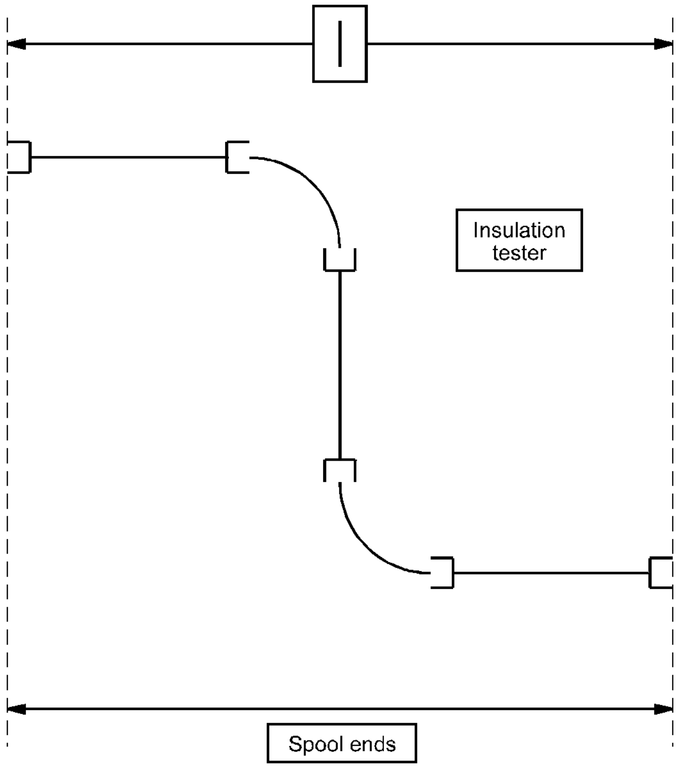
Required apparatus:

One standard generator-type insulation tester capable of applying up to 1 500 V (dc) with a scale reading minimum of one mega-ohm.

Procedure:

1) Place at the inside of both ends of the spool (see Figure D.2) a small sponge, wetted in water and connected with the insulation tester. Ensure that the inside of the spool is dry. Measure the resistance in Ω after applying 500 V (dc).
2) The measured resistance should not exceed one mega-ohm.
3) The test frequency should be 100%
4) Mark each passed spool with a "C" and record in the pre-fabrication report that the spool has been tested for conductivity.

Figure D.2 Example of experimental test set-up


Insulation
tester
Spool ends

PART E AMENDMENTS/SUPPLEMENTS TO THE UKOOA "SPECIFICATIONS AND RECOMMENDED PRACTICE FOR THE USE OF GRP PIPING OFFSHORE: PART 3 - SYSTEM DESIGN"

3. BACKGROUND TO PRESSURE RATING QUALIFICATION

3.1 PRESSURE RATING METHODOLOGY

Amended per Circular 60/99

Replace last sentence of NOTE with:

The design pressure shall be LCL x f_2. This definition of design pressure does not take allowance of any system axial stress, and is based solely on internal pressure containment. System design shall also include the influence of axial stresses from sources other than internal pressure (e.g. bending, torsional and temperature effects). The level of axial stress is strongly dependent on the application; for example, the axial stresses will be less for buried pipelines than for an above ground piping system.

In quoting a design pressure, the Manufacturer shall also quote the system axial stress or f_3 factor (Section 3.1.3) that has been used to develop the quotation.

3.1.1 Part factor f_1

Delete the last two sentences of the final paragraph.

3.1.2 Part Factor f_2

Replace this section with the following:

Part factor f_2 is a load factor (or safety factor) for which defaults are given in Table 3.1.2 as a function of loading type.

Table 3.1.2 Default values for f_2

Loading type	Description	f_2	Load duration	Example of loading type
Occasional	Short term	1	Short term	Hydrotest
Operational - sustained plus thermal	Long term	0.83	Long term	Self-weight plus thermal expansion
Sustained	Long term	0.67	Long term	Self-weight

The load or safety factor is related to confidence in the pipework system, the nature of the application, the type of loading and the consequences of failure. It allows for the effects of occasional overloading so that hydrotesting can be safely accommodated. It should be noted that no links have been established between the effects of long term loading and those of higher loads 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.

3.1.3 Part factor f_3

Replace this section with the following:

3.1.3 System design

3.1.3.1 System design, axial tension and internal pressure

This section provides the procedure for designing for the effects of non-pressure induced stresses (system loads). With isotropic materials such as steel, the effects of combined (pressure plus non-pressure induced) loading are greatly simplified as hoop and axial strengths are identical. This results in a significant margin in allowable strength to accommodate this extra axial stress (load) as the pressure induced axial stress (load) is one half the hoop stress (load). For anisotropic materials such as filament wound GRP pipes, the hoop and axial strengths are significantly different.

Notations used for stress analysis:

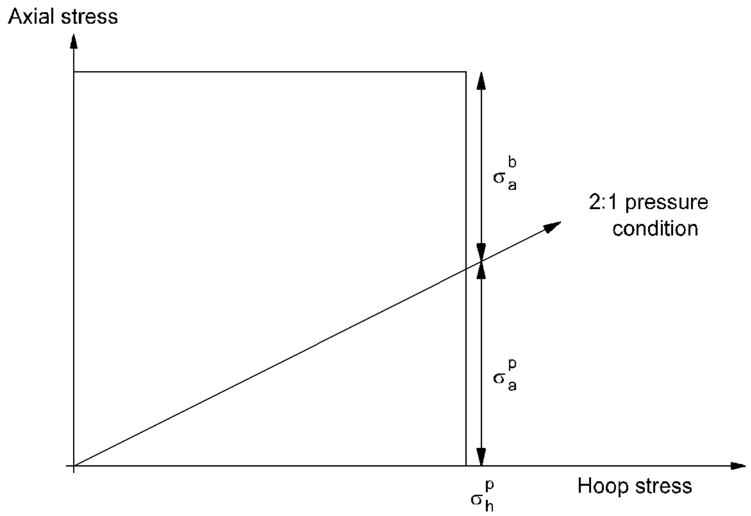
σ_a^b	=	axial stress due to non-pressure induced loads
σ_a^p	=	axial stress due to pressure
σ_h^p	=	hoop stress due to pressure

(Figure E.3.1.3.1a) shows an allowable design envelope for an isotropic material, with equal hoop and axial strengths. For the condition of internal pressure with unrestrained ends, the pressure induced axial stress is half the pressure induced hoop stress:

$$\sigma_a^p = 0.5\sigma_h^p$$

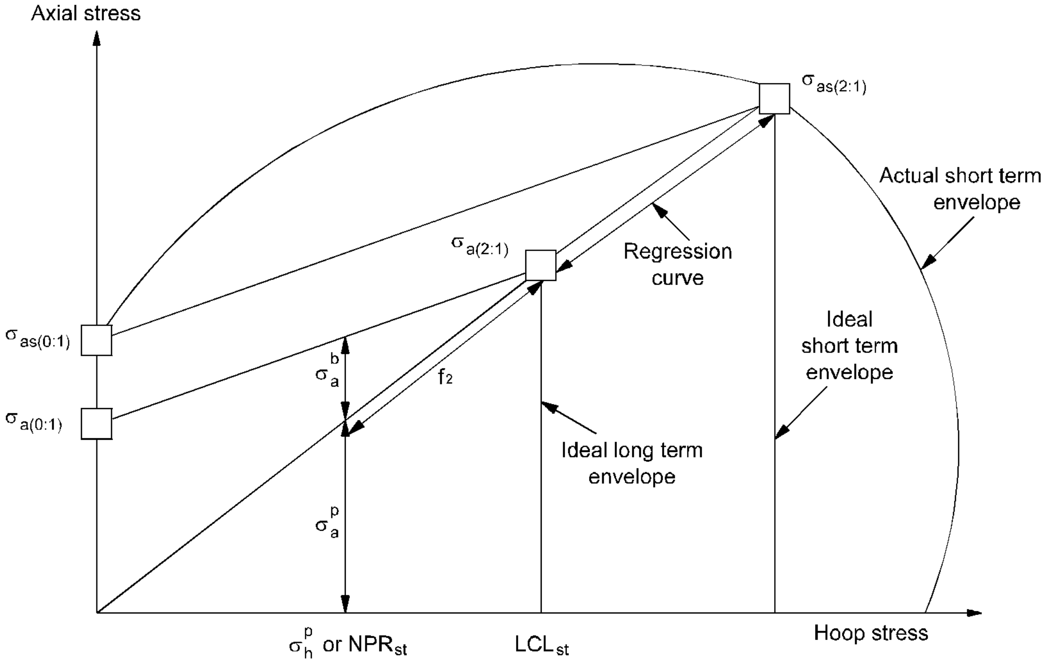
This implies that 50% of the axial strength is available for non-pressure induced axial stresses, which typically include the self-weight of pipe and transported fluid or thermal expansion loads.

Figure E.3.1.3.1a Design envelope for an isotropic material



For commercially available filament-wound GRP pipes and components, the design approach adopted by Manufacturers attempts to optimise performance for the 2 : 1 pressure condition (system with closed ends). Therefore the hoop strength is significantly greater than the axial strength. (Figure E.3.1.3.1b) shows a design envelope for a single wound angle ply GRP pipe with winding angle in the range ± 45° to ± 75°.

Figure E.3.1.3.1B Ideal long term envelope for a single wound angle ply GRP pipe with winding angles in the range of approximately 45° to 75°



It is constructed from the following steps. An idealised short term envelope is inferred from the actual short term envelope using two data points $\sigma_{as(0:1)}$ and $\sigma_{as(2:1)}$ defined as:

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

$\sigma_{as(2:1)}$ = short term axial tensile strength at the 2:1 condition (i.e. internal pressure test).

NOTE: The numbers in brackets refer to the ratio of hoop to axial stress.

The idealised long term failure envelope is geometrically similar to the short term envelope and is derived using two data points $\sigma_{a(0:1)}$ and $\sigma_{a(2:1)}$ defined as:

$$\sigma_{a(0:1)} = \sigma_{as(0:1)} \frac{\sigma_{a(2:1)}}{\sigma_{as(2:1)}}$$

NOTE: Manufacturers are required to measure the short term axial strength as part of the qualification data requirements.

$$\sigma_{a(2:)} = \frac{LCL_{st}}{2}$$

NOTE: NPR_{st}, hoop stress (N/mm^2) resulting from the f_2*LCL (bar) and LCL_{st}, hoop stress (N/mm^2) resulting from the LCL (bar) are defined as;

$$NPR_{st} = NPR\frac{(D_i + t)}{20t} \text{ and } LCL_{st} = LCL\frac{(D_i + t)}{20t}$$

Where

D_i = Inner pipe diameter (mm)

t = Pipe wall thickness (mm)

The long term design envelope is based on this idealised envelope times an appropriate factor of safety (Section 6.6.10). The important feature of (Figure E.3.1.3.1b) is that the axial tensile strength, $\sigma_{a(0:1)}$, is lower than the axial stress at the 2:1 pressure case, $\sigma_{a(2:1)}$. The ratio of these strengths, r, can range between 0.5 and 0.75 depending on winding angle and specific pipe type.

For adequate design, the sum of the axial stress	$\sigma_a^b + \sigma_a^p$	must lie within the long term design envelope.
The non-pressure induced axial stress	σ_a^b	can be calculated using standard industry-approved manual or computer methods (See Section 6 for details).
The pressure induced axial stress	σ_a^p	is calculated from the NPR_{st}.

If the sum of these stresses lies outside the long term design envelope then the next higher pressure rated pipe from the product family must be chosen and the stress calculation repeated until the sum of the stresses lies within the long term design envelope.

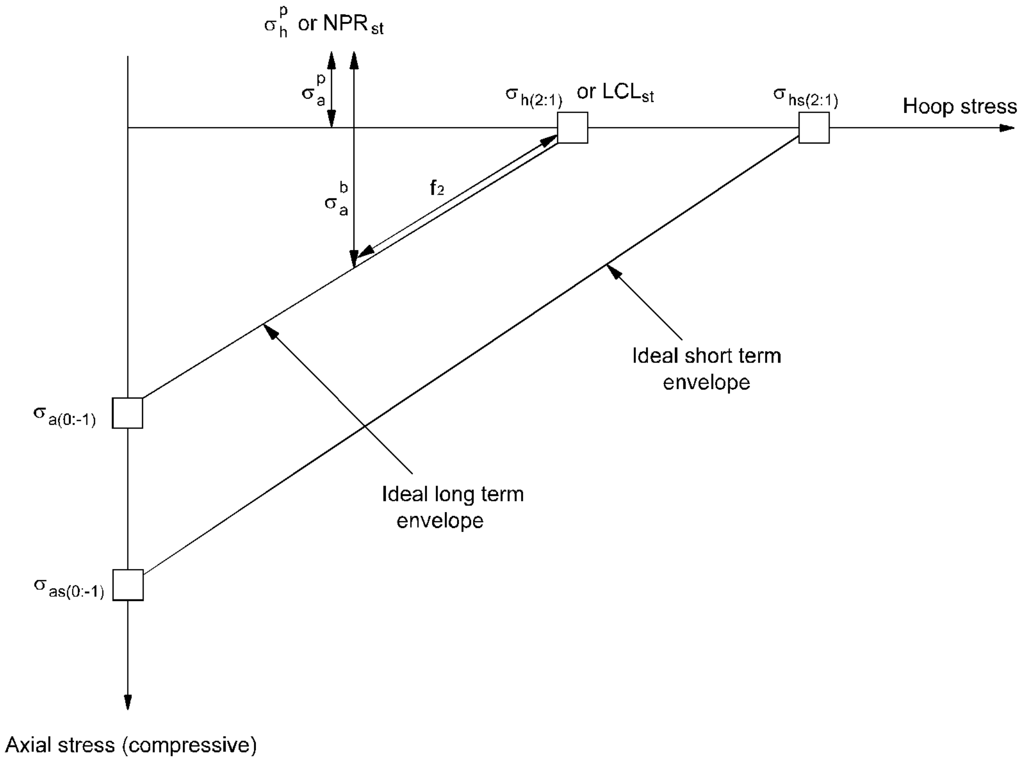
If the short term axial tensile strength, $\sigma_{as(0:1)}$, is unknown then a conservative estimate can be made by assuming it is equal to half the short term axial strength at the 2:1 condition, $\sigma_{as(2:1)}$, i.e.

$$\sigma_{as(0:1)} = \frac{\sigma_{as(2:1)}}{2} = \frac{\sigma_{hs(2:1)}}{4}$$

3.1.3.2 System design, axial compression and internal pressure (continued)

For some applications, e.g. large diameter drain or sewer systems, the possibility arises of axial compressive loads being superimposed on internal pressure loads. (Figure E.3.1.3.2) shows a design envelope for a tensile hoop with compressive axial stress for a single wound angle ply GRP pipe with winding angle in the range of approximately 45° to 75°.

FIGURE E.3.1.3.2 Ideal long term envelope for a single wound angle ply GRP pipe with winding angles in the range of approximately 45° to 75°



It is constructed from the following steps. An idealised short term envelope is inferred from the actual short term envelope using two data points $\sigma_{as(0:-1)}$ and $\sigma_{hs(2:1)}$ defined as:

$\sigma_{as(0:-1)}$ = short term axial compressive strength at the 0:-1 condition (i.e. zero pressure, axial compression test).

$\sigma_{hs(2:1)}$ = short term hoop tensile strength at the 2:1 condition (i.e. internal pressure test).

NOTE: The numbers in brackets refer to the ratio of hoop to axial stress.

If the short term axial compressive strength, $\sigma_{as(0:-1)}$, is unknown then a conservative estimate can be made by assuming it is equal to one-third the short term hoop strength at the 2:1 condition, $\sigma_{hs(2:1)}$, i.e.

$$\sigma_{as(0:-1)} = -\frac{\sigma_{hs(2:1)}}{3}$$

The idealised long term failure envelope is geometrically similar to the short term envelope and is derived using two data points $\sigma_{a(0:-1)}$ and $\sigma_{h(2:1)}$ (or LCL_{st}) defined as:

$$\sigma_{a(0:-1)} = \sigma_{as(0:-1)} \frac{\sigma_{h(2:1)}}{\sigma_{hs(2:1)}}$$

$$\sigma_{h(2:1)} = LCL_{st}$$

For adequate design the sum of the axial stress	$\sigma_a^b + \sigma_a^p$	must lie within the long term design envelope.
The non-induced axial stress	σ_a^b	can be calculated using standard industry-approved

manual or computer methods (See Section 6 for details).

The pressure induced axial stress σ_a^p is calculated from the NPR_{st}.

If the sum of these stresses lies outside the long term design envelope then the next higher pressure rated pipe from the product family must be chosen and the stress calculation repeated until the sum of the stresses lies within the long term design envelope.

Add new section:

3.1.4 Bends and fittings

The system design procedure of (Section 3.1.3) is also applicable to both bends and fittings. For the purposes of the design calculation for fittings, an equivalent $(LCL_{st})_{CV}$ is required. It is taken as the product of the $(LCL_{st})_{PSR}$ of the product sector representative times the ratio $(STHP)_{CV}/(STHP)_{PSR}$, i.e.

$$\left(LCL_{st}\right)_{CV} = \left(LCL_{st}\right)_{PSR} \frac{(STHP)_{CV}}{(STHP)_{PSR}} \frac{10^{G}}{10^{G_{CV}}}$$

Or if 1 000 hour test data is available, $(LCL_{st})_{CV}$ is defined as;

$$\left(LCL_{st}\right)_{CV} = \left(LCL_{st}\right)_{PSR} * \frac{\left(\text{Test Pressure}_{1000}\right)_{CV}}{\left(\text{Test Pressure}_{1000}\right)_{PSR}} \frac{10^{G}}{10^{G_{CV}}}$$

The calculation of the component variant $(LCL_{st})_{CV}$ 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.

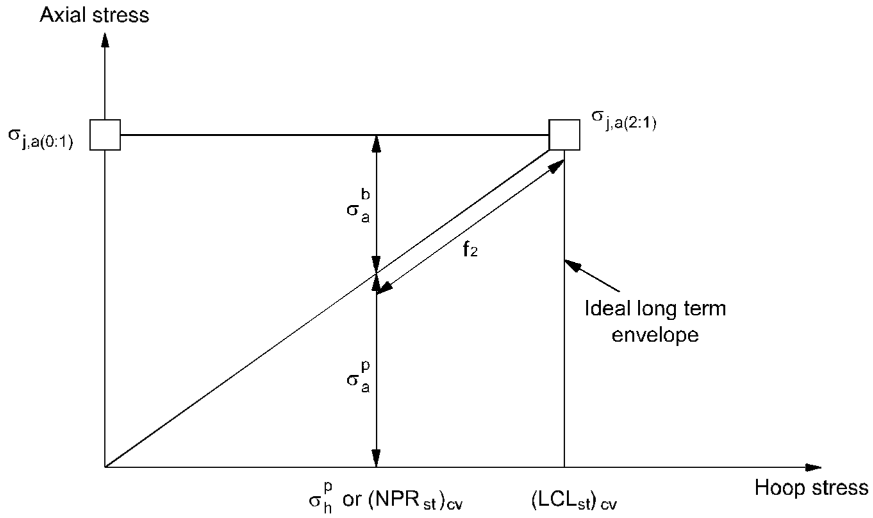
NOTE: For all fittings the failure envelope is based on the short term axial strength. Manufacturers are required to measure the short term axial strength as part of the qualification data requirements.

3.1.4.1 Joints

Replace entire section with the following:

Joints, either adhesive or threaded, are limited by the axial tensile strength. This implies that the long term failure envelope will be rectangular, with the edges determined by the $(LCL_{st})_{Joint}$ and the long term axial strength of the joint, $\sigma_{j,a(0:1)}$. The design envelope is shown in (Figure E.3.1.4.1).

Figure E.3.1.4.1 Ideal long term envelope for GRP joints



In (Figure E.3.1.4.1), $\sigma_{j,a(2:1)}$ is defined as:

$$\sigma_{j,a(2:1)} = \frac{(LCL_{st})_{CV}}{2}$$

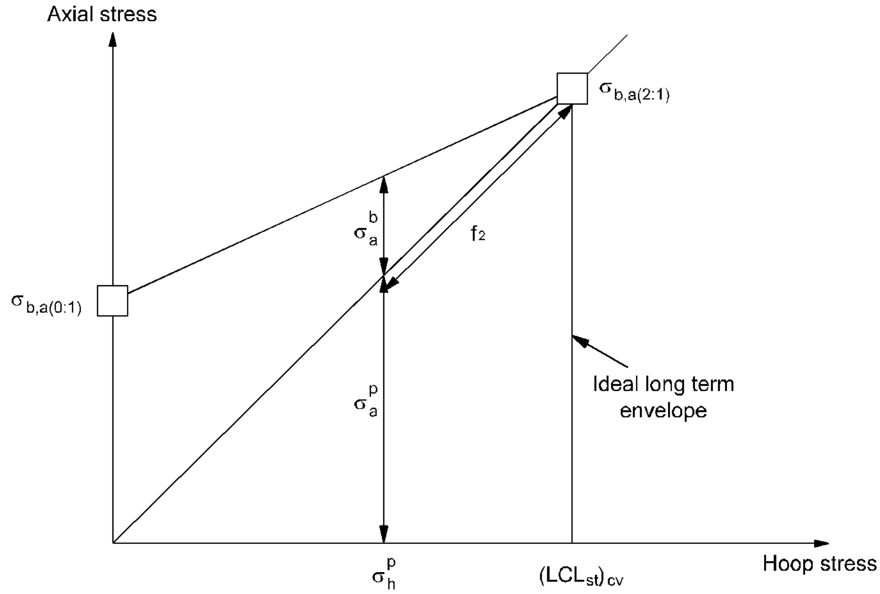
3.1.4.2 Bends

Replace this section with the following:

The response of bends to pressure induced axial and bending loads is more complex than the equivalent loads on a straight pipe. Application of a bending moment causes ovalisation resulting in both induced axial and hoop stresses. The ratio of the induced hoop to axial stresses resulting from bending can for example range between 2.1 and 2.8 depending on the direction of loading, in-plane or out-of-plane. Therefore, stresses within bends and their direction become complex and cannot easily be related to applied pressure and tensile loads. There are no analytical expressions which can be used to calculate stresses within bends and as a consequence of this, relationships for pressure stress multipliers, stress intensification factors and flexibility factors available in piping codes are empirical.

The potential of applied pressure and bending loads to induce axial as well as hoop stresses results in a conservative approach to defining the long term strength of a GRP bend. The long term axial strength, $\sigma_{b,a(0:1)}$ is taken as one-half the long term axial strength at the 2:1 condition, $\sigma_{b,a(2:1)}$. This is the same as in the conservative approach to the system design of straight pipes. The design envelope using these constraints is shown in (Figure E.3.1.4.2).

Figure E.3.1.4.2 Ideal long term envelope for GRP bends



To include bends in piping system design calculations, the following parameters are required: flexibility factor, stress intensification factors and pressure stress multipliers. The following empirical relationships for these parameters are based on BS 7159. The assumptions and restrictions of the empirical formulae must be considered when using these relationships in a piping system design. In particular, attention should be paid to the wall thickness of the adjoining pipe. The empirical correlations for flexibility factor, pressure stress multipliers and stress intensification factors assume that the wall thickness of the bend iss 1.75 times the wall thickness of the pipe.

NOTE: In terms of laminate types as described in BS 7159, only type 3 laminates are considered.

3.1.4.2.1 Flexibility factor (κ_b)

The flexibility factor $\kappa_b$for GRP bends is based on the pipe factor, λ_b, and an axial pressure correction factor, δ_a

where λ_b is given by:

$$\lambda_b = \frac{4t_b R}{D_i^2}$$

where:

t_b = average wall thickness of the reinforced laminate of the bend (mm)

D_i = internal diameter of the main body of the bend (mm)

R = mean pipe bend radius (mm).

If R is not available then assume R = 1.5 D_i.(see Table E.3.1.4.2 for details).

NOTE: The wall thickness of the reference laminate is defined as the wall thickness of the equivalent pipe section used for modelling purposes in the piping system design calculations.

and where δ_a is given by:

$$\delta_a = \frac{1}{\left(1 + 2.53\varepsilon_d \left(\frac{R}{t_b}\right)^{1/3} \left(\frac{D_i}{2t_b}\right)\right)}$$

where:

ε_d = design strain (mm/mm)

$$\varepsilon_d = \frac{P}{10E_a}\frac{(D_i + t_b)}{2t_b}$$

P = applied pressure (bar)
E_a = axial modulus (N/mm^2)

The flexibility factor for smooth bends is given as a function of λ_b, see (Table E.3.1.4.2):

$$\kappa_b = \delta_a \frac{0.77}{\lambda_b}\frac{t_{pipe}}{t_b}$$

The flexibility factor for mitred bends is given as a function of λ_b, see (Table E.3.1.4.2):

$$\kappa_b = \delta_a \frac{0.64}{(\lambda_b)^{0.83}}\frac{t_{pipe}}{t_b}$$

where t_{pipe} is the reinforced wall thickness of the adjacent pipe.

An upper limit, based on experience, is placed on κ_b. For either smooth or mitred bends it shall not be greater than 3.

3.1.4.2.2 Stress intensification factor (SIF_b)

For bends, smooth or mitred, four stress intensification factors, SIF_b, are required to quantify the principal stresses. They are:

$SIF_{b,xi}$ - axial SIF under in-plane bending
$SIF_{b,xo}$ - axial SIF under out-of-plane bending
$SIF_{b,hi}$ - hoop SIF under in-plane bending
$SIF_{b,ho}$ - hoop SIF under out-of-plane bending

These SIF_b's are functions of the pipe factor, λ_b, the axial pressure correction factor, δ_a, and the hoop pressure correction factor, δ_h where δ_h is given by:

$$\delta_h = \frac{1}{\left(1 + 1.1\varepsilon_d\left(\frac{R}{t_b}\right)^{2/3}\left(\frac{D_i}{2t_b}\right)^{5/6}\right)}$$

The axial SIF under in-plane bending for a smooth bend, $SIF_{b,xi,}$ is given by (see (Table E.3.1.4.2)):

$$SIF_{b,xi} = \delta_a \frac{0.76}{(\lambda_b)^{2/3}}$$

The axial SIF under in-plane bending for a mitred bend, $SIF_{b,xi,}$ is given by (see (Table E.3.1.4.2)):

$$SIF_{b,xi} = \delta_a \frac{0.5}{(\lambda_b)^{2/3}}$$

The axial SIF under out-of-plane bending for a smooth bend, $SIF_{b,xo}$ is given by (see (Table E.3.1.4.2)):

$$SIF_{b,xo} = \delta_a \frac{0.56}{(\lambda_b)^{2/3}}$$

The axial SIF under out-of-plane bending for a mitred bend, $SIF_{b,xo}$, is given by (see (Table E.3.1.4.2)):

$$SIF_{b,xo} = \delta_a \frac{0.51}{(\lambda_b)^{2/3}}$$

The hoop SIF under in-plane bending for a smooth bend, $SIF_{b,hi,}$ is given by (see (Table E.3.1.4.2)):

$$SIF_{b,hi} = \delta_h \frac{1.6}{(\lambda_b)^{2/3}}$$

The hoop SIF under in-plane bending for a mitred bend, $SIF_{b,hi,}$ is given by (see (Table E.3.1.4.2)):

$$SIF_{b,hi} = \delta_h \frac{1.2}{(\lambda_b)^{2/3}}$$

The hoop SIF under out-of-plane bending for a smooth bend, $SIF_{b,ho}$, is given by (see (Table E.3.1.4.2)):

$$SIF_{b,ho} = \delta_h \frac{1.58}{(\lambda_b)^{2/3}}$$

The hoop SIF under out-of-plane bending for a mitred bend, $SIF_{b,ho}$, is given by (see (Table E.3.1.4.2)):

$$SIF_{b,ho} = \delta_h \frac{1.53}{(\lambda_b)^{2/3}}$$

An upper limit, based on experience, is placed on all four SIF_b 's. No SIF_b shall be greater than 2.5.

3.1.4.2.3 Pressure stress multiplier (PSM_b)

The pressure stress multiplier, PSM_b or m_b, for smooth bends shall be 1. For mitred bends PSM_b or m_b shall be 1.3 (see (Table E.3.1.4.2)).

3.1.4.2.4 Stress analysis

The purpose of the stress analysis is to calculate an effective hoop and axial stress which can then be used to assess whether the stress levels in the bend are within acceptable limits, i.e. within the failure envelope as defined in (Figure E.3.1.4.2).

The effective hoop and axial stresses, $\sigma_{h,eff,b}$ and $\sigma_{a,eff,b}$ (MPa) are given by:

$$\sigma_{h,eff,b} = \sqrt{(\sigma_{h,p} + \sigma_{h,b})^2 + 4\sigma_s^2}$$

$$\sigma_{a,eff,b} = \sqrt{(\sigma_{a,p} + \sigma_{a,b})^2 + 4_s^2}$$

where,

$\sigma_{h,p}$ = circumferential pressure stress (MPa) = $\frac{m_b P(D_i + t_b)}{20 t_b}$

$\sigma_{a,p}$ = axial pressure stress (MPa) = $\frac{P(D_i + t_b)}{40 t_b}$

$\sigma_{h,b}$ = circumferential bending stress (MPa) = $\frac{(D_i + 2t_b)}{2I_b}\sqrt{(SIF_{b,hi}M_i)^2 + (SIF_{b,ho}M_o)^2}$

$\sigma_{a,b}$ = axial bending stress (MPa) = $\frac{(D_i + 2t_b)}{2I_b}\sqrt{(SIF_{b,xi}M_i)^2 + (SIF_{b,xo}M_o)^2}$

σ_s = torsional stress (MPa) = $1.5\frac{M_s(D_i + 2t_b)}{4I_b}$

P = applied pressure (bar)

M_i = applied in-plane bending moment (Nmm)

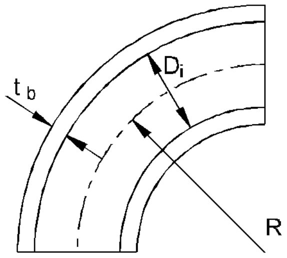
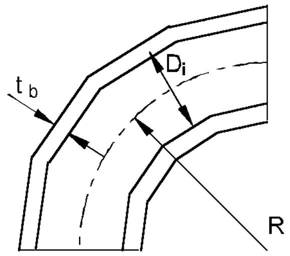
M_o = applied out-of-plane bending moment (Nmm)

M_s = applied torsional moment (Nmm)

I_b = second moment of area (mm4) = $\frac{p}{64}\left([D_i + 2t_b]^4 - D_i^4\right)$

If the stresses $\sigma_{h,eff,b}$ and $\sigma_{a,eff,b}$ lie inside the long term failure envelope then the bend is designed within acceptable limits. If the stresses lie outside the long term failure envelope, then a higher rated bend, i.e. thicker walled bend must be chosen and the stress calculations repeated.

Table E.3.1.4.2 Piping design factors for bends

Bends	Smooth	Mitred
Diagram		
Pipe factor	$\lambda_b = \frac{4t_bR}{D_i^2}$	
Axial pressure correction factor	$\delta_a = \frac{1}{\left(1+2.53\varepsilon_d\left(\frac{R}{t_b}\right)^{1/3}\left(\frac{D_i}{2t_b}\right)\right)}$	
Hoop pressure correction factor	$\delta_h = \frac{1}{\left(1+1.1\varepsilon_d\left(\frac{R}{t_b}\right)^{2/3}\left(\frac{D_i}{2t_b}\right)^{5/6}\right)}$	
Flexibility factor	$\kappa_b = \delta_a \frac{0.77}{\lambda_b}\frac{t_{pipe}}{t_b}$	$\kappa_b = \delta_a \frac{0.64}{\lambda_b^{0.83}}\frac{t_{pipe}}{t_b}$
SIF axial/in-plane	$SIF_{b,xi} = \delta_a \frac{0.76}{(\lambda_b)^{2/3}}$ with $SIF_{b,xi} \leq 2.5$	$SIF_{b,xi} = \delta_a \frac{0.5}{(\lambda_b)^{2/3}}$ with $SIF_{b,xi} \leq 2.5$
SIF axial/out-of-plane	$SIF_{b,xo} = \delta_a \frac{0.56}{(\lambda_b)^{2/3}}$ with $SIF_{b,xo} \leq 2.5$	$SIF_{b,xo} = \delta_a \frac{0.51}{(\lambda_b)^{2/3}}$ with $SIF_{b,xo} \leq 2.5$
SIF hoop/in-plane	$SIF_{b,hi} = \delta_h \frac{1.6}{(\lambda_b)^{2/3}}$ with $SIF_{b,hi} \leq 2.5$	$SIF_{b,hi} = \delta_h \frac{1.2}{(\lambda_b)^{2/3}}$ with $SIF_{b,hi} \leq 2.5$
SIF hoop/out-of-plane	$SIF_{b,ho} = \delta_h \frac{1.58}{(\lambda_b)^{2/3}}$ with $SIF_{b,ho} \leq 2.5$	$SIF_{b,ho} = \delta_h \frac{1.53}{(\lambda_b)^{2/3}}$ with $SIF_{b,ho} \leq 2.5$
Pressure stress multiplier	1	1.3

3.1.4.3 Tees

Replace this section with the following:

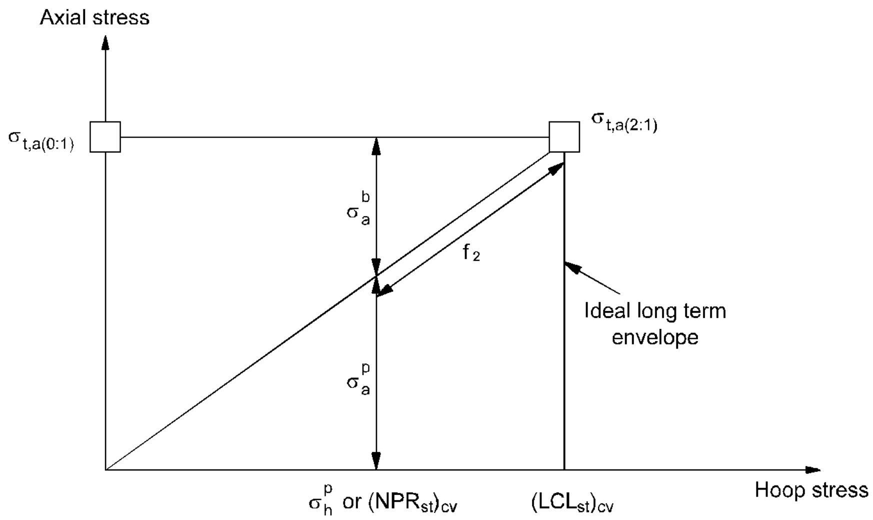
At the intersection point of tee sections, stresses and their direction become complex and cannot easily be related to applied pressure and tensile loads. There are no analytical expressions which can be used to calculate stresses within tees and, as a consequence of this, relationships for pressure stress multipliers, stress intensification factors and flexibility factors available in piping codes are empirical.

NOTE: From recent work within the Marinetech Programme - Composites for Offshore Use, where typical tee sections were loaded under combined bending and internal pressure, the following conclusions can be drawn:

- Maximum stress intensification factors due to pressure are of the order of unity and are located in the intersection region.
- Maximum stress intensification factors due to bending are also of the order of unity. Additional stresses due to bending can therefore be added to pressure stresses.

It is the intersection region which governs component performance, and therefore the design envelope for tees is therefore similar to that for joints, (Section 3.1.4.1). That is, failure under tensile load is dominated by axial 'pull out' at the intersection of the pipe and tee and under pressure is dominated by weepage. This implies that the long term failure envelope will be rectangular, with the edges determined by the $(LCL_{st})_{CV}$ and the long term axial strength of the tee, $\sigma_{t,a(0:1)}$. The design envelope for GRP tees is shown in (Figure E.3.1.4.3).

Figure E.3.1.4.3 Ideal long term envelope for GRP tees



In Figure E.3.1.4.3, $\sigma_{t,a(2:1)}$ is defined as:

$$\sigma_{t,a(2:1)} = \frac{(LCL_{st})_{CV}}{2}$$

To include tees in piping system design calculations, the following parameters are required: flexibility factor, stress intensification factors, and pressure stress multipliers. The following empirical relationships for these parameters are based on BS 7159. The assumptions and restrictions of the empirical formulae must be considered when using these relationships in a piping system design.

NOTE : In terms of laminate types as described in BS 7159, only type 3 laminates are considered.

3.1.4.3.1 Flexibility factor (κ_t)

The flexibility factor, κ_t, for GRP tees irrespective of whether the tee is equal or unequal, moulded or fabricated shall be 1 (see (Table E.3.1.4.3)).

3.1.4.3.2 Stress intensification factor (SIF_t)

The stress intensification factor, SIF_t, for tees is non-directional and is a function of the pipe factor, λ_t, where λ_t is given by:

$$\lambda_t = \frac{2t_t}{D_i}$$

where:

t_t = average wall thickness of the reinforced laminate of the tee (mm)

D_i = internal diameter of the main body of the tee (mm)

(see Table E.3.1.4.3 for details)

NOTE : The wall thickness of the reference laminate is defined as the wall thickness of the equivalent pipe section used for modelling purposes in the piping system design calculations.

The stress intensification factor is given as a function of λ_t:

$$SIF_t = \frac{0.66}{(\lambda_t)^{0.5}}$$

An upper limit, based on experience, is placed on SIF_t . It shall not be greater than 2.3.

3.1.4.3.3 Pressure stress multiplier (PSM_t)

The pressure stress multiplier, PSM_t, for tees is non-directional and is a function of the pipe factor, λ_z, where λ_z is given by;

$$\lambda_z = \lambda_t \text{ for equal tees}$$

$$\lambda_z = \frac{\left(\frac{2t_{br}}{D_b}\right)^2}{I_t} \text{ for unequal tees}$$

where:

t_{br} = average wall thickness of the branch laminate of the tee (mm)

D_b = internal diameter of the branch of the tee (mm)

(see Table E.3.1.4.3 for details)

The pressure stress multiplier, m_t, is given as a function of λ_z:

$$m_t = \frac{1.4}{(\lambda_z)^{0.25}}$$

An upper limit, based on experience, is placed on m_t. It shall not be greater than 3.

$$\sigma_{h,eff,b} = \sqrt{(\sigma_{h,p} + \sigma_{h,b})^2 + 4\sigma_s^2}$$

$$\sigma_{a,eff,b} = \sqrt{(\sigma_{a,p} + \sigma_{a,b})^2 + 4\sigma_s^2}$$

The effective hoop and axial stresses $\sigma_{h,eff,t}$ and $\sigma_{a,eff,t}$ (MPa) are given by:

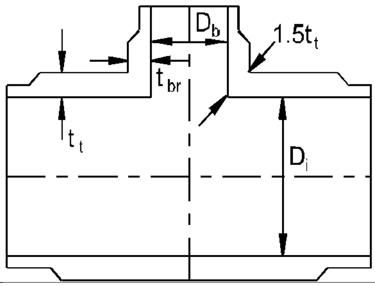
$\sigma_{h,p}$ = circumferential pressure stress (MPa) = $\frac{m_b P(D_i + t_t)}{20t_t}$

$\sigma_{a,p}$ = axial pressure stress (MPa) = $\frac{P(D_i + t_t)}{40t_b}$

$\sigma_{h,b}$	=	circumferential bending stress (MPa)	= $\frac{(D_i + 2t_t)}{2I_b}\sqrt{(SIF_{b,hi}M_i)^2 + (SIF_{b,ho}M_o)^2}$
$\sigma_{a,b}$	=	axial bending stress (MPa)	= $\frac{(D_i + 2t_t)}{2I_b}\sqrt{(SIF_{b,xi}M_i)^2 + (SIF_{b,xo}M_o)^2}$
σ_s	=	torsional stress (MPa)	= $1.5\frac{M_s(D_i + 2t_t)}{4I_b}$
P	=	applied pressure (bar)	
M_i	=	applied in-plane bending moment (Nmm)	
M_o	=	applied out-of-plane bending moment (Nmm)	
M_s	=	applied torsional moment (Nmm)	
I_b	=	second moment of area (mm4)	= $\frac{\pi}{64}\left([D_i + 2t_t]^4 - D_i^4\right)$

If the stresses, $\sigma_{h,eff,b}$ and $\sigma_{a,eff,b}$, lie inside the long term failure envelope then the bend is designed within acceptable limits. If the stresses lie outside the long term failure envelope, then a higher rated bend, i.e. thicker walled bend must be chosen and the stress calculations repeated.

Table E.3.1.4.3 Piping design factors for tees

Diagram	 	
Flexibility Factor	$\kappa_t = 1$	
Pipe Factor	$\lambda_t = \frac{2t_t}{D_i}$	
Stress Intensification Factor	$SIF_t = \frac{0.66}{(\lambda_t)^{0.5}}$ with $SIF_t \le 2.3$	
Pipe factor	Equal tee	Unequal tee
	$\lambda_z = \lambda_t$	$\lambda_z = \frac{\left(\frac{2t_{br}}{D_b}\right)^2}{\lambda_t}$
Pressure Stress Mulitplier	$m_t = \frac{1.4}{(\lambda_z)^{0.25}}$ with $m_t \le 3$	

3.2 CHEMICAL DEGRADATION

At the end of this section, add the following:

If there is evidence that the transported fluids degrade the pipe material faster than the fluids used in the regression and qualification tests, then additional long term testing, either further regression or 1 000 hour tests, should be considered.

3.3 CYCLIC VERSUS STATIC RATINGS

Replace this section with the following:

3.3 CYCLIC/STATIC SERVICE

Manufacturers may assign their products either static or cyclic ratings, i.e. $LTHP_S$ or $LTHP_C$ and corresponding NPR_S or NPR_C. Piping components may be selected for either static or cyclic service based on either an $LTHP_S$ or $LTHP_C$ using (Part D, Table D.2.1.3.3). If the $LTHP_C$ of the component is unknown then it can be estimated from:

$$LTHP_C = \frac{LTHP_S}{4}$$

NOTE: Components for cyclic service may be qualified from static qualification data. Components for static service shall not be qualified from cyclic qualification data.

3.4 DESIGN TEMPERATURE RANGE

Before the last sentence, insert the following:

For service temperatures of minus 35 °C and lower, the Principal should consider the need for additional testing at the design temperature. Both qualification and additional mechanical tests should be considered.

4. LAYOUT CONSIDERATIONS

Add to the list of system design requirements the following:

- external pressure loading
- interfaces/connections from other systems.

4.1 NOMINAL PRESSURE RATINGS

Add to the list of nominal pressure ratings the following:

55, 70, 85, 100, 135, 170, 205, 240, 275

4.2 NOMINAL DIMENSIONS

4.2.1 Nominal diameters

Add to the list of nominal diameters the following:

1 400, 1 600, 1 800, 2 000, 2 400

4.2.4 Support spacing

Replace this section with the following:
For minimum span length requirements refer to (Part D, Section 3.2.4).

4.2.5 Minimum thickness

Replace this section with the following:
For minimum thickness requirements refer to (Part D, Section 2.1.7).

4.3 SITE JOINTS

Replace first sentence with the following:

GRP piping systems should be designed to maximise shop-fabrication of piping spools for assembly on site.

The term “site joint” applies to both onshore and offshore applications. The specific joint types and the length of “cut-to-fit” that will be installed on site shall be agreed between the Principal and Manufacturer. The minimum “cut-to-fit” length should be 150 mm for pipes and 250 mm for pipe spools.

4.4 ISOLATION

Extra care is required with electrically conductive piping to ensure that the removal of a spool does not break the electrical conductivity of the system. Where appropriate, additional earthing shall be provided.

5. HYDRAULIC DESIGN

5.3 VELOCITY LIMITATIONS

Replace Table 5.3 with the following:

Table E.5.3 Flow velocity

	Normal flow (m/s)	**Maximum intermittent flow** (m/s)
Liquid	1 to 4	10
Gas	1 to 10	20

NOTE: The above values are based on the assumption that there are no hard particles present in the flow. Higher velocities (even with hard particles) can be tolerated but an assessment of the potential erosion rate shall be made.

5.3.2 Water hammer

Replace this section with the following:

5.3.2 Pressure surges

Pressure surges are created by a change in momentum of the moving fluid stream, e.g. by fast closing a valve, the origin of the pressure surge being at the point where the momentum of flow is changed. The longer the line and the higher the liquid velocity, the greater the surge pressure will be. Because of the low density of gases, compared to liquids, pressure surges are not of concern in gas transport applications.

Pressure surges may be minimised by the use of surge tanks or by increasing actuated valve closing times.

The theoretical maximum surge pressure that would be caused by an instantaneous total blockage of the flow, occurring at the point of flow retardation, e.g. a valve, is the sum of two components:

a) the instantaneous pressure increase at the instant of flow blockage;

b) the subsequent gradual pressure increase due to the “line packing” effect.

The increase in instantaneous surge pressure i.e. the pressure rise above normal operating pressure, shall be calculated from:

$$P_i = \rho c \Delta v * 10^{-6}$$

where,

P_i = instantaneous pressure change (N/mm^2)
c = wave velocity (m/s)

ρ = liquid density (kg/m^3)
Δv = change in flow velocity (m/s).The wave velocity, c, shall be calculated from the following formula:

$$c = \sqrt{\frac{K/\rho}{1 + \frac{DK * 10^{-6}}{E_h t}}}$$

where,

K = bulk modulus fluid (N/m^2) (for water, K = 1962*10^6 N/m^2 at 0 °C, 1 bar)
ρ = fluid density (kg/m^3) (for water, ρ = 1 000 kg/m^3)
D = pipe inside diameter (mm)

E_h = hoop modulus (N/mm^2)
t = reinforced wall thickness (mm)

The gradual pressure increase due to line packing shall be calculated as follows:

If no protective measures are taken, the pressure due to line packing at the point of closure will continue to rise until the positive surge travelling upstream has reached the constant pressure end-point (e.g. a tank) and returned to the valve.

The duration of line packing, t (secs), is given by;

$$t = \frac{2L}{c}$$

where L = length of pipeline section (m)

The pressure rise can be calculated using (Figure E.5.3.2), where

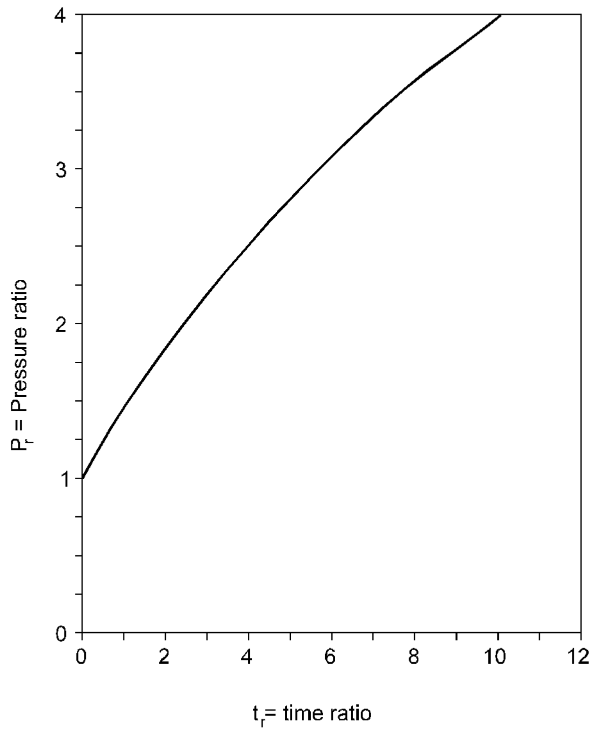
P_r = pressure ratio, defined as P_{ts}/P_i
P_i = initial surge pressure (N/mm^2)
P_{ts} = total surge pressure (N/mm^2)

and

t_r = time ratio, defined as $t\frac{P'c}{P_i}$

P' = pressure gradient for steady state flow ($N/mm^2/m$)

Figure E.5.3.2 Pressure surge due to line packing



If a potentially critical surge problem exists, then a more thorough analysis should be performed by modelling the pipeline or piping system using a transient pressure simulation program.

The total transient pressure, i.e. operating plus surge pressure, shall not exceed 1.5 times the f_2*LCL.

5.3.3 Erosion

Replace this section with the following:

The recommended normal and intermittent flow limits in Table E-5.3 are for fluids with no particulates. Lower flow velocities need to be applied where there are solid particulates.

During the transport of fluids containing hard particles, abrasion or erosion of GRP can occur. The term abrasion or erosion can be used to describe GRP material removal (loss) due to sliding and impacting particles, respectively. At relatively low velocities (<10 m/s), material loss will be mainly caused by abrasion/wear, whereas material loss due to erosion will take place at much higher velocities (>25 m/s). In general, hard particle erosion of GRP is approximately 3 to 10 times higher than for steels. In a combined erosive/corrosive environment, the difference in erosion between GRP and steel is often lower. Because GRP is a brittle material, maximum erosion damage occurs at a hard particle impingement angle of 90 degrees, i.e. at bends and tees. At low impingement angles (< 5 degrees), i.e. at relatively straight sections, erosion damage will be minimal. Only at velocities higher than 25 m/s is loss of material due to hard particle erosion of concern.

To significantly reduce the risk of erosion problems at critical locations, e.g. bends, tees, etc., lining of the GRP component with a thermoplastic material, e.g. PE, PP or PU, should be considered. To minimise potential erosion damage in GRP pipe systems, the following should be avoided:

(i) sudden changes in flow direction;
(ii) local flow restrictions or initiators of flow turbulence, e.g. excessive adhesive at the inside diameter of bonded connections (adhesive beads).

Further information on erosion can be obtained in DNV RP O501.

5.4 VACUUM

Replace section heading with the following:

5.4 EXTERNAL PRESSURE / VACUUM RESISTANCE

6. STRUCTURAL DESIGN

6.1 ANALYSIS METHODS

Add new paragraph at end of section:

In the following sections various design formulae are presented. Other formulae can be used instead of the presented ones, but must be demonstrated to the Principal's satisfaction to be both valid and applicable.

6.2 ANALYSIS REQUIREMENTS

Add to the list of information the following:

- external loads (e.g. soil/backfill loads); and
- connections: type, location, support type (e.g. anchor, guide).

6.3 MATERIAL PROPERTIES

Delete this Section and replace with the following:

6.3.1 Stress/strain analysis

Manufacturers attempt to optimise the performance of GRP pipes for the 2:1 pressure condition. This implies that the material behaviour is anisotropic and therefore the hoop modulus is greater than axial modulus.

The material properties for GRP pipes/piping systems relevant for system design are:

E_a = Young's modulus in the axial direction
E_h = Young's modulus in the hoop direction
ν_{ha} = Poisson's ratio, axial to hoop strain resulting from a stress in the hoop direction
ν_{ah} = Poisson's ratio, hoop to axial strain resulting from a stress in the axial direction
G = Shear modulus
α_a = Coefficient of thermal expansion in the axial direction
α_h = Coefficient of thermal expansion in the hoop direction

NOTE: $$\frac{\upsilon_{ha}}{E_h} = \frac{\upsilon_{ah}}{E_a}$$

Typical values for the above mentioned properties for 55° filament wound glass fibre reinforced matrix pipe with a glass volume fraction of 55% for Epoxy, Vinylester and Polyester resins are given in (Table E.6.3.1):

Table E.6.3.1 Typical material properties

Material property	**Value**
E_a (MPa)	12 000
E_h (MPa)	22 000
ν_{ha}	0.55
ν_{ah}	0.30
G (MPa)	11 000
α_a (µm/m°C)	15
α_h (µm/m°C)	12

The relevant strains and stresses for GRP pipes/piping systems for system design are:

ε_a = Strain in axial direction
ε_h = Strain in hoop direction
ε_{sh} = Shear strain (in-plane)
σ_a = Stress in the axial direction
σ_h = Stress in the hoop direction
σ_{sh} = Shear stress (in-plane)

The strains for a given applied stress are given by:

$$\varepsilon_a = \frac{\sigma_a}{E_a} - \nu_{ha}\frac{\sigma_h}{E_h}$$

$$\varepsilon_h = -\nu_{ah}\frac{\sigma_a}{E_a} + \frac{\sigma_h}{E_h}$$

$$\varepsilon_{sh} = \frac{\sigma_{sh}}{G}$$

Conversely, the stresses for a given applied strain are given by;

$$\sigma_a = \frac{E_a}{(1 - \nu_{ha}\nu_{ah})}(\varepsilon_a + \nu_{ha}\varepsilon_h)$$

$$\sigma_h = \frac{E_h}{(1 - \nu_{ha}\nu_{ah})}(\varepsilon_h + \nu_{ah}\varepsilon_a)$$

$$\sigma_{sh} = G\varepsilon_{sh}$$

6.4 DESIGN CODES

Add the following new paragraph:

For pipelines, the following design standards should be referred to:

ANSI/ASME B31.4, ANSI/ASME B31.8 and DEP 31.40.00.10-Gen.

6.5 LOADS

Replace this Section with the following:

Designers shall consider the following loads, see (Table E.6.5), that can potentially be experienced by the piping system during the anticipated service life.

Table E.6.5 Loads experienced by a GRP piping system

Static	Dynamic
internal, external or vacuum pressure, hydrotest	water hammer, equipment vibrations
piping self weight, piping insulation, transported medium, buoyancy, other system loads	impact
thermal induced loads	adiabatic cooling loads
environmental loads, ice	earthquake, wind
	blast over-pressures
encapsulation in concrete	
soil loads (burial depth)	soil subsidence

6.6 COMPONENT VERIFICATION

The following sections describe the allowable stresses and deflections plus procedures to calculate the various stresses and deflections. (Section 6.6.1) describes the allowable stress failure envelope. (Section 6.6.2) describes the maximum allowable deflections. The remaining sections define the procedures for calculating the stresses and deflections.

Replace this section with the following:

6.6.1 Allowable stresses

6.6.1.1 External pressure loads; allowable stresses

For external pressure (Section 6.6.4), vacuum loads (Section 6.6.5) and buckling loads (section 6.6.8), P_{load}, the allowable load or pressure, P_{allow}, is given by

$$P_{allow} = \frac{P_{load}}{SF}$$

where,

for short term loads, SF = 1.5

for long term loads, SF = 3

NOTE: Short term is defined as incidental or "one-off" – Long term is defined as continous.

For soil loads (Section 6.6.11.1), to prevent the collapse of a buried pipe, the external soil pressure $P_{ext,soil}$ (bar) must be less than the collapse resistance of the pipe, P_c (bar), i.e. (this collapse resistance pressure is defined in Section 6.6.4):

$$P_{ext,soil} < P_c$$

$$\text{where } P_{ext,soil} = \frac{4}{\pi D_o}\left[D_o(h+\frac{D_o}{2}) - \frac{\pi D_o^2}{8} + \frac{1}{3}(h+\frac{D_o}{2})^2\right]\gamma_s$$

If soil loading plus vacuum occurs, then

$$P_{ext,soil} + P_{vac} < P_c$$

Where P_{vac} (bar) is the vacuum pressure.

6.6.1.2 Internal pressure loads + axial tension

The general requirement is that the component stresses, i.e. the sum of all axial stresses and the sum of all hoop stresses (pressure plus system design) shall fall within the long term design envelope.

The ideal long term failure envelopes for pipes and bends are described in Sections (3.1.3.1) and (3.1.4.2), respectively. Relevant long term loads are described in Table E.6.5.

Where the safety factor, f_2, is defined using the hoop stresses, the long term design envelope is defined as:

$$\sigma_h^{total} \le f_2 * LCL_{st}$$

and

$$\sigma_a^{total} \le f_2 * \left[\left(\sigma_{a(2:1)} - \sigma_{a(0:1)}\right)\frac{\sigma_h^{total}}{LCL_{st}} + \sigma_{a(0:1)}\right]$$

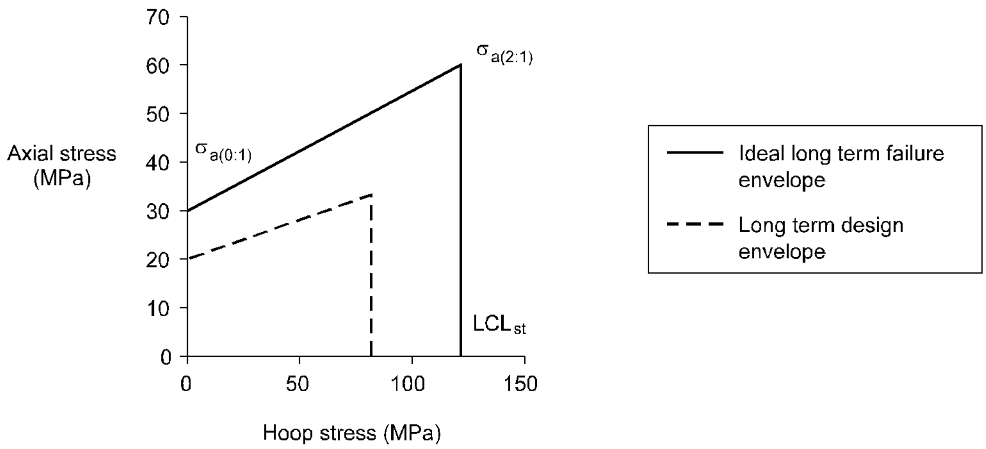
In the above criterion, σ_h^{total} is the sum of all hoop stresses and

σ_a^{total} is the sum of all axial stresses.

If the component stresses lie outside the long term design envelope then the next higher pressure rated system shall be used and the component stresses recalculated. This procedure shall be repeated until the component stresses lie inside the long term design envelope.

An example of the design envelope is presented in Figure E.6.6.10.2a. In the Figure the long term strength values, typical for Glass/Epoxy pipes, are LCL_{st} = 120 MPa, $\sigma_{a(2:1)}$ = 60 MPa, $\sigma_{a(0:1)}$ = 30 MPa.

Figure E.6.6.1.2a Long term design envelope for pipes and bends for internal pressure plus axial tension



The ideal long term failure envelopes for joints and tees are described in Sections (3.1.4.1) and (3.1.4.3) respectively. Relevant long term loads are described in (Table E.6.5).

Where the safety factor, f_2, is defined using the hoop stresses, the long term design envelope is defined as:

$$\sigma_h^{total} \leq f_2 * LCL_{st}$$

and

$$\sigma_a^{total} \leq f_2 * \sigma_{a(0:1)}$$

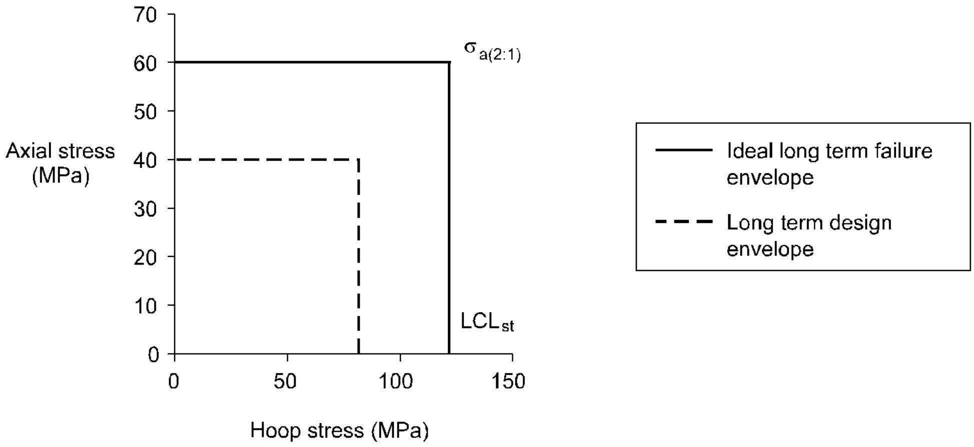
In the above criterion, σ_h^{total} is the sum of all hoop stresses and

σ_a^{total} is the sum of all axial stresses.

If the component stresses lie outside the long term design envelope then the next higher pressure rated system shall be used and the component stresses recalculated. This procedure shall be repeated until the component stresses lie inside the long term design envelope.

An example of the design envelope is presented in Figure E.6.6.1.2b. In the Figure the long term strength values, typical for Glass/Epoxy pipes, are LCL_{st} = 120 MPa, $\sigma_{a(2:1)}$ = 60 MPa.

Figure E.6.6.1.2b Long term design envelope for joints and tees for internal pressure plus axial tension



The safety factors presented previously represent the minimum required safety factors. Depending on the area or country of application, further additional safety factors may be required as determined by the local regulatory authority. Consultation with the local regulators is recommended to define the allowable safety factors during the design process.

6.6.1.3 Internal pressure loads; axial compression

The general requirement is that the component stresses, i.e. the sum of all axial stresses and the sum of all hoop stresses (pressure plus system design) shall fall within the long term design envelope.

The ideal long term failure envelopes for all components are described in Section 3.1.3.2. Relevant long term loads are described in Table E.6.5.

Where the safety factor, f_2, is defined using the hoop stresses, the long term design envelope is defined as:

$$\sigma_a^{total} \leq \sigma_{a(0:-1)} * \left[f_2 - \frac{\sigma_h^{total}}{LCL_{st}} \right]$$

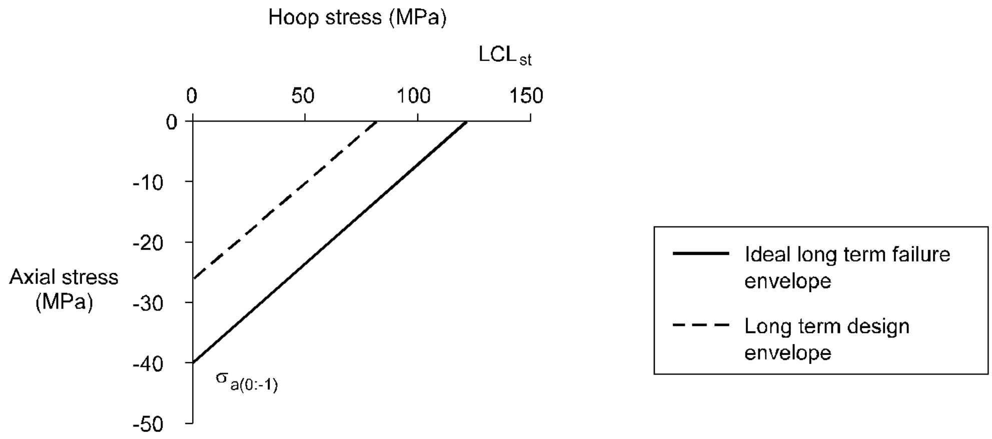
In the above criterion, σ_h^{total} is the sum of all hoop stresses and

σ_a^{total} is the sum of all axial stresses.

If the component stresses lie outside the long term design envelope then the next higher pressure rated system shall be used and the component stresses recalculated. This procedure shall be repeated until the component stresses lie inside the long term design envelope.

An example of the design envelope is presented in Figure E.6.6.1.3. In the Figure the long term strength values, typical for Glass/Epoxy pipes, are LCL_{st} = 120 MPa, $\sigma_{a(0:-1)}$ = -40 MPa.

Figure E.6.6.1.2c Long term design envelope for pipes and components for internal pressure plus axial compression



The safety factors presented previously represent the minimum required safety factors. Depending on the area or country of application, further additional safety factors may be required as determined by the local regulatory authority. Consultation with the local regulators is recommended to define the allowable safety factors during the design process.

6.6.2 Allowable deflections

6.6.2.1 Deflection

Deflections shall not exceed the lesser of 12.5 mm or 0.5% of span length or support spacing.

Where the Manufacturer's minimum support spacings are not exceeded then deflections shall be within these allowable limits. It should be agreed between the Principal and the Manufacturer that the quoted minimum support spacings do not result in deflections greater than prescribed.

6.6.2.2 Ovalisation

Ovalisation relative to pipe diameter shall not exceed 5%.

6.6.3 Internal pressure

The pressure rating (f_2*LCL) of all pipes and fittings as determined in (Part D) shall be equal or greater than the design pressure of the piping system.

6.6.3.1 Free standing pipes (unrestrained ends)

The change in axial length, ΔL_{ax} (mm), due to internal pressure of a straight length of pipe, L (mm), shall be calculated from the following formula:

$$\Delta L_{ax} = \frac{L}{E_a}\left(\frac{1}{2} - \nu_{ah}\right)\frac{P_i(D+t)}{20t}$$

where:

P_i = internal pressure (bar)

D = average pipe diameter (mm)

t = reinforced wall thickness (mm)

6.6.3.2 Buried pipelines (restrained ends)

The induced axial stress, σ_{ax} (N/mm2), and axial load, F_{ax} (N), due to internal pressure shall be calculated from the following formula:

$$\sigma_{ax} = \frac{E_a}{E_h} \nu_{ha} \frac{P_i(D + t)}{20t}$$

and

$$F_{ax} = \sigma_{ax} \pi D t$$

6.6.4 External pressure

External over-pressure resistance, P_c (bar), shall be calculated using the following formula:

$$P_c = \frac{10}{12(1 - \nu_{ah}\nu_{ha})} \left(\frac{t}{R}\right) \left[\left(\frac{\pi R}{L}\right)^4 \frac{\left(E_a - \nu_{ha}{}^2 E_h\right)}{4} + \left(\frac{t}{R}\right)^2 \left(3E_h + \frac{1}{4}\left(\frac{\pi R}{L}\right)^2 \left(E_h\left(1 + 7\nu_{ah}\right) + 14G\left(1 - \nu_{ah}\nu_{ha}\right)\right)\right)\right]$$

where:

t	=	reinforced wall thickness of the pipe (mm)
R	=	mean pipe radius, pipe centre to mid-wall (mm)
L	=	length of pipe section (mm)

NOTE: Unit of modulus is MPa, whereas unit of external pressure, P_c, is bar. Definitions of Modulus and Poisson's ratio are given in (Section 6.3.1).

If the length of pipe section is much greater than the mean pipe radius, i.e. L > 10*R, the above equation reduces to:

$$P_c = \frac{10}{4(1 - \nu_{ah}\nu_{ha})} \left(\frac{t}{R}\right)^3 E_h$$

6.6.5 Vacuum

Resistance to vacuum pressure, P_v (bar), which is defined as the difference between the external and internal absolute pressures, shall be calculated using the following formula:

$$P_v = \frac{10}{12(1 - \nu_{ah}\nu_{ha})} \left(\frac{t}{R}\right) \left[\left(\frac{\pi R}{L}\right)^4 \frac{\left(E_a - \nu_{ha}{}^2 E_h\right)}{4} + \left(\frac{t}{R}\right)^2 \left(3E_h + \frac{1}{4}\left(\frac{\pi R}{L}\right)^2 \left(E_h\left(7\nu_{ah} - \frac{3}{2}\right) + 14G\left(1 - \nu_{ah}\nu_{ha}\right)\right)\right)\right]$$

where:

P_{va}	=	allowable vacuum pressure (bar)

NOTE: Unit of modulus is MPa, whereas unit of external over-pressure, P_V, is bar. Definitions of Modulus and Poisson's ratio are given in (Section 6.3.1). Definitions of dimensions are given in (Section 6.6.4).

If the length of pipe section is much greater than the mean pipe radius, i.e. L > 10*R, the above equation reduces to:

$$P_v = \frac{10}{4(1 - \nu_{ah}\nu_{ha})} \left(\frac{t}{R}\right)^3 E_h$$

6.6.6 Cyclic excitation and vibration

GRP pipe has a lower stiffness in both axial and hoop directions than the equivalent steel pipe. This implies a different dynamic response when subjected to external dynamic forces.

Low amplitude vibrations of magnitude much less than the wall thickness can be dampened and absorbed although the designer should ensure that the vibration does not cause chafing of supports, over-stress in branch lines, or fatigue of adhesive bonds.

High amplitude vibrations of a magnitude roughly equal to or greater than the wall thickness from pumps or other equipment shall be accounted for in the system design and where possible minimised through appropriate design. The resulting stresses from such vibrations should always be included in the system design.

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

If the predicted number of pressure or other loading cycles exceeds 7 000 over the design life, then the designer shall determine the design cyclic severity, R, of the piping system. R is defined as:

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

where F_{min} and F_{max} are the minimum and maximum loads (or stresses) of the load (or stress) cycle. Where account is taken of the variation in cyclic amplitude, the equivalent or effective hoop stress, $\sigma_{h,eff}$, is given by:

$$\sigma_{h,eff} = \sigma_{h,max}\sqrt{1-R^2}$$

where $\sigma_{h,max}$ is the maximum hoop stress of the loading cycle.

NOTE: This formula is only valid for the range $0 < R < 0.8$

6.6.8 Buckling

For axial compressive system loads, e.g. constrained thermal expansion or vertical pipe runs with end compressive loads, and a given length of unsupported pipe, L (m), the axial compressive load should not exceed $F_{ax,allow}$ (kN), defined using the following formula:

$$F_{ax,max} = \frac{\pi^3 R^3 t}{L^2} E_a \left(1 + \frac{1}{3}\left(\frac{t}{R}\right)^2 \left(1 - \frac{\nu_{ah} G}{2E_a}\right)\right) * 10^{-9}$$

where,

E_a = axial modulus (N/mm^2)

G = shear modulus (N/mm^2)

ν_{ah} = Poisson's ratio, hoop to axial strain from a stress in the axial direction

t = reinforced wall thickness (mm)

R = pipe radius (mm)

6.6.9 Thermal loads

6.6.9.1 Unrestrained pipes

The variation in length, ΔL (mm), and diameter, ΔD (mm), due to a temperature difference of an unrestrained pipeline shall be calculated using the following formula:

$$\Delta L = L\alpha_a \Delta T$$
$$\Delta D = D\alpha_h \Delta T$$

where $\Delta T = T_{op} - T_{ins}$, i.e. the difference between the operating temperature, T_{op}, and installed temperature, T_{ins}, (K), and the other symbols are as previously defined.

6.6.9.2 Axially restrained pipes

The induced thermal axial stress, $\sigma_{a,T}$ (MPa), due to axial restraint shall be calculated using the following formula:

$$\sigma_{a,T} = -E_a \alpha_a \Delta T$$

and the corresponding hoop strain from:

$$\varepsilon_h = (\alpha_h + \nu_{ah}\alpha_a)\Delta T$$

6.6.9.3 Residual stresses (only applicable at temperatures lower than minus 35 °C)

Residual stress can become significant in low temperature applications, particularly at temperatures below minus 35 °C. These residual stresses are generated as the change in dimension of the overall structure of the pipe is different to the change in dimension of the individual plies that make up the overall pipe structure. This difference generates the internal residual stresses, the magnitude of which is strongly dependent on the pipe wall lay-up.

To calculate the residual stresses, the thermal expansion coefficients of the individual plies in the axial and hoop directions, $\alpha_{a,ply}$ and $\alpha_{h,ply}$, are required. Typical values for a glass fibre reinforced Epoxy, Vinylester or Polyester pipe, 55% fibre volume fraction, winding angle 55° are:

$\alpha_{a,ply}$ = 22 µm/m°C
$\alpha_{h,ply}$ = 14 µm/m°C

The residual axial and hoop stresses, $\sigma_{a,r}$ and $\sigma_{h,r}$, (MPa), shall be calculated using the following formulae:

$$\sigma_{a,r} = \frac{E_a}{(1-\nu_{ah}\nu_{ha})}\left(\alpha_{a,ply} - \alpha_a + \nu_{ha}\left(\alpha_{h,ply} - \alpha_h\right)\right)\Delta T$$

$$\sigma_{h,r} = \frac{E_h}{(1-\nu_{ah}\nu_{ha})}\left(\alpha_{h,ply} - \alpha_h + \nu_{ah}\left(\alpha_{a,ply} - \alpha_a\right)\right)\Delta T$$

where,

$$\Delta T = T_{op} - (T_g - 30)$$

T_{op} = operating temperature (°C)

T_g = glass transition temperature (°C)

6.6.10 Bending loads

The additional axial tensile stress induced through bending, $\sigma_{a,b}$ (MPa), of the GRP pipe shall be calculated using one of the following formulae. If the bending radius is given then:

$$\sigma_{a,b} = \frac{E_a(R_i + t_w)}{R_{bend}}$$

where:

R_{bend} = bending radius, measured to the pipe neutral axis (mm)
R_i = pipe inner radius (mm)
t_w = total wall thickness (mm)

Otherwise, if the applied in-plane moment, M_i (MN mm), is given;

$$\sigma_{a,b} = \frac{M_i(R_i + t_w)}{I}$$

where:

I = second moment of area about an axis through the centroid normal to the pipe axis (mm^4)

= $\frac{\pi}{4}\left(R_o^4 - R_i^4\right)$ which for thin walled pipes = $\pi R_i^3 t_w$

R_o = pipe outer radius (mm)

6.6.11 Soil loads

6.6.11.1 Stresses and deflections due to soil loading

The vertical soil load, W_c (N/m), acting on the pipe shall be calculated using the following formula:

$$W_c = g\gamma_s h D_o$$

where:

γ_s = specific soil density (kg/m^3)
(in absence of specific data assume γ_s = 2 000 kg/m^3)
g = acceleration of gravity, 9.81 m/s^2
h = burial depth, height of soil (m)
D_o = outer pipe diameter (m)

The live load, W_l (N/m), due to transient passing loads, e.g. trucks, shall be calculated using the following formula:

$$W_l = C_L L_{wh}\left(1.766 - 0.436h\right)$$

where:

L_{wh} = wheel load (N)
C_L = live load coefficient (1/m)

For single wheel load, C_L is given by:

$$C_L = 1 - \frac{2}{p}\arcsin\left[h * \sqrt{\frac{D_o^2/4 + h^2 + 0.25}{\left(D_o^2/4 + h^2\right)\left(h^2 + 0.25\right)}}\right] + \frac{D_o h}{2\pi}\frac{\left(\frac{1}{D_o^2/4 + h^2} + \frac{1}{h^2 + 0.25}\right)}{\sqrt{D_o^2/4 + h^2 + 0.25}}$$

For two passing trucks, C_L is given by:

$$C_L = \frac{3D_o}{ph^2}\left[\left(\cos\left\{\arctan\left(\frac{0.5}{h}\right)\right\}\right)^5 + \left(\cos\left\{\arctan\left(\frac{2.3}{h}\right)\right\}\right)^5\right]$$

The vertical deflection or ovalisation of the pipe, Δy (mm), caused by both vertical soil and live loads shall be calculated using the following formula:

$$\Delta y = \frac{\frac{0.15\left(D_L W_c + W_l\right)}{E_h}\left(\frac{D_o}{t}\right)^3 * 10^6}{1 + 0.09\frac{E_{soil}}{E_h}\left(\frac{D_o}{t * 10^{-3}}\right)^3}$$

The maximum allowable vertical deflection or ovalisation based on pipe diameter is 5% i.e.

$$\frac{\Delta y}{D} \le 0.05$$

The additional hoop stress, $\sigma_{h, soil}$ (N/mm^2), caused by both vertical soil and live loads shall be calculated using the following formula:

$$\sigma_{h,soil} = D_f (1 - \frac{P}{30}) E_h \frac{\Delta y}{D_o} \frac{t}{D_o} * 10^{-6}$$

NOTE: For operating pressures above 30 bar, $\sigma_{h, soil}$ is assumed to be zero.

where:

P = operating pressure (bar)

t = reinforced wall thickness (mm)

D_f = shape factor (typically in the range 4 to 6)

D_L = deflection lag factor, (D_L = 1.5 for slight degrees of compaction, D_L = 2 for high degrees of compaction)

E_h = Young's modulus in the hoop direction (N/mm^2)

E_{soil} = modulus of soil reaction (N/mm^2) (E_{soil} ranges typically from 1 to 20 N/mm^2)

For a full description of soil loadings, refer to ANSI/AWWA C950.

6.6.11.2 Buoyancy

If the water table (or level) is at ground level then a check for buoyancy effects is required. The combined load, F_{down}, (N/m) due to the sum of loads, weight of the soil, W_s, (N/m) plus weight of pipe, W_p, (N/m) and its contents, W_i, (N/m) has to be greater than the upwards buoyancy force, F_{up}, i.e.

$$W_s + W_p + W_i = F_{down}$$

where

$$W_s = D_o \gamma_s h (1 - \frac{h_w}{3h})$$

and

$$F_{down} \geq F_{up}$$

where

$$F_{up} = \frac{\pi}{4} D_o^2 \gamma_w$$

In the above,

h_w = height of water above top of pipe (m)

h = height of soil above top of pipe (m)

γ_w = specific water density (kg/m^3)

7. OTHER DESIGN ASPECTS

7.2 IMPACT

7.2.1 General

Replace this section with the following:

Refer to (Part D, Section 2.2.3).

7.3 ELECTRIC SURFACE HEATING

Replace the second paragraph with the following:

Electrical heat tracing shall be carried out in accordance with DEP 33.68.30.32-Gen.

7.4 ACCUMULATION OF SCALE DEPOSITS

Add the following:

Pipeline pig traps shall be designed in accordance with DEP 31.40.10.13-Gen.

7.5 FIRE

7.5.3 Fire protection coatings

Add the following to the end of the section:

- the fire risk (fire zone) for the area in which the piping is installed;
- the type, grade and diameter(s) of pipe;
- the jointing system(s) used;
- whether the piping is ‘dry’ or contains stagnant or flowing water; and
- the type and thickness of passive fire protective coating.

The fire protection requirements for piping shall be evaluated from the dry exposure time and total endurance time established in the safety case for the facility.

Utilising the dry exposure time and total endurance time from the safety case for the facility, the designer shall assess whether passive fire protective coating needs to be applied to above-ground GRP piping systems. The design shall reference hydrocarbon fire curve data (the so-called NPD or Mobil curve) to substantiate the decisions taken for the presence (or absence) of a fire protective coating and the type and thickness of coating to be applied. Although the total fire endurance time is related to the time required for personnel to evacuate an area or facility, it should be noted that in some cases, where asset protection requirements are imposed, a longer total endurance time may be needed for process and storage areas with a liquid hydrocarbon inventory.

7.5.5 Pressure and flow retention

Delete from the last sentence the word "is".

Add the following new section:

7.6 BURIED PIPELINES

When considering the design of buried pipelines, the designer shall consider the following issues:

- settlement of the soil and the potential for induced stresses;
- road crossings;
- pipe attachments to the surface (i.e. risers). Particular attention should be paid to supports and the consequent induced stresses;
- pigging.

Add the following new section:

7.7 INSPECTION STRATEGY

During the design phase of a GRP piping system or pipeline it is important to define, up-front, the inspection strategy and operational procedures. The anisotropic nature of GRP means that only limited inspection methods can be used and therefore the inspection strategy will differ from "normal steel" strategies. Provisions and requirements for inspections during the operational lifetime may have consequences for the design of the system. The inspection strategy and chosen methods have to focus on the specific properties of GRP. GRP will not corrode but the material and resistance properties will degrade in certain operating environments. The inspection strategy must be able to monitor these properties in relation to the initial design basis (e.g. regression line) and the required lifetime. The inspection methods are presently limited to visual external and internal (video camera), some NDT techniques (e.g. US and X-rays), hydro-testing and destructive testing.

Add the following new section:

7.8 REPAIR PROCEDURE

Repair procedures should be taken into account during the design stage of any GRP pipeline or piping system project.

8. DETAIL CONSIDERATIONS

8.1 JOINTS

In the list of joint types, replace "other mechanical joints" *by*:

- threaded joints

Add to second paragraph the following sentence:

For onshore applications the same joint types are also applicable but for high pressure applications threaded connections may also be used.

8.1.4 Flanged joints

Add at end of section:

In order to achieve reliable flange sealing, even with relatively low bolt tensioning, so-called G-ST type gaskets (steel ring reinforced elastomer) should be used. Only soft type elastomers should be used, preferably with a hardness of about Shore A 60. The gasket material shall match the pressure, temperature and chemical resistance capabilities of the piping system. In general, Teflon envelope type of gaskets are not recommended and should not be used for larger diameters and higher pressures.

8.1.5 Threaded connections

Replace this section with the following:

Three types of threaded connections are available for both high and medium pressure pipe systems:

1. Male/Male joint, using a coupler with standard API threads (e.g. EUE 10RD, EUE 8RD, so called round threads), see (Figure E.8.1.5a);
2. Female/Male threaded "integral" joint with standard API threads and sealing via the threads using PTFE tape and/or special compounds as recommended by the Manufacturer, see (Figure E.8.1.5b);
3. Female/Male course threaded "integral" joint, including O-ring for sealing, see (Figure E.8.1.5c).

To reduce friction and enhance sealing performance, thread fillers may be used, e.g. graphite and/or ceramic particles. PTFE-based lubricants may also be used to reduce friction, i.e. to facilitate low make and break torque. Threaded end connections shall meet the requirements of API Specification 15 HR - Section 5.3.

Threaded end connections which conform to API standards shall meet the requirements of API Specification 15 HR. Threaded end connections which are the design of the Manufacturer shall meet the specification e.g. manufacturing quality, surface finish etc., of the Manufacturer.

Figure E.8.1.5a Standard API joint

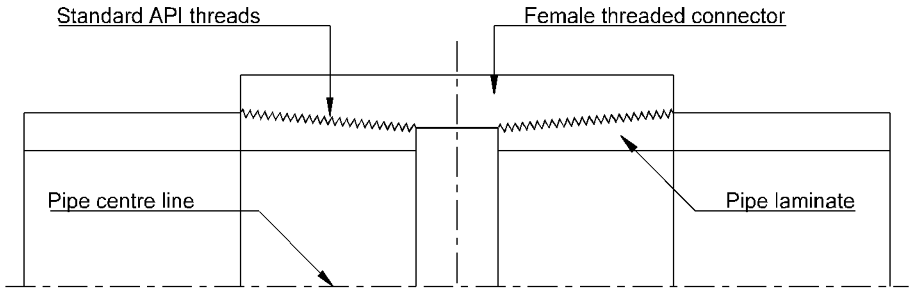


Figure E.8.1.5b Integral joint (API thread)

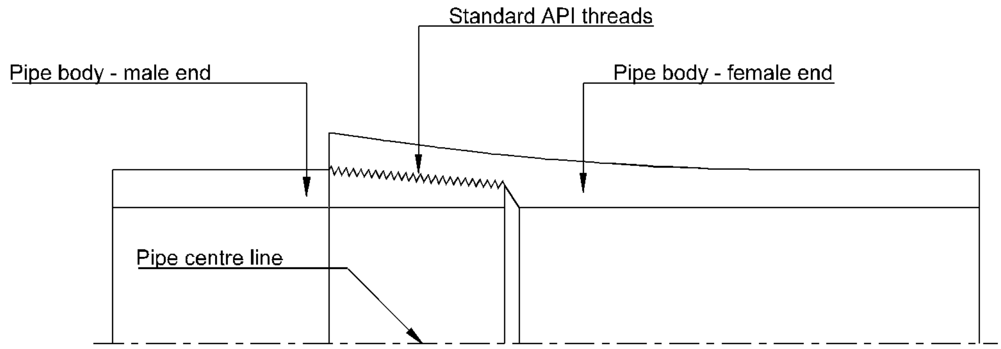
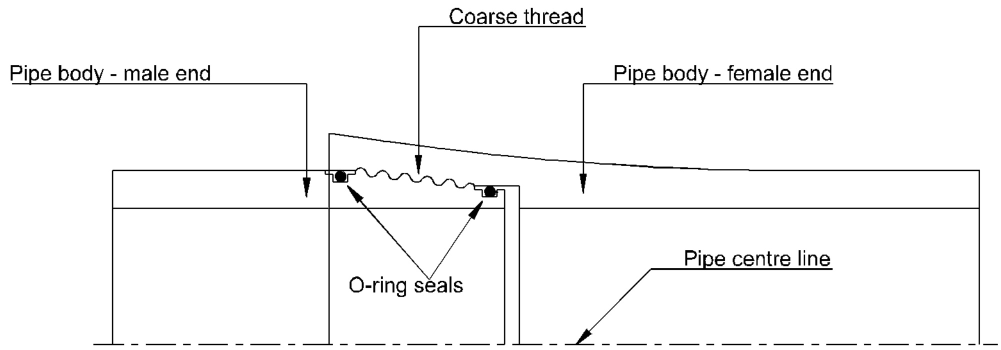


Figure E.8.1.5c Integral thread (coarse thread + O-ring seals)



8.1.6 Metallic/GRP interfaces

In the first sentence, replace the word "should" *by* "shall".

8.3 SUPPORTS

In the fourth paragraph, replace the word "should" *by* "shall".

Add new section:

8.4 POTENTIAL DESIGN/SYSTEM IMPLEMENTATION PROBLEMS

The designer should be aware of the types of design-related problems that have been experienced in onshore and offshore installations. This knowledge will enable the designer to avoid potential shortcomings during installation and commissioning. The following design-related problems have all been experienced and are listed in order from worst to least consequences:

DEFECT	CONSEQUENCE(S)
Bad dimensioning, improper placement of field joints	- Joint failure (poor piping design/layout may result in pipe spools being manufactured to spec. but difficult to install resulting in poor quality mechanical or adhesive joints)
Improper design of branches, nozzles	- Branches or nozzles < 100 mm diameter are susceptible to mechanical damage resulting in leakage
Improper supporting of valves, pipe	Failure of pipe resulting from e.g.: - vibration from pumps on small diameter pipe - not installing pipe supports prior to pressure testing - excessive loads imposed on pipe due to unsupported valves
Improper placement or opening of valves, incorrect dimensioning of pipe	- Resulting water hammer can cause pipe weepage or burst
Transitions, above/below ground	- Shear failure of pipe - Induced axial loads causing joint pull-out
Use of incorrect accessories; gaskets, bolts, supports, valves, other fittings	- Corrosion (using incorrect specs. can result in greater than expected corrosion of metallic components) - Leakage (e.g. from incorrect gaskets, etc.)

9. FIRE PERFORMANCE

9.7 PIPE-SYSTEM FIRE CLASSIFICATION CODE (TYPE TEST ENVELOPES)

Replace this section with the following:

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 is 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 whether an updated and endorsed version is available.

The Fire Classification Code is designated by a five field number: **1.2.3/xxx-(4.5)** where:

1	=	fluid or fluid state;
2	=	fire type;
3/xxx	=	integrity/duration;
4	=	fire reaction: spread of fire and heat release;
5	=	fire reaction: smoke and toxicity.

The minimum standard (default value **Z**) is indicative of either unlimited or unquantified performance. A value **Z** for a particular performance category **3**, **4** or **5** is indicative of the non-availability of fire test data.

1	**=**	**Fluid or fluid state**
	= A	flammable gas
	= B	hydrocarbon or other flammable liquid
	= C	chemical service (consult corrosion guide)
	= D	empty
	= E	initially empty for minimum of 5 minutes followed by flowing water
	= F	initially empty for minimum of 1 minute followed by flowing water
	= G	stagnant water
	= H	initially stagnant water for a minimum of 5 minutes followed by flowing water
	= I	initially stagnant water for a minimum of 1 minute followed by flowing water
	= J	flowing water
	= Z	other non-critical water based service
2	**=**	**Fire Type (heat flux in kW/m^2)**
	= A	full scale jet fire (>400)
	= B	medium scale jet fire (300 to 400) [SWRI, Sintef]
	= C	large hydrocarbon pool fire (158 ± 8) [ASTM E1529-93]
	= D	impinging flame (113.6) [ASTM F 1173-95 and IMO A.753(18)]
	= E	hydrocarbon fire [NPD]
	= F	hydrocarbon fire mitigated by cooling effects of firewater sprinkler system {hold at 650 °C after 5 minutes}
	= G	cellulosic fire [BS 476 Part 20]
	= H	cellulosic fire mitigated by cooling effects of firewater sprinkler system {hold at 650 °C after 5 minutes}
	= Z	other less severe fire exposure
3/xxx	**=**	**Integrity/Duration** **Integrity**
3	**= A**	complete integrity maintained, capable of resumed service after fire
	= B	no leakage at rated pressure during or after fire
	= C	no leakage within 15 minutes at rated pressure when cooled after fire
	= D	leakage less than 0.2 litres/min at rated pressure when cooled after a fire

	= E	leakage less than 2% of rated flow at rated pressure when cooled after fire
	= F	leakage less than 10% of rated flow when cooled after a fire
	= O	no structural collapse, unlimited leakage allowed
	= Z	no requirements
		Duration
/XXX	**= /020**	endurance greater than 20 minutes
	= /030	endurance greater than 30 minutes
	= /060	endurance greater than 60 minutes
	= /120	endurance greater than 2 hours
	= /180	endurance greater than 3 hours
4	**=**	**Fire Reaction: Spread of Fire and Heat Release**
	= A	no spread of fire permitted
	= B	spread of fire is limited (SOLAS class 1)
	= C	spread of fire is limited (SOLAS class 3)
	= D	spread of fire is limited (SOLAS class 3)
	= E	spread of fire unlimited or not quantified
	= **Z**	no test data available
5	**=**	**Fire Reaction: Smoke and Toxicity**
	= A	representative of needs within a safe area
	= B	levels must not exceed 10 minute emergency exposure level
	= C	levels must be acceptable within evacuation time
	= D	levels are limited
	= E	levels unlimited or not quantified
	= Z	no test data available

Whilst the number of test scenarios 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 the code for GRP.

a) **F.B.D/120-(D.Z)** 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) **I.F.E/060-(B.C)** 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 an area subject to fire, and smoke and toxicity levels must remain acceptable within the evacuation time.
c) **Z.G.Z/000-(A.A)** represents 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) **B.E.A/120-(D.D)** represents systems containing hydrocarbons 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, e.g. blast, endurance time, pressure and flow retention, fire spread and smoke/toxicity levels achieved during testing.

ANNEX A CALCULATION OF EXTERNAL COLLAPSE PRESSURE OF GRP PIPES

Delete this Annex.

PART F AMENDMENTS/SUPPLEMENTS TO THE UKOOA "SPECIFICATIONS AND RECOMMENDED PRACTICE FOR THE USE OF GRP PIPING OFFSHORE: PART 4 - FABRICATION AND INSTALLATION

1. SCOPE

Add at end of section:

This document is also applicable to shop spool fabrication irrespective of location and both onshore and offshore installation.

Interchangeability of different Manufacturers' products is not permitted.

2. DELIVERY INSPECTION

2.1 INSPECTION

In the fifth paragraph, replace "(Table 2.2)" *with the following:*

(Part D, Appendix D.1, Table 1.1)

After the fifth paragraph, add the following new paragraph:

If a minor repair of damaged pipe and/or piping component is permitted, the repair shall be carried out in accordance with the Manufacturer's recommended procedures.

2.2 DEFECT EVALUATION

Delete this Section.

2.3 DOCUMENTATION

Replace this section with:

Refer to Part D, Section 7.5.2.

Clear project specific markings shall be made on the outside of all pipes and fittings to simplify traceability for QA/QC procedures.

3. HANDLING AND STORAGE

3.2 STORAGE

3.2.4 Adhesive/Resin system

Add at the end of first paragraph:

The shelf life of the adhesive kits and resin systems shall be recorded to enable them to be used in chronological sequence.

3.2.5 Ancillaries

Add to the list of ancillary materials in brackets the following:

sealant,

Final part of last sentence to read as follows:

"... biological growth, extremes of temperature and Manufacturers' recommended shelf-life."

Add new section:

3.2.7 Long term storage

For pipes and fittings that have to be stored for a period of 3 months or more after delivery from the manufacturing plant, consideration should be given to appropriate storage procedures. Where possible use the Manufacturer’s recommended guidelines.

Storage using “poly-pack” is recommended to prevent movement of the pipes and fittings during storage thereby minimising potential damage. Tarpaulins to cover the pipe storage rack are also recommended.

Add new section:

3.2.8 After storage inspection

Pipes and fittings that have been in storage for 3 months or longer should be inspected as outlined in (Part F Section 2.1).

4. INSTALLATION METHODS

4.1 CUTTING

Add the following new sentence:

Threads shall not be cut in the field.

In the fourth paragraph, insert after the second sentence:

Alternative equipment shall be subject to the Manufacturer's approval prior to application.

4.3 INSTALLATION

4.3.1 General requirements

Add at end of section:

During fabrication and installation open fire and/or steel welding in the vicinity of GRP shall not be permitted without proper protection of the GRP and approval from the Principal.

In general, during installation, it is recommended that an inspector approved by the GRP Manufacturer is present, with sufficient authority to check and approve the installation procedure and to prevent unacceptable deviations from the project schedule.

4.3.2 Tolerances

In Table 4.3.2, in the Column headed "ID", replace the entry "1000 -1200" by:

1 000 and higher

4.4 JOINTING

In the list of joint types, replace "other mechanical joints" *with the following*:

threaded joints;

After the first paragraph, insert the following:

Jointing shall be done by installation Contractors who are approved by the Manufacturer, following procedures which are fully in accordance with the Manufacturer's instructions and using personnel qualified in the jointing method being used (refer to Part F, Section 5).

For critical connections such as field jointing of large diameter pipes, on-site supervision by an experienced representative of the pipe Manufacturer should be considered.

4.4.1 Adhesive-bonded joints

Add at the start of this section:

A bonding procedure specification shall be prepared in accordance with the GRP Manufacturer's recommendations and shall be approved by the Principal. It shall cover the preparation, cutting, cleaning, assembly, adhesive type, mixing instructions, curing times, curing temperatures, ambient conditions and humidity. It shall also include details of tests required to assess joint integrity.

4.4.1.1 Preparation

Replace second paragraph with:

Manufacturer's recommendations regarding preparation and adhesive application at the appropriate temperature and humidity shall be followed. The temperature and humidity at the site shall be monitored daily. Spools shall be fabricated in a clean/separate enclosed environment. All field joints made onshore shall be protected from the environment by an approved enclosure method, with protection from welding sparks, impacts etc. Offshore all field adhesive joints shall be performed inside an enclosed habitat (where possible) providing full protection from the external environment.

4.4.1.3 Assembly

Add to the third paragraph the following:

If it is suspected that an internal adhesive bead is present, then immediately after making the joint a ball with diameter just less than the pipe's internal diameter should be dragged through the pipe and joint to remove the excess adhesive. The same method may be used where concern about erosion calls for any reduction of internal diameter to be minimised.

Replace the fourth and fifth paragraphs with:

Piping up to 150 mm in diameter may be assembled by hand. The proper insertion of straight spigot connections is verified by measuring the reference mark of the spigot (it should be 25 mm from the bell). Fit up shall be done without hammering.

Piping that cannot be assembled by hand and connections with a diameter of 200 mm or larger shall be assembled with a ratchet winch or hydraulic pullers. All temporary attachments for fitting up joints e.g. hydraulic pullers, clamps etc. must be in place prior to the adhesive being applied to the joint. After the adhesive has been applied, joints shall be completed immediately. No delay shall be accepted. Spigots shall be inserted until they bottom against pipe stop and the reference marks are in their fully home position.

Add new paragraph at end of section:

Any supports required to keep the joint together shall remain in place until the curing operation is complete. The methods of support must be clearly outlined in an assembly procedure.

4.4.1.4 Curing

Add to end of section:

Where heat assisted curing is required by the Manufacturer the following conditions shall apply:

Heating coils shall be controlled from thermocouples attached to the joint preferably in the adhesive itself. The thermocouples shall be linked to a recorder and for each joint a temperature/time trace shall be fully recorded and signed for.

A detailed procedure for the heat treatment shall be submitted to the Principal and GRP pipe Manufacturer for review. The procedure shall outline all requirements including equipment, method of application, temperature and curing time. This procedure shall be subject to a qualification test on a representative product.

All joints must be fully supported, clamped and braced to ensure that no movement occurs during curing.

4.4.2 Laminated joints

Add at end of section:

Laminated joints shall only be used in non-critical applications. The definition of critical shall be agreed between the Principal and the Manufacturer.

4.4.5 Other mechanical joints

Replace this section with the following:

4.4.5 Threaded joints

The types of threaded joints commonly used are given in (Part E, Section 8.1.5).

Manufacturers' installation instructions for threaded joints shall be followed. The main points to be observed are the cleaning of the threads prior to making up the joint and the use of the correct torque when tightening the joint. Only tools recommended by the Manufacturer shall be used.

4.4.6 Metallic/GRP interfaces

Replace this section with the following:

Interfaces with other systems, metallic or otherwise (e.g. tanks, vessels, piping or equipment) shall be by flanged (i.e. mechanical) connections. Other alternative connections are allowable but must be qualified by procedures as outlined in Part D. Installation of flanges shall be as described in Part F, Section 4.4.4.

Add new section:

4.4.7 Instrument connections

Instrument connections shall match the pressure, temperature and chemical resistance capabilities of the main pipe. The end of the branch pipe shall be flanged and the flanged end dimensions shall conform with DEP 31.38.01.11-Gen. The diameter of the GRP branch pipe shall be selected to ensure sufficient robustness to withstand external forces.

An adhesive bonded GRP saddle with a flanged end branch connection shal be used, preferably pre-fabricated to Manufacturer's specification. The adhesive bonded GRP saddle shall match the pressure, temperature and chemical resistance capabilities of the piping system.

If the instrument connection has to be made during operations, the procedure (hot-tapping), as described in (Part G, Section 5), shall be followed.

4.5 APPLICATION OF FIRE PROTECTION

Replace this section by the following:

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 methods, which are fully in accordance with the Manufacturer’s instructions and which are approved by the Principal.

4.6 QUALITY PROGRAMME FOR INSTALLATION

Replace "bond", "bonds" *and* "bonding" *by* "joint", "joints" *and* "jointing", *respectively throughout the Section.*

In the third paragraph, sub-paragraph 2 and fifth paragraph delete the words "adhesive bonded".

Add new section:

4.7 SUPPLEMENTARY INSTALLATION REQUIREMENTS FOR GRP PIPELINES

4.7.1 Trenching/ lowering-in/ backfill

The trench depth shall be sufficient to allow a minimum depth of cover as per project specification, unless otherwise agreed in writing with the Principal. In cold climate regions, the trench depth shall be deeper than the lowest 'frost' level of the soil.

Small changes in direction, in the vertical as well as the horizontal plane, may be achieved by elastic bending providing the bend radius is greater than the specified minimum elastic bending radius. Where this is not possible, e.g. due to right-of-way restrictions, fabricated elbows shall be used.

Special attention is required at transitions between above ground and buried installation. At locations where the pipeline comes above ground, the bottom of the trench shall be flat for a minimum distance of 25 m. In this section, elastic bends are not permitted.

During lowering-in, the pipe curvature shall not be less than the minimum specified elastic curvature.

Wherever possible the pipe shall be installed on undisturbed soil to avoid potential problems with differential settlement. Before pipe is laid in the trench, sharp objects e.g. rocks, bricks etc., must be removed. Where this is not possible, e.g. at excavations for boring equipment at cased crossings, attention shall be given to compacting the backfill material. In this case it is recommended to backfill in small amounts, compacting each layer before further back-filling. The pipeline shall be surrounded by sand to a minimum level of 150 mm above the crown of the pipe.

To allow for large expansion at bends caused by wide temperature fluctuations, for example, expansion cushions can be installed behind each bend and extending to approximately 5 m each side of the bend. Details of expansion cushions are given in (Appendix F.1). However, it is preferred to accommodate the expansion of bends through standard design procedures.

4.7.2 Cased crossings

If a section of GRP pipe is to be installed in a casing (e.g. at a road or rail crossing), it shall be subjected to an air leaktightness test prior to installation. During laying of the GRP pipe in the casing, it shall be ensured that the pipe does not contact the outer casing to avoid scraping and external damage. Three insulators/spacers per pipe joint shall be securely attached to the pipe section before it is inserted into the casing. Following installation in the casing, any bends required to bring the pipe elevation up to the normal pipeline elevation shall be installed together with at least one full pipe length on either side. This complete section shall then be subjected to a full hydrostatic test. Following successful completion of the hydrotest, the ends of the annular space between the carrier pipe and casing shall be sealed by a rubber manchet or plug. Filling the entire annular space with e.g. polyurethane foam may also be considered.

Prior to backfilling, suitable devices shall be securely attached to both the carrier pipe and casing pipe on each side to enable their elevation to be monitored for differential movement.

4.7.3 High pressure systems

For high pressure pipe systems, special attention is required with respect to the use of "thrust-blocks" at locations of 90 degree bends or tees. Detailed design is required to ensure that no unnecessary loads are applied to the pipe system.

4.7.4 Marsh or swamps

For pipeline installation in marsh or swamp areas, detailed data on soil instability and buoyancy effects is required to ensure that the additional induced loads are minimised.

5.1.2 Certification

In the first sentence, replace the word “may” *with* “shall”.

At the end of the third paragraph, add the following:

Previously qualified fitters may only be employed if they have worked using the Manufacturer’s system within the previous three months.

6. REPAIRS

Replace this section with the following:

6.1 SCOPE

This part summarises NDE methods to be used to locate defects which may occur during the fabrication, handling, transportation-to-site and installation phase of a GRP project. Probable defects have been derived from experience with offshore GRP piping systems. However, the conclusions drawn from these experiences apply equally to onshore systems.

The use of qualified personnel shall be verified when defect detection/evaluation activities are included in the inspector's scope of work, e.g. as a part of the quality control procedure on a new system, since this is a key means of eliminating avoidable defects.

6.2 NDE METHODS AND DEFECT ACCEPTANCE CRITERIA

NDE methods recommended for use in detecting the defects which are most likely to occur during the fabrication, handling, transportation-to-site and installation of GRP piping systems are given in (Table F.6.2) along with recommended acceptance criteria. Possible causes and recommended corrective actions are also included.

Visible defects along with acceptance criteria and corrective actions are listed in (Part D, Appendix D.1, Table 1.1).

6.3 REPAIR METHODS

Add at start of section:

No repairs shall be made to the internal surface.

The repair procedure shall be produced and qualified by the Contractor in accordance with the GRP pipework Manufacturer’s recommendations and reviewed by the Principal prior to implementation.

It shall be demonstrated that the repair method restores the specified properties. Test methods (if appropriate) shall be agreed between the Principal and Manufacturer.

Areas and number of repairs shall be reported and recorded.

6.3.1 Replacement

Pipe sections with major damage shall 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.

6.3.2 Minor repairs

Minor repairs to pipe and fittings may be repaired on site in accordance with the Manufacturer's recommended procedures.

Table F.6.2 General description of defects that could potentially occur during fabrication, handling, transportation to site and installation

POSSIBLE DEFECTS	CAUSE(S)	CONSEQUENCE(s)	RECOMMENDED NDT METHOD(S)	CRITERIA	CORRECTIVE ACTION
1) Incorrect dimensions	- incorrect prefabrication - joint not shaved correctly	- joint cannot be sealed, leakage - GRP can be overstressed if joint pulled up	- measurement to verify documented dimensions	- in accordance with UKOOA Part 2 Section 2.1.8	- replace (major defect) - compensate elsewhere in piping system (e.g. use field joints, hook-up adjustments etc.)
2) Impact, wear or abrasive damage	- incorrect transport - incorrect handling	- weepage or pipe failure	- visual inspection, with light source inside pipe	- in accordance with Appendix D.1,Table 1.1	- replace (major defect) - repair (minor defect)
3) Incorrect curing of: a) adhesive b) laminated joint	- outside temperature and humidity specifications - improper mixing - heating pad overlap or controller problems - cooling effect of air in pipe - out of date or incorrect materials	- weakened joint or leakage	- DSC (Epoxy systems) - Styrene content (Vinylester & Polyester systems)	- T_g must be at least 15 to 30 °C (depending on resin system) above operating temperature or to adhesive supplier's requirements	- remake joint (major defect) - post-cure joint (minor defect)
4) Misaligned joints	- movement during curing - bending - incorrect dimensions	- air sucked in resulting in voids - residual stress resulting in less than rated performance	- visual inspection - ultrasonics	- alignment to project specifications	- replace components (major defect) - remake joint (minor defect)
5) Defects in adhesive bond	- too little adhesive or not applied uniformly - movement during curing	- weakened joint or leakage	- ultrasonics, or - radiography	- debond area greater than 30% of total bond area - axial length of the debond area greater than 20% of total axial bond length	- remake joint
6) Improper treatment of joint adherents	- contaminated surface after grinding	- weakened joint or leakage	- visual inspection	- in accordance with adhesive supplier's requirements	- remake joint
7) Excess adhesive	- too much adhesive applied	- restriction in pipe to flow - increased risk of erosion damage of pipe	- radiography	- more than a 10% reduction in internal diameter.	- remove excess adhesive
8) Damaged threads	- teeth chipped - damaged end faces	- joint cannot be sealed, leakage	- visual inspection	- in accordance with Appendix D.1, Table 1.1	- replace thread in accordance with supplier's guideline

7. SYSTEM TESTING AND CERTIFICATION

7.1 TESTING REQUIREMENTS

Add new section:

7.1.3 Specific requirements for testing GRP pipelines

7.1.3.1 Daily production testing

At the end of each day's production a low pressure (approximately 5 bar) air test shall be carried out to check the quality of the joints. This test shall be carried out after lowering the pipe into the trench. A leakage check shall be carried out by applying a soap solution to each pipe joint. Any joints found to be leaking shall be repaired and a re-test carried out.

7.1.3.2 Hydrostatic testing

Upon completion of installation, the pipeline or piping system shall be subjected to hydrostatic strength and tightness tests. The pipeline trench shall be completely backfilled prior to the hydrotest except for the test-ends and tie-in connections and joints. These exposed sections shall be kept as short as possible.

All necessary measures shall be taken to remove air from the pipeline during filling. This includes back-pressure control, a steady controlled filling rate, use of a break tank, and use of at least two foam pigs with water in front and in between. If possible, the line should be filled from the lower end. Venting shall be carried out repeatedly at points in the test section where air might accumulate, e.g. at ancillary piping. The filling pig speed shall be controlled at approximately 0.6 m/s and should not exceed 1.8 m/s.

After filling, a minimum period of between 6 and 48 hours shall be allowed for temperature stabilisation before commencing pressurisation. The length of the stabilisation period will depend on the temperature difference between the fill water and the soil surrounding the pipeline, the type of soil and the air content.

Once the temperature has stabilised, a strength test shall be carried out at a pressure equal to 1.5 times the design pressure and held for a period of 15 minutes. The rate of pressurisation shall not exceed 2 bar per minute.

Following successful conclusion of the strength test, a leaktightness test shall be carried out at a pressure equal to 1.1 times the design pressure. The test pressure shall be held for a minimum of 24 hours during which time no water shall be added to or removed from the pipeline. During the test, the pressure shall be recorded continuously and deadweight tester readings shall be recorded every 30 minutes.

In the event of a pressure drop during the leak tightness test, a "step-test" shall be performed. In this test, the test section shall be re-pressurised to the leaktightness test pressure (i.e. 1.1 times design pressure) and after each hour the pressure shall be recorded and the section re-pressurised by adding water. The quantity of water required to bring the section back up to test pressure shall also be recorded. This shall continue for a further period of 24 hours. If the quantity of water added each hour shows a decreasing trend, then it may be considered that the pipeline is tight. If the quantity of water added remains constant, then it must be assumed that the pipeline is not leaktight.

As an additional check to determine whether any pressure variation has been caused by a temperature change or whether a leak is present, the theoretical pressure change resulting from the measured temperature change shall be calculated using the formulae given in (Appendix F.2).

Add new section:

8. HEALTH AND SAFETY

8.3 DISPOSAL OF MATERIALS AND TEST FLUIDS

Disposal of all materials, e.g. leftover adhesives, hydro-test fluids cleaning fluids etc., shall be in accordance with local regulations.

Add new section:

9. COMMISSIONING

9.1 INSPECTION DURING COMMISSIONING

9.1.1 Scope

This section summarises NDE methods to be used to locate defects which may occur during the commissioning phase of a GRP project. Probable defects have been derived from experience with offshore GRP piping systems. This experience base includes both new projects and maintenance of existing systems.

9.1.2 Defects, NDE methods and acceptance criteria

NDE methods recommended for use in detecting defects which are most likely to occur during the commissioning of GRP piping system are given in (Table F.9.1.2) along with recommended acceptance criteria. Possible causes and recommended corrective actions are also included.

Visible defects along with acceptance criteria and corrective actions are listed in (Part D, Appendix D.1, Table 1.1).

Table F.9.1.2 General description of defects that could potentially occur during commissioning

POSSIBLE DEFECTS	CAUSE(S)	CONSEQUENCE(S)	RECOMMENDED NDT METHOD(S)	CRITERIA	CORRECTIVE ACTION
1) Flange cracks, leaks	- bolts over or under-torqued - GRP against raised face flanges - wrong GRP flange design selected	- joint not sealed, leakage - reduced life	- visual inspection	- no leakage permitted	- replace flange (major defect) - grind and fill minor cracks with resin - tighten flange bolts to Manufacturer's recommended torque
2) Vibration	- poor design of connections to pumps, compressors with poor design of supports, clamps of piping system	- weepage or pipe failure - joint leaks	- visual inspection - accelerometer, as appropriate	- in accordance with Manufacturer's recommendations	- redesign pipe supports and clamps
3) Cavitation	- bends radius too sharp - over-complicated pipe routing	- wall thickness loss, pipe weepage or failure	- acoustic emission	- no cavitation allowed	- redesign pipe routing and supports - alter process parameters

NOTE: Cavitation may be a contributing factor in erosion downstream of an excessive adhesive bead or other restriction, such as improperly sized valves. Cavitation, i.e. the collapsing of air bubbles in the fluid, can be clearly audible. Although only a small number of GRP piping failures have been attributed to cavitation, it is detrimental to GRP. If noticed during commissioning the cause shall be corrected prior to continuing.

Add new Appendix:

APPENDIX F.1 EXPANSION CUSHIONS

Expansion cushions shall comply with the following requirements:

Length: to extend a minimum of 5 m beyond each side of the bend.

Height: 1.5 times the pipe O.D.

Thickness: 80 mm.

Other properties are given in the (Table A.1.1) below:

Table A.1.1 Overview of expansion cushion properties

Property	Applicable Standard	Unit	Value
Density	DIN 53420	kg/m^3	33
Tensile Strength	DIN 53571	N/mm^2	0.32
Elongation at failure	DIN 53571	%	170
Required pressure to compress material:	DIN 53577	kPa	
30%			55
50%			100
70%			200
Heat Transfer Coefficient	DIN 52612	W/m.K	0.033
Service Temperature		°C	-80, +80
Water Absorption after:	DIN 53528	Vol. %	
7 days			0.8
28 days			1.6
Water Vapour Permeation Factor (for 5 mm thick sample)	DIN 53122	g/m^2.24 hrs	1.3
Water Vapour Diffusion Factor	DIN 52615		1 400

Add new Appendix:

APPENDIX F.2 HYDROSTATIC TESTING PRESSURE CHANGE CALCULATION

To determine the theoretical pressure change resulting from a given temperature change the following formulae shall be used:

$$P_f - P_i = A_1(T_f - T_i) + A_2 \log\left(\frac{\frac{d}{t}\frac{(1-\nu^2)}{E} + C_1 + a_2T_f + a_3T_f^2}{\frac{d}{t}\frac{(1-\nu^2)}{E} + C_1 + a_2T_I + a_3T_i^2}\right) + A_4\left(\arctan\left(\frac{a_2 + 2a_3T_f}{A_3}\right) - \arctan\left(\frac{a_2 + 2a_3T_i}{A_3}\right)\right)$$

where

$$A_1 = \frac{b_3}{a_3} \qquad A_2 = \frac{1}{2a_3}\left(b_2 - \frac{b_3a_2}{a_3}\right) \qquad A_3 = \sqrt{4a_1a_3 - a_2^2}$$

For restrained ends:

$$A_4 = \frac{2\left(C_2 - 2(1+\nu)\alpha\right) - 2\frac{a_1b_3}{a_3} - \frac{a_2b_2}{a_3} + \frac{a_2^2b_3}{a_3^2}}{A_3}$$

For unrestrained ends:

$$A_4 = \frac{2(C_2 - 3(1+\nu)\alpha) - 2\frac{a_1b_3}{a_3} - \frac{a_2b_2}{a_3} + \frac{a_2^2b_3}{a_3^2}}{A_3}$$

where,

P_i	=	Initial pressure (MPa)
P_f	=	Final pressure (MPa)
T_i	=	Initial temperature (°C)
T_f	=	Final temperature (°C)
E	=	Hoop modulus (16 000 MPa)
ν	=	Poisson's ratio (0.35)
α	=	Thermal expansion coefficient (30 µm/m°C)
C_1	=	$498.3*10^{-6}$ (1/MPa)
C_2	=	$-63.32*10^{-6}$ (1/ °C)
a_2	=	$-2.93*10^{-6}$ (1/MPa°C)
a_3	=	$0.038*10^{-6}$ (1/MPa°C^2)
b_2	=	$1.58*10^{-6}$ (1/ °C^2)
b_3	=	$-0.0113*10^{-6}$ (1/ °C^3)

PART G AMENDMENTS/SUPPLEMENTS TO THE UKOOA "SPECIFICATIONS AND RECOMMENDED PRACTICE FOR THE USE OF GRP PIPING OFFSHORE: PART 5 - OPERATION"

2. OPERATORS DOCUMENTATION

2.2 OPERATING AND DESIGN PARAMETERS

Add to end of list:

- type of operation, static or cyclic;
- valve opening and closing times;
- pump start-up, shut-down characteristics;
- hydraulic design parameters, maximum surge pressures.

2.3 SYSTEM DRAWINGS

At the end of this section, add the following:

For pipelines, a complete set of route maps shall be available. The route maps shall include locations of valves and other facilities. The locations of all road, water, rail, pipeline and cable crossings shall also be indicated.

3. INSPECTION

Replace this section with the following:

GRP piping systems shall be inspected in accordance with the Principal's inspection strategy - refer (Part C Section 2.2).

4.2 DAMAGE/REPAIR EVALUATION

Replace this section with the following:

4.2 DEFECTS, NDE METHODS, ACCEPTANCE CRITERIA AND DAMAGE/REPAIR EVALUATION

NDE methods recommended for use in detecting defects which are most likely to occur during operation of GRP piping systems are given in (Table G.4.2.1) along with recommended acceptance criteria. Possible causes and recommended corrective actions are also included.

Visible defects along with acceptance criteria and corrective action are listed in (Part D, Appendix D.1, Table 1.1).

Table G.4.2.1 General description of defects that could potentially occur during operation

OPERATIONAL DEFECTS	CAUSE(S)	CONSEQUENCE(S)	RECOMMENDED NDT METHOD(S)	CRITERIA	CORRECTIVE ACTION
1) Flange cracks, leaks	- bolts over- or under-torqued - GRP against raised face flanges - wrong GRP flange design selected	- joint not sealed, leakage - reduced life	- visual inspection	- no leakage permitted	- replace flange (major defect) - grind and fill minor cracks with resin
2) System failure, e.g. burst pipe	- design conditions, loads, temperatures exceeded - operational procedures inadequate (e.g. water hammer due to valve opening)	- system failure	- visual inspection	- no failure permitted	- replace
3) Ageing	- long term materials degradation	- weepage	- ultrasonics	- more than 20% reduction in original axial modulus	- accept, but monitoring required
4) Impact damage	- impact from e.g. dropped scaffolding, tools	- weepage	- visual inspection - ultrasonics	- in accordance with Appendix D.1, Table 1.1	- replace (major defect) - temporary repair (minor defect)
5) Earthing cable damage	- some cables susceptible to corrosion in marine atmosphere	- earthing reduced or eliminated	- visual inspection - ohm meter	- none permitted	- replace cables
6) Scale deposits (salt water systems only)	- operating conditions resulting in e.g. barium sulphate deposits	- reduced flowrate	- visual (reduced flow) - radiography	- more than a 10% reduction in internal diameter	- clean using e.g. water jetting
7) Erosion	- particulates in flow	- reduction in wall thickness leading to pipe weepage	- ultrasonics	- more than a reduction of 20% of original wall thickness	- accept, but monitoring required
8) Chalking	- exposure to UV radiation	- minor breakdown of outer surface	- visual inspection	- depth limited to surface resin layer	- accept

5. MODIFICATIONS AND TIE-INS

Add the following to this section:

Tie-ins, e.g. plant modifications and instrument connections, made during operation of the pipe system by what is termed 'hot-tapping' should be performed during a planned shutdown. However, if a tie-in must be performed during operation of the pipe system, the hot-tapping instructions given by the Manufacturer shall be followed.

Tie-ins made during operations shall match the pressure, temperature, and chemical resistance capabilities of the main pipe.

The following hot-tapping options should be used, but option 1 is preferred:

1. Adhesive bonded 180 degree GRP saddle with flanged end branch connection and 180 degree GRP back saddle.
2. Mechanically mounted steel clamps, e.g. Helden clamping system. The system is based on stainless steel pre-formed half shells, mechanically connected via bolts; sealing is based on the pre-compression of a 'ribbed' rubber or elastomeric sheet. The seal material shall be resistant against the service conditions.

Although not intended to cover GRP systems, many of the aspects covered in DEP 31.38.60.10-Gen. are relevant for such applications.

7. TESTING AND RE-CERTIFICATION

7.1 TESTING REQUIREMENTS

At the end of the first sentence, add the following:

..... in accordance with (Part F, Section 7.1).

PART H REFERENCES

In this DEP, reference is made to the following publications.

NOTE: Unless specifically designated by date the latest edition of each publication shall be used together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Piping general requirements	DEP 31.38.01.11-Gen.
SIOP piping classes	DEP 31.38.01.12-Gen.
SIEP piping classes	DEP 31.38.01.15-Gen.
Hot-tapping on pipelines, piping and equipment	DEP 31.38.60.10-Gen.
Pipeline engineering	DEP 31.40.00,10-Gen.
Design of pipeline pig trap systems	DEP 31.40.10.13-Gen.
Electrical trace heating	DEP 33.68.30.32-Gen.

AMERICAN STANDARDS

Chemical plant and petroleum refinery piping	ANSI/ASME B31.3
Liquid transportation systems for hydrocarbons, liquid petroleum gas, anhydrous ammonia and alcohols	ANSI/ASME B31.4
Gas transmission and distribution piping systems	ANSI/ASME B31.8

Issued by:
The American Society of Mechanical Engineers,
345 East 47th Street,
New York, NY 10017,
USA

Fiberglass pressure pipe	ANSI/AWWA C950-95

Issued by:
American Water Works Association
6666 W Quincey Ave.
Denver CO 80235
USA

Specification for high pressure fiberglass line pipe	API 15 HR
Gauging and inspection of casing, tubing, and line pipe threads	API RP 5B Fourteenth Edition

Issued by:
The American Petroleum Institute
1220 L Street Northwest
Washington, DC 20005-4074
USA

Standard practice for determining chemical resistance of thermosetting resins used in glass-fibre reinforced structures intended for liquid service	ASTM C 581
Test method for time-to-failure of plastic pipe under constant internal pressure	ASTM D 1598
Test method for short-time hydraulic failure pressure of plastic pipe, tubing, and fittings	ASTM D 1599
Test method for cyclic pressure strength of reinforced thermosetting plastic pipe	ASTM D 2143
Practice for obtaining hydrostatic or pressure design basis for "fibreglass" (glass fibre reinforced	ASTM D 2992-96

thermosetting resin) pipe and fittings	
Standards test methods for determining effects of large hydrocarbon pool fires on structural members and assemblies	ASTM E1529
Standards specifications for thermosetting resin fiberglass pipe and fittings to be used for marine applications	ASTM F1173

Issued by:
American Society for Testing & Materials
100 Bar Harbor Drive, West Conshohocken
PA 19428 – 2959
USA

BRITISH STANDARDS

Fire tests on building materials and structures. Part 20: Method for determination.	BS 476-20
Code of practice for design and construction of glass reinforced plastics (GRP) piping systems for individual plants or sites.	BS 7159

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
UK

GERMAN STANDARDS

Testing of thermal insulating materials; determination of thermal conductivity by the guarded hot plate apparatus; and evaluation	DIN 52612-1
Testing of thermal insulating materials; determination of thermal conductivity by means of the guarded hot plate apparatus; conversion of the measured values for building applications	DIN 52612-2
Testing of thermal insulating materials; determination of thermal conductivity by the guarded hot plate apparatus; thermal resistance of laminated materials for use in building practice	DIN 52612-3
Testing of thermal insulating materials; determination of water vapour (moisture) permeability of construction and insulating materials	DIN 52615
Testing of plastics films, elastomer films, paper, board and other sheet materials; determination of water vapour transmission rate; gravimetric method	DIN 53122-1
Determination of water vapour transmission (density of moisture flow rate) of plastic films, elastomer films, paper, board and other sheet materials; electrolysis method	DIN 53122-2
Testing of cellular materials, determination of apparent density	DIN 53420
Pruefung von gummierten Textilien; Verschleisspruefung durch Scheuern; Bestimmung des Abriebs mit dem Frank-Hauser-Geraet	DIN 53528
Pruefung von weichelastischen Schaumstoffen; Zugversuch; Bestimmung der Zugfestigkeit und der Dehnung beim Bruch	DIN 53571

Issued by:

Beuth Verlag GmbH
Burggrafenstrasse 6
D-10787, Berlin
Germany

NORWEGIAN STANDARDS

GRP piping materials	NORSOK M-621
Guideline for NDT of GRP piping systems and tanks	NORSOK M-622

Issued by:
NORSOK SECRETARIAT
c/o OLF- Box 547
Lervigsveien 32
4001 Stavanger
Norway

INTERNATIONAL STANDARDS

Reinforced plastics based on unsaturated polyester resins – determination of residual styrene monomer content	ISO 4901
Quality management and quality assurance standards	ISO 9000

Issued by:
International Organisation for Standardization
1, Rue de Varembé
CH-1211 Geneva 20
Switzerland.
Copies can also be obtained from national standards organizations.

INDUSTRY STANDARDS

Erosive wear in piping systems	DNV RP O501

Issued by:
Det Norske Veritas Classification A/S
Veritasveien 1
1322 Hovik
Norway

Guidelines for GRP use offshore	UKOOA, first edition, April 1994.
Specification and recommended practice for the use of GRP piping offshore	UKOOA, first edition, March 1994.

Issued by:
UK Offshore Operators Association
3 Hans Crescent
London, SW1X 0LN
UK

9. BIBLIOGRAPHY

NOTE: The following documents are for information only and do not form an integral part of this DEP.

Polymer composites: Fatigue performance of filament wound GRE pipes	AMGR.92.059
Engineering composites: The response of glass fibre, Epoxy matrix filament wound pipes to drop weight impact testing	AMGR.93.078
Engineering composites: Damage tolerance of glass fibre, Epoxy matrix filament wound pipes to drop weight impact testing	AMGR.93.102
Composite piping and pipelines in bending - predictions of optimal support spacing and minimum bending radius	AMGR.95.717
Hydro-testing of a Smith's 1 000 psi GRE line-pipe	ARTR. 93.03
Test method for steady-state heat flux measurements and thermal transmission properties by means of the guarded hot plate apparatus	ASTM C 177
Test methods for determining chemical resistance or conductance of insulating materials	ASTM D 257
Test method of rate of burning and/or extent and time of burning of self-supporting plastics in a horizontal position	ASTM D 635
Test method for coefficient of linear thermal expansion of plastics	ASTM D 696
Test method for longitudinal tensile properties of reinforced thermosetting plastic pipe and resin tube	ASTM D 2105
Practice for classifying visual defects in glass-reinforced plastic laminate parts	ASTM D 2563
Test method for ignition loss of cured reinforced resins.	ASTM D 2584
Test method for measuring the minimum oxygen concentration to support candle-like combustion of plastics (oxygen index)	ASTM D 2863
Standard practice for determining dimensions of "fiberglass" (glass-fiber-reinforced thermosetting resin) pipe	ASTM D 3567
Test method for surface burning characteristics of building materials	ASTM E 84
Test method for surface flammability of materials using a radiant heat energy source	ASTM E 162
Test method for specific optical density of smoke generated by solid materials	ASTM E 662
Test method for heat and visible smoke release rates for materials and products	ASTM E 906