

GENERAL SPECIFICATION

PIPELINES - RISERS

GS EP PLR 109

Design, fabrication and testing of submarine unbonded flexible pipes and risers
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1. Scope

This General Specification is applicable to the design, procurement, manufacturing and, testing of flexible pipes for offshore application (the installation is covered by **GS EP PLR 401**).

Further information on the Scope is provided in section 4 hereof.

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

In case of conflict with listed data, this document shall apply.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and addendums, shall be the latest revision published at the effective date of this document.

Reference	Title
API RP 17B	Recommended Practice for Flexible Pipe
API SPEC 17J	Specification for Unbonded Flexible Pipe
API TR 17TR1	Evaluation Standard for Internal Pressure Sheath Polymers for High Temperature Flexible Pipes
API TR 17TR2	The Ageing of PA-11 in Flexible Pipes
ASTM E45	Standard Test Methods for Determining the Inclusion Content of Steel
ASTM E739	Standard Practice for Statistical Analysis of Linear or Linearized Stress-Life and Strain-Life Fatigue Data
DNV-OS-C501	Composite Components
DNV-RP-F202	Composite Risers
DNV-RP-F203	Riser Interference
ISO 16120-4	Non-alloy steel wire rod for conversion to wire - Part 4: Specific requirements for wire rod for special applications
ISO 9001	Quality management systems - Requirements

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Reference	Title
ISO/TS 29001	Petroleum, petrochemical and natural gas industries - Sector - specific quality management systems - Requirements for product and service supply organizations

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and addendums, is the latest revision published.

Reference	Title
GS EP EXP 311	Plant integrity - Minimum inspection requirements
GS EP PLR 001	Documentation requirements
GS EP PLR 100	Submarine pipeline systems
GS EP PLR 227	Carbon Steel Flanges, Branch Outlet Fittings and Forged Components for Pipelines
GS EP PLR 401	Installation of submarine pipelines
GS EP PVV 610	Welding of pressure containing piping and equipment
GS EP SAF 337	Passive Fire Protection: basis of design
GS EP SPS 029	Metallic Materials for Subsea Production Facilities
GS EP STR 204	Subsea structures: Carbon Steel Material and Fabrication

3. Definitions and Abbreviations

3.1 Definitions

For the purpose of this document, the following terms and definitions apply:

Annulus The space between the internal pressure sheath and the outer sheath.

Bore The Internal flexible pipe volume delimited by the pressure sheath.

Third Party Means a Certifying Authority, or a Classification Authority, or an Independent Company in charge of any independent design review, appraisal, or analysis.

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3.2 Abbreviations

The following technical definitions and abbreviations are used in this document:

COC	Certificate of Conformance
EC	Eddy Current
FAT	Factory Acceptance Test
FMECA	Failure Mode Effects and Criticality Analysis
GRV	Gas Release Valve
HIC	Hydrogen Induced Cracking
IRC	Independent Review Certificate
ITP	Inspection and Test Plan
MBR	Minimum Bending Radius
MPQR	Manufacturing Procedure Qualification Report
MQP	Manufacturing Quality Plan
NCR	Non Conformance Request
NDE	Non Destructive Examination
PFP	Passive Fire Protection
PPS	Particular Project Specification
SMYS	Specified Minimum Yield Strength
SN	Stress-cycles curve
SSC	Sulfide Stress Cracking
TAN	Total Acid Number
UTS	Ultimate Tensile Strength
UV	Ultra Violet radiation
WPQR	Welding Procedure Qualification Report
WPS	Welding Procedure Specification

4. Applicability and Limitations

This General Specification covers the minimum requirements, provides recommendations and guidelines as well as selecting the reference documents for unbonded flexible pipelines and risers.

4.1 Applicability

This specification applies to unbonded flexible pipe and does not cover bonded flexible pipe, kill and choke pipeline and umbilical.

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This specification addresses both static (buried and unburied) and dynamic (riser and jumper) applications of flexible pipe.

This specification covers the use of flexible pipe for the transportation of crude oil, stabilised or commercial oil, rough or treated gas, injected or treated water, methanol and glycol.

This specification does not apply to the transportation of cryogenic products.

Design, procurement, manufacturing and testing activities involve:

- Engineering the flexible pipe structure and its ancillary components
- Procuring materials, manufacturing, assembling, inspecting, testing and storing all flexible pipes and associated equipment
- Verifying that all goods and services to be delivered meet the specified requirements, and providing adequate documentation.

Material and fabrication of subsea ancillary components shall be in accordance with [GS EP STR 204](#).

Material for subsea bolting components shall be in accordance with [GS EP SPS 029](#).

4.2 Basic Principle

The design, fabrication and testing shall be performed according to [GS EP PLR 100](#).

5. Design Brief and Deliverables

The type and details of a flexible pipe structure and configuration shall be selected according to:

- The fluid composition
- The type of application: static (buried or unburied), dynamic riser or jumper
- The design and operating conditions
- The external environment conditions such as met-ocean data, geometrical limitation, and attachment point displacement, etc.

The reasons for the selection of the flexible pipe structure and of each individual layer characteristics shall be fully justified and documented.

Limitation and risk associated to each layer shall be identified and quantified.

Measures taken to alleviate these risks shall be described in details.

Similarly, the design of the end fitting shall be documented in details.

End fittings detailed drawings shall be available for review.

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Behavior of the flexible pipe during installation and in service shall be assessed.

Associated detailed documentation shall be produced.

Design documentation shall be provided according to [GS EP PLR 001](#).

6. Design Data

The information required to design a flexible pipe is defined in [GS EP PLR 100](#) and [API SPEC 17J](#).

The information shall be collected prior to start of design activities and gathered into the design basis document as required in [GS EP PLR 100](#) and in [GS EP PLR 001](#).

7. Design Methodology

In the following sections, when testing is required, it shall be understood that Company may relax this requirement if tests have already been conducted in conditions at least as stringent as the conditions of the project development under consideration.

Full details of the test protocol, test results and justification for the validity of the existing tests to cover the project development conditions shall be provided to Company for approval.

7.1 Pipe Structure Design

7.1.1 Polymer sheaths

This section applies to all the non metallic layers manufactured as a sheath i.e. internal tube, pressure sheath, anti-collapse sheath, outer sheath, protective sheath and any intermediate sheath.

Qualification and design of the polymer layer shall have been performed according to requirement specified in [API SPEC 17J](#), [API TR 17TR1](#) and [API TR 17TR2](#).

For all polymer sheaths, minimum allowable thickness shall be documented.

It shall be clearly specified whether it is driven by manufacturing constraints and/or design requirements as per [API SPEC 17J](#) - section 7.8.

Furthermore the minimum allowable thickness shall prevent any risk of ripples when the flexible pipe is bent at its MBR for storage.

For insulated flexible pipes, when inserts are used at buoyancy module locations, design of the insert shall be such that it does not compromise the integrity of the outer sheath when the flexible pipe is bent at its MBR for storage.

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The design of the inserts shall be reviewed and approved by Company prior start of the flexible pipe manufacturing.

With the exception of water injection applications, the pressure sheath material shall be selected so as to allow visual identification of flaws i.e. not black.

For smooth bore structure, black pressure sheath material is allowed provided that X ray inspection is performed on the entire length of the line.

To complement the [API SPEC 17J](#) requirements the following issues and their variations along the field life shall be addressed and fully documented in order to justify the polymer sheaths material and thickness selected.

Permeability to the different components of the transported fluids shall be determined for the range of temperatures representing the operating conditions together with the effect of degradation of the polymer.

The permeation results shall enable the corrosion rate of steel armors and H₂S/CO₂ resistance to be calculated.

In the case of a multi-layer PVDF system, diffused gas and entrapped gas in between the layers shall be evaluated for assessment of potential collapse issue and associated maximum allowable decompression rate.

Where applicable, potential creeping of polymer sheath due to external hydrostatic pressure and/or mechanical contact pressure shall be evaluated and documented (for instance outer sheath creeping into insulation layers, anti-collapse sheath creeping into pressure vault).

Smooth bore should not be considered in case of risk of partial vacuum in the bore.

Otherwise it shall be validated by Company HQ Pipeline & Riser Department specialist based on project conditions.

7.1.2 Metallic layers

This section applies to carcass, pressure armor and tensile armor wires and outlines additional requirements to complement the [API SPEC 17J](#).

For dynamic application, only product family I and III according to [API RP 17B](#) are allowed.

Product family II may be allowed for dynamic oil offloading lines.

The use of product family II for other dynamic applications and static applications shall be submitted to Company for approval.

To avoid additional stresses on tensile armor wires, the distance between the bend stiffener anchoring point and the end fitting rear collar shall be greater than one armor pitch length.

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Residual stress in steel wires and welds induced during the manufacturing of the layer shall be determined and taken into account in the design as per [API SPEC 17J](#) - section 5.2. e).

7.1.2.1 Selection of steel wires and SSC/HIC testing

Detailed requirements are provided in Section 15 Appendix 3.

Tests conditions shall be established and agreed before contract award.

7.1.2.2 SN Curve selection

For dynamic applications, S-N data generated as per the [API SPEC 17J](#) requirements shall be documented in details.

For each steel material used in the structure, SN curve shall be presented.

The SN curves to be employed in the design shall be established with a 2.3% failure probability.

The effect of the annulus environment due to permeation in normal operating condition shall be accounted for, including water condensation (see specific requirements in section 7.4.4.2).

SN curves shall be based on experimental data covering the range of mean and alternate stress of the application.

Regression and statistical analysis shall be performed as per [ASTM E739](#).

Standard mean stress correction, Goodman or Gerber is valid for dry environment condition. However for corrosion fatigue, mean stress correction methodology shall be presented and submitted to Company HQ Pipeline & Riser Department Specialist for approval.

Endurance limit is not acceptable unless it has been validated by experimental data.

This must be documented and submitted to Company HQ Pipeline & Riser Department Specialist for approval.

7.1.3 Composite fiber armor

Design and fabrication of composite pressure or tensile armor shall be performed as per recommendations defined in Annex H of [API RP 17B](#) with reference to [DNV-RP-F202](#) and [DNV-OS-C501](#).

7.1.4 Anti-wear tapes

For anti-wear tape selection, consideration shall be given to the maximum operating temperature and mean contact pressure versus intended service life.

The use of anti-wear tapes is mandatory for flexible spools connected to bottom assembly of hybrid risers.

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7.1.5 Insulation tapes

The detailed design of insulated flexible pipe shall take into account the combined effect of temperature and pressure as per [API SPEC 17J](#) - sections 6.1.2.5 & 5.4.3.

Mechanical behavior of the insulation layer shall be taken into account when assessing the maximum tightening force as well as the minimum tightening force required to avoid sliding of the pipe during installation, i.e. vault effect.

Furthermore when buoyancy modules are used for insulated flexible risers without including inserts, the module clamp design shall be able to accommodate the pipe diameter variations due to creeping of insulation tapes to prevent any risk of buoyancy module sliding.

7.1.6 High strength tapes

In addition to the requirements of [API SPEC 17J](#) - section 6.1.1, ageing of these tapes under the annulus environment shall be addressed.

Abrasive wear of these tapes with respect to contact pressure shall be addressed.

7.2 End Fittings Design

In addition to the [API SPEC 17J](#) requirements the following issues and their variations along the field life shall be addressed and fully documented.

At critical stress locations the resulting usage factor shall be presented for all load cases.

The polymer sheaths shall be continuously supported by a steel support unless it can be demonstrated to Company that either proposed design and/or inspection procedures during manufacturing are suitable to guarantee the long term integrity of the sheaths at this location.

In this case Company shall approve the proposed solution.

Stress concentration factors at and within the end fitting shall be established and documented.

Full Inconel 625 clad shall be provided for the end fittings (bore, groove and flange face).

Any partial cladding or any other corrosion protection system proposed for specific project conditions or applications shall be validated by Company HQ Pipeline & Riser Department specialist.

The weld overlay procedure and qualification shall be compliant with the requirements included in [GS EP PVV 610](#).

Load transfer from end fitting outer casing to end fitting body through a thread is forbidden.

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When the flexible pipes are insulated, a dedicated system for the insulation of the end fitting may be required to prevent thermal losses at these locations.

In all cases, the cool down time performance of the insulation system at the end-fitting location shall fulfil the requirements for the flexible line current section.

Furthermore the U-value performance of the insulation system at the end-fitting location shall guarantee an average U-value along the pipeline system in accordance with the thermal requirements.

Long term thermal performance of such system shall be demonstrated and effect of installation addressed.

For dynamic riser application, in case of multiple sections, intermediate connections shall be located in the vertical part of the riser and equipped with bend stiffeners.

In addition, for applications with high CO₂ content in the transported fluid (>15%mol), communication between annuli shall be implemented in the design.

Proposed communication system shall be validated by Company HQ Pipeline & Riser Department specialist.

The use of multiple sections for offloading lines is not acceptable.

7.3 Clamps Design

Any clamping system proposed which requires that axial loads are transmitted through the clamp into the flexible pipe structure shall consider:

- Static and dynamic load capacity of clamp and flexible pipe body
- Stiffness of clamp and bolting system and dimensional changes of flexible pipe
- Manufacturing tolerances
- Ability of clamp to maintain its load capacity over the full design range of internal and external pressure, temperature and axial tension loading
- Ensure no movement over the design life
- Clamp make-up requirements
- Friction between layers during installation and operation
- Dry and flooded riser annulus
- Documented evidence of testing
- Fatigue loading.

7.4 In-Place Behavior

The additional requirements to the [API SPEC 17J](#) presented below shall be addressed.

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7.4.1 Collapse resistance

The flexible pipe design shall satisfy the collapse resistance criteria when the flexible pipe is empty and bent to its operating minimum bending radius at the maximum operating water depth.

The effect of carcass erosion, pressure vault corrosion and cross section ovality shall be taken into account.

7.4.2 Expansion and upheaval buckling

Pipeline shortening or lengthening shall be calculated as per the [API SPEC 17J](#) requirements section 5.3 and cover the hydrostatic test conditions.

The temperature range for internal and external surfaces shall be included in the calculation.

7.4.3 Reverse end cap effect

A armor layers and high strength tapes shall be selected taking into consideration the effect of the reverse end cap effect and resulting risk of bird cage and wire disorganisation.

The detailed assessment of the potential risk of armor wires lateral buckling shall be completed using predicting tools validated by full scale testing and Deepwater Immersion Tests.

The assessment shall cover both intact annulus and accidentally flooded annulus cases.

7.4.4 Riser system analysis

7.4.4.1 Interference analysis

Interference Analysis shall be performed in order to avoid any contact or crossing between flexible line and other items, i.e. mooring lines, risers, structures, etc.

In any conditions, it is not allowed that dynamic flexible, crosses above or below any other dynamic lines, i.e. flexible, steel risers, umbilicals and mooring lines.

A no clashing criteria shall be used to provide details for riser arrangement, hang-off angle and azimuth separation angles between adjacent risers.

No interference or clashing is allowed at any time between the flexible riser and mooring lines.

Shield effect of two adjacent lines has to be evaluated and documented.

Effect of the shield may be modeled by adjusting the Cd value as detailed in [DNV-RP-F203](#).

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7.4.4.2 Fatigue analysis

The flexible pipe shall be designed for the specific project service life with a safety factor of 10.

In case that water condensation is foreseen in normal operating condition, fatigue corrosion shall be accounted for from day the analysed area is wet with accumulated condensed water.

Total damage shall be the combination of the dry fatigue damage and corrosion fatigue damage.

Total damage shall remain below 0.1.

In case of seawater ingress in the annulus, the calculated service life using de-aerated seawater SN curve shall exceed 5 years with a safety factor of 10.

7.4.5 Gas venting system

Gas venting system allowing access to the annulus shall be included in every aerial end fitting, including for water injection application.

Gas release valves shall be designed so as to properly operate even when the pipeline subsea end fitting sinks into the mud.

The proposed design shall be approved by Company.

7.4.6 Fire resistance

When required by PPS, design of the PFP shall be performed following requirement defined in **GS EP SAF 337**.

7.4.7 Marine growth

Effect of marine growth shall be included in the design of the flexible pipes.

7.4.8 Flow induced pulsation

For dry gas application (liquid content < 1%), specific dedicated study shall be performed to quantify the risk of flow induced pulsation.

Flow induced pulsation frequencies and onset velocity shall be evaluated and documented, and compared to the project conditions for validation of the carcass dimensions prior start of manufacturing.

7.4.9 Abrasion layer

For all dynamic and static risers, as well as flowlines when installed in shallow water (< 200 m water depth), an additional protective polymer sheath shall be extruded over the entire length of the flexible pipe.

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The protective sheath shall not be anchored within the end-fitting.

In areas where this protective sheath is in contact with ancillaries or guiding equipment (l-tube, bellmouth, etc.), abrasion due to relative displacement shall be evaluated and documented.

For flexible pipes including an intermediate leakproof plastic sheath this requirement can be relaxed providing that integrity of external sheath is maintained with respect to abrasion.

8. Design Tools

Design tools used in design and analysis shall be in compliance with [API RP 17B](#) and [API SPEC 17J](#).

In addition the design tools shall have been certified by a Third Party approved by Company.

Certificates and associated reports and comments shall be made available to Company.

9. Qualification Program

For all flexible pipes under consideration, design and operational conditions shall be compared with qualification program already performed or with field proven track record on similar flexible structure (cross section, internal diameter, material).

The following aspects of the design shall be addressed as a minimum:

- Bursting performance for pipe sample that includes welds
- Hydrostatic collapse performance in straight and bent configuration
- Flexible pipe behavior under tensile and pressure loads
- Flexible pipe behavior under high compressive loads due to hydrostatic pressure or mechanical compression, combined with cyclic bending
- Flexible pipe behavior under installation loads (contact with gutter under tension and crushing loads in caterpillar)
- Flexible pipe behavior on mid water arch gutter (crushing, fatigue of carcass)
- Flexible pipe thermal behavior
- Properties and ageing of material, polymers and high strength tapes used within the proposed structure under design and operational conditions, i.e. abrasion, creeping, blistering, hydrolysis, crack propagation, etc.
- End fitting sealing system suitability under foreseen conditions
- Subsea vent valves performance
- Anchoring performance of the tensile armors in the end fitting
- Polymer sheath creeping due to hydrostatic or mechanical pressure
- Fatigue performance of the pressure and tensile armors.