



Exploration & Production

GENERAL SPECIFICATION

PIPELINES - RISERS

GS PLR 109

Design, fabrication and testing of submarine unbonded flexible pipes and risers

02	10/04	General review
01	10/03	General review – Change of Group name and logo
00	10/02	First Issue
Rev.	Date	Notes



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1. Scope

This General Specification is applicable to the design, procurement, manufacturing and testing of flexible pipes (the installation is covered by the **GS PLR 409**).

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. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
API SPEC 17J	Specification for unbonded flexible pipe
ISO 13628-2	Petroleum and natural gas industries - Design and operation of subsea production systems - Part 2 : Flexible pipe systems for subsea and marine applications
ISO 9001	Quality Management Systems – Requirements

Professional Documents

Reference	Title
API RP 17B	Recommended practice for flexible pipe
API Technical Report 17TR1	Evaluation Standard for Internal Pressure Sheath Polymers for High Temperature Flexible Pipes
API Technical Report 17TR2	The Ageing of PA-11 in Flexible Pipes

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS PLR 001	Documentation requirements
GS PLR 002	Organisation of the design works
GS PLR 100	Submarine pipelines systems
GS PLR 151	Design of steel catenary riser systems
GS PLR 409	Installation of submarine cables, umbilicals and flexible pipes

3. Definitions and abbreviations

3.1 Definitions

Throughout this specification, the following definitions apply:

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

3.2 Abbreviations

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

FAT Factory Acceptance Test

PT Test Pressure to be applied during the FAT

MQP Manufacturing Quality Plan

VIV Vortex Induced Vibration

UV Ultra Violet Radiation

4. Applicability and limitations

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

Applicability:

This specification applies to unbonded flexible pipe and does not cover bonded flexible pipe, kill and choke pipeline, flexible pipe with non-metallic tensile armour wires and umbilical.

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

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. Engineering the behaviour of the flexible pipe during installation and in service including defining the riser configuration.
- 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.

Basic Principle:

The design, fabrication and testing shall be performed according to the **GS PLR 100** and **GS PLR 002**.

In addition, the present General Specification amends, replaces or supplements various sections of **API SPEC 17J**, **API RP 17B** and **ISO 13628-2**.

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, 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. In addition, for each flexible pipe structure, stresses in the pressure vault and tensile armour wires shall be tabulated as per Appendix 1 format.

Limitation and risk associated to each layer shall be identified and quantified (e.g. risk of creep of pressure sheath between the wires of the first armour layer, deep water application limitations...). 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 disclosed.

Behaviour 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 PLR 001** and Prime References requirements.

Documentation shall be issued early enough to allow for design review and approval prior to the start of procurement and manufacturing.

6. Design data

The information required to design a flexible pipe is defined in the **GS PLR 100** and the **API SPEC 17J**.

The information shall be collected prior to start of design activities and gathered into the design basis document as required in the **GS PLR 100** and in the **GS PLR 001**.

In addition, the detailed requirements from the **GS PLR 151** for met-ocean data shall be satisfied.

7. Design Methodology

Although it is understood that the design of flexible pipe involves an iterative process combining the selection of material type, grade and thickness for each layer and the definition of the configuration (static behaviour, dynamic riser: free-hanging, lazy-wave.. etc) it has been decided to separate the two issues for clarity purposes.

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 onerous 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. Company will finally approve or not this relaxation.

7.1 Pipe structure design

Based on the type of fluid transported, a smooth bore or a rough bore structure shall be selected. Each flexible pipe layer shall be designed so as to comply with the Prime References requirements.

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 and any intermediate sheath.

For smooth bore structures in subsea application, the use of anti-collapse plastic sheath is mandatory.

The pressure sheath material shall be selected so as to allow visual identification of flaws i.e. it shall not be black.

To complement the Prime References requirements the following issues and their variations along the field life shall be addressed and fully documented in order to justify the plastic sheaths material and thickness selected:

- Compatibility with the transported fluid (fluid chemical additives and media used for hydraulic testing shall be analysed too).
- Damage of the plastic sheath by inner fluid and diffused gas shall be accounted for in the design. Detailed evaluation shall be presented and validated. For example, but not limited to, in the case of oxidation issues, when anti-oxidisers are used to avoid this degradation, the efficiency of the additives shall be tested for the design conditions.
- Damage of the plastic sheath by the external environment shall be prevented. For example, but not limited to, photo-oxidation issues during storage (including during manufacturing) and operation shall be addressed.
- When additives to the polymer are used to make the plastic sheath, as for example a plasticizer incorporated to ease the manufacturing process, the loss of the additives by the polymer and the parameters driving this mechanism shall be quantified, and,

- Subsequent effects on the plastic sheath physical and mechanical characteristics, permeability, ageing as well as design of the mechanical gripping system at the end fitting shall be accounted for and documented.
- Replacement of the additives by some elements of the transported fluid and subsequent effects shall be captured.
- Permeability to the different components of the transported fluids shall be determined for the range of temperatures representing the design conditions.
- Calculations results shall be validated by experimental measurements obtained when the pressure has been applied to one side of the specimen only. Effect of ageing shall be analysed. The permeation results shall enable the corrosion rate of steel armours and H₂S resistance to be calculated.
- Thermal degradation shall be analysed.
- Chemical ageing characterised by the degradation of the chemical structure shall be established based on tests where effects of temperature, fluid, pH, water cut, time, bending, ...etc. on specified mechanical properties are quantified.
- Physical ageing such as swelling, stress cracking and blistering shall be assessed.
- Tests shall be performed for a range of temperature, pressure and decompression conditions covering the design conditions.
- Effect of the layer thickness and bending shall be quantified and accounted for. Results from long term tested samples shall also be presented.
- Temperature/pressure/design life limitations shall be provided.
- Wear induced by adjacent steel layer shall be accounted for in the design.
- Effect of increase in stress / strain resulting from gas diffusion in the annulus shall not be forgotten in the calculation.
- In addition, it shall be demonstrated that the thickness of the sheath ensures that:
 - it can withstand the manufacturing process without detrimental folding.
 - Creeping of the plastic material in the adjacent steel layers will not impair the layer's fitness for purpose both during hydrotest and in service conditions.
- Detailed documentation shall be provided and shall explain as a minimum, how the combined effects of the manufacturing tolerances, temperature and pressure conditions, plastic sheath thickness and hydrostatic effect of the external fluid pressure have been accounted for in the calculations.
- Validation of the creeping calculation based on full scale flexible pipe shall be carried out. Dynamic testing shall also be performed and results accounted for.
- In the case of a 3-layer PVDF system, diffused gas entrapment in between the layers shall be evaluated and subsequent potential for collapse shall be prevented. Detailed assessment shall be justified and if required, validated by tests.

7.1.2 Metallic layers

This section applies to carcass, pressure armour and tensile armour wires and outlines additional requirements to complement the Prime References' ones.

When the design pressure is in excess of 17.5 MPa, it is mandatory that the structure is made of, at a minimum, **both** a pressure armour layer and tensile armour layers.

All steel grades for carcass, pressure, armour wires and any additional metallic layer shall be indicated in AISI and both ISO / NFA standards (latest revision).

It shall be demonstrated that variations in wire dimensions and effect of manufacturing tolerances do not affect the designed structure (number of wires, thickness of pressure sheath, etc).

For sour service applications, selection of steel wires grade and dimension shall be based on SSC and HIC testing results as required in the Prime References. Detailed documentation shall be provided.

Residual stress in steel wire induced during the manufacturing of the layer shall be determined and accounted for in the design; this is an issue particularly for sour service and dynamic applications but shall be assessed for all types of application.

In all cases, prediction of residual stress shall be validated by measurements and detailed documentation provided.

For dynamic applications, S-N data generated as per the Prime References requirements shall be documented in details.

The S-N curves shall be generated on tests covering both the mean stresses and stress ranges of the given application under consideration.

Endurance limit of steel wire materials shall not be used in the design.

S-N data and stress concentration factors shall also be established for the steel wires welds and accounted for in the design.

In addition, the effect of corrosive environment and carried fluid on fatigue resistance shall be assessed:

- Detailed investigation and test campaign shall be carried out and documented.
- Effect of test frequency shall be quantified.

Effect of cathodic protection shall be analysed.

The annulus condition based on permeated fluid (H_2S and CO_2) and deaerated seawater is the design case to be analysed. This is the design case for which the safety factor of 10 on fatigue life is compulsory.

Two other cases also need to be captured:

- first, in case of outer sheath damage, the annulus condition and subsequent testing media is aerated seawater and Cathodic Protection
- secondly, in case of water ingress through the vent hole/valves located in the endfitting, the annulus condition and subsequent testing media is deaerated seawater plus cathodic protection plus permeated CO_2 and H_2S .

For these last two cases, Company may relax the safety factor of 10 on fatigue life provided that mitigation measures and reliable monitoring systems have been developed to ensure that remedial actions can be taken on time. Details of the proposed system in addition to detailed fatigue curves and fatigue life assessment shall therefore be submitted to Company for its approval.

7.1.3 Polymer tapes

For high design temperature, dedicated anti-wear material may have to be qualified. This issue shall be properly captured in particular for the high temperature projects where insulation is required.

7.1.4 Insulation tapes

As it can not be guaranteed that the outer sheath will not be damaged during installation, the detailed design of insulated flexible pipe shall account for insulation material thermal properties based on a flooded annulus case.

7.2 End Fittings Design

In addition to the Prime References requirements the following issues and their variations along the field life shall be addressed and fully documented:

For all plastic and steel layers:

- The additional requirements stated in section 7.1 shall also be addressed in order to capture the end fitting functionality.
- For example, but not limited to, specific requirements associated to gripping & crimping issues at the end fitting location shall be assessed and accounted for in the design.
- As part of this assessment, resistance of the external sheath at the crimping/sealing ring location to the loads applied both during installation and in-service shall be established and clearly documented.

At the end fitting location:

- The plastic sheaths shall be continuously supported by a steel support.
- Direct contact of the pressure sheath with the injected epoxy is not allowed.
- A conical ring shall be included between the pressure sheath and the armours termination for flexible pipe where the armours are laid at 55°. The objective is to prevent creeping and potentially bursting of the plastic sheath resulting from a default in the injected epoxy in areas where the sheath was previously supported directly by the epoxy. The conical ring shall be designed to withstand loads induced during testing, installation and in service.
- Stress concentration factors at and within the end fitting shall be established and documented.
- A consistent level of corrosion resistance between the end fitting and the carcass layer shall be ensured and documented.

As a general requirement, the flexible pipe end fittings shall be designed on the basis of a seawater flooded annulus.

It shall be emphasised that the end fitting shall be more resistant than the flexible pipe structure i.e. in case of rupture under external loading, rupture shall not occur in the end fitting.

7.3 Loads

In order to address the requirements from the two previous sections, all analyses and structure definition shall take into account the loads encountered during the whole cycle life of the flexible pipe.

Prime References requirements shall be satisfied and in addition, special attention shall be paid to:

- transitory phases when the content is not the final fluid or when the fluid density varies during the field life (temperature, pressure, flow, chemical composition, ratio liquid / gas, etc.) with effects on gravity loads, stability, expansion ..etc..
- effect of buoyancy modules and attachments to the pipe: local additional weight or buoyancy loads shall be included. Computer models shall represent not only additional weights but shall model hydrodynamic forces.
- effect of additional equipment required for the installation shall not be forgotten.
- hydrodynamic forces: for each wave and current direction, the phase shall be considered to produce the maximum hydrodynamic horizontal force.

7.4 In-Place Behaviour

The additional requirements to the Prime References presented below shall be addressed.

7.4.1 Internal friction coefficient

The internal friction coefficient (or roughness) of flexible pipes shall be documented.

7.4.2 Expansion and Upheaval buckling

Pipeline shortening or lengthening shall be calculated as per the Prime References requirements and cover the hydrostatic test conditions.

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

Following installation, during the hydrostatic test, measurement of the flexible pipe displacement shall be carried out.

Remedial action shall be undertaken if displacement is not in-line with the predictions from the calculation.

Pipe walking and requirement for anchoring the flexible pipe shall be assessed.

7.4.3 Reverse End cap effect

Detailed documentation based on qualification test results demonstrating that issues associated to the reverse end cap effect are under control shall be produced.

Particular attention shall be given to "bird cage" and lateral buckling of the different steel layers. Reference is made to Petrobras and Technip papers presented at OMAE 2004.

7.4.4 Dynamic and Fatigue assessment

The global riser behaviour shall be analysed as per the Prime References requirements as well as per **GS PLR 151 requirements**.

Fatigue induced by vortex induced vibrations shall be accounted for. The structural damping coefficient employed in the analysis shall be justified.

The steel wires shall satisfy the fatigue resistance criteria required in the Prime References.

The computer model used to assess the fatigue life resistance shall be able to analyse several wire shapes (removing corrosion and wear allowance) and conditions (parent material or weld) under different loading configurations.

The computer model shall have been validated on small and full scale tests covering the design conditions. Supportive documentation shall be provided.

Fatigue at the end termination location shall also be assessed.

Effect of end stiffeners when used shall be addressed.

COMPANY is concerned that although it might not affect the global response of the flexible pipe the rupture of a steel wire can impair the pipe lifetime fitness for purpose by damaging the plastic sheaths.

As a result, the manufacturing process shall ensure that wire welds are not located in fatigue sensitive areas such as for example, the touch down point and top connection areas of flexible risers.

For the other sections, the minimum distance in between welds shall be justified.

7.4.5 Gas venting System

Gas venting system shall be designed so as to prevent pressure built up in closed area. In restricted locations, such as for example manned areas or gas monitoring areas, routing of the vented gas shall be engineered to satisfy COMPANY safety requirements.

Gas venting system shall be designed so as to properly operate even when the pipeline end fitting sinks into the mud, and the proposed design shall be approved by COMPANY.

7.4.6 Fire resistance

Fire resistance should be governed by a survival time, which is project's specific; if beneficial and feasible change in the general pipeline layout shall be investigated.

In all cases, the fire resistance of the flexible pipe and the end fitting shall be documented.

7.4.7 Marine growth

When a dynamic end termination is to be designed at a bell mouth location, fouling prevention shall be established and documented.

7.4.8 Transfer of loads to the piping

All loads, including VIV induced by the flow regime on the internal carcass in case of rough bore structure shall be estimated. Results shall be provided to COMPANY, for subsequent use in the design - by others - of the piping connected at the extremities of the flexible line.

7.4.9 Stress utilisation factors

For all flexible pipes under consideration, stress utilisation factors shall be tabulated and account for the stress associated to pipe bending (see Appendix 1).

8. Design Tools

The design tools i.e. software, spreadsheets and computer models used in the design of flexible pipe structure and end fittings shall have been validated and calibrated upon small and full scale tests:

- Tests conditions shall cover the design ones.
- Supportive documentation shall be made available to COMPANY.
- Design tools shall have been certified by a Certifying Authority approved by COMPANY. Certificate and associated reports and comments shall be made available to COMPANY.

9. Qualification program

For all flexible pipes under consideration, a detailed qualification program or if already performed, detailed results to cover the issues listed below for the specific application under consideration shall be documented and tabulated:

- Internal pressure test up to burst of sample (samples with and without a weld shall be tested)
- Radial mechanical compression to simulated lay operations & evaluated the structure resistance to crushing loads combined to tension; this shall also address issues associated to thick coating when used and potential sliding of inner pipe.
- Combined tensile & pressure test to verify the structure behaviour when submitted to internal pressure with the maximum design tension.
- External pressure test to check the adequacy of the end fitting sealing system
- Hydrostatic collapse test
- Fatigue test – full scale
- Bird caging and lateral buckling tests of tensile armour wires when submitted to the combination of the full water column external pressure with 1.5 times the Minimum Bending Radius of the flexible structure and curvature variation.
- End fitting integrity test

In addition, if components, materials or technologies used in the flexible pipe and associated equipment do not satisfy the Prime References and additional requirements defined in sections 6 and 7, a detailed qualification program shall be prepared according to [API SPEC 17 J](#) section 6.2 and [ISO 13628-2](#) section 6.2.

In all cases, the qualification programs, including test specifications and procedures with acceptance criteria, shall be submitted to COMPANY for approval prior to the implementation of the components, materials or technologies in the design.

The resulting qualification reports, reproducing the original qualification program together with the achieved results, shall be issued to COMPANY as part of the final documentation.

10. Manufacturing and testing

Manufacturing and testing of flexible pipe shall satisfy the Prime References requirements.

This section defines additional requirements to be satisfied.

Prior to start of the manufacturing activities a manufacturing kick-off meeting shall be organised.

10.1 Quality Assurance Requirements

10.1.1 General

The quality assurance system shall be [ISO 9001](#) compliant and shall be certified. The Certifying Authority reports and conclusions shall be issued to COMPANY.

It shall be demonstrated that Prime References quality assurance requirements are fully satisfied.

COMPANY is concerned by potential deviations between the characteristics of the pipe and its components used in the design and the final product resulting from the manufacturing process.

At all levels of the manufacturing process, clear evidence of the compliance of components, intermediate and final product to the design parameters shall be produced.

Corrective measures shall be undertaken in case of deviation from the design parameters.

10.1.2 Documentation

10.1.2.1 Procurement Plan

Based on the overall delivery schedule, a procurement plan shall be prepared for all materials required including specific equipment for testing.

The procurement activities shall be co-ordinated and corrective actions initiated in order to ensure that the requirements of the procurement plan are met.

During the procurement phase, a progress report shall be issued on a regular basis, with particular emphasis on performance of quality control and acceptance testing.

10.1.2.2 Manufacturing Quality Plan

The Manufacturing Quality Plan (MQP) shall contain as a minimum:

- Detailed fabrication and assembly procedures, including a step by step description of the fabrication process, working procedures and repair procedures to be used during the fabrication and assembly of the flexible lengths and associated termination parts.
- A Control Inspection Plan, defining all inspections, verifications and controls to be carried out prior to start off production i.e; on raw material and base material, during the fabrication and assembly phases, together with references to the relevant documents containing the associated acceptance criteria.
- A Factory Acceptance Testing (FAT) Procedure, defining all tests to be carried out during the fabrication and assembly phases.

Witness and hold points during fabrication shall be indicated.

The MQP shall be submitted for review, comments and approval by the COMPANY.

All specific requirements indicated in the sections below shall be included in the MQP and identified by the code "Client Requirements".

A progress report of the manufactured lines shall be issued on a weekly basis.

10.1.3 Certifying Authority

Independent verification agent approved by Company Certifying Authority shall certify the flexible line.

10.1.4 Storage

Detailed storage instructions shall be provided taking into account the nature of the goods and their vulnerability to high or low temperatures, dust, impact, moisture, light (sunlight), corrosion, oxidation, magnetism, theft, etc.

The Manufacturer shall be fully responsible for the proper organisation of his warehouses and stocks, including clear, unambiguous marking of the goods for their identification and location.

More generally, all equipment forming part of the final delivery, as well as any component thereof, shall remain the full responsibility of the Manufacturer until the complete job has been delivered and accepted.

10.1.5 Traceability

Throughout the fabrication and assembly process, all components shall be clearly identified and marked with a unique reference code, which must be quoted in all associated documentation.

For flexible lengths, a proper identification system shall be implemented, to ensure that the line, and section if relevant, can be quickly identified at any time during the fabrication process.

10.1.6 Control and Inspection

The fabrication and assembly controls and inspections shall be performed in accordance with the Control Inspection Plan approved by COMPANY.

COMPANY shall be granted unrestricted access to the fabrication, assembly and/or testing sites, as well as to all documentation and control/inspection data.

To ensure quality and dimensional tolerances (diameter, thickness, length), the following minimum inspections shall be performed:

- Continuous measurement of diameters during all stages of fabrication:
if continuous measurement is not possible, the flexible diameter shall be checked every 10 meters and at shorter intervals in the event of problems or at any COMPANY representative's request.
- Continuous measurement of thickness of the inner pipe and pressure sheath:
for subsequent sheaths, continuous measurement shall be carried out at the beginning of the extrusion process, then discontinuous measurements shall be taken every 10 meters at four points at 90° (with an offset of 30° between two consecutive series of measurements).
electronic files on CD-ROM records shall be included in the as built data documentation.
- Continuous measurement of the reeling pitch during fabrication.
- During the fabrication phase, the entire length of the various flexible lines shall be monitored with an indication and record of any particular points or repairs.
- Length tolerance for flexible lines, when assembled, if appropriate, and fitted with their end fittings, shall not exceed $-0.0/+0.3$ % of the required overall length as previously determined. No negative tolerance shall be accepted.

10.2 Manufacturing Process Requirements

10.2.1 Carcass forming

Before start of the COMPANY job, the machine shall be cleaned from any other part remaining from the previous job.

An inspection hold point shall be included in the Manufacturing Quality Plan.

At the beginning of the process, a visual inspection shall be followed by a measurement of the carcass section using a profile projector.

This inspection must conform to the theoretical profile dimensions (overlaid surface coping 85 %) and the outer plane of interlocked steel wires shall be compared with the allowable value indicated in the MQP (slope < 3 %).

No weld shall be done without gas protection (front and back).

10.2.2 Polymer extrusions

Before start of the COMPANY job, the machine shall be cleaned from any other part remaining from the previous job. An inspection hold point shall be included in the Manufacturing Quality Plan.

The minimum manufactured thickness shall be at least equal to $1.05 \times$ (minimum design thickness + largest defect depth + minimum thickness measurement tolerance of the measurement probe).

Repairs on pressure sheath are not permitted.

The integrity of the intermediate and outer sheaths shall be inspected with a holiday detector (the voltage shall comply with the product and its thickness).

In particular, the inspections carried out during fabrication shall be described and shall ensure that sheaths are free of any unacceptable defects, such as reduction in mechanical strength, etc., and that under no circumstances could the fluid conveyed spread over the outer sheath and cause corrosion to the armour wires.

In case of the voltage needed for the sparking test is greater than 20kV/mm polymer thickness, for safety and health reasons a dedicated procedure shall be submitted for approval to COMPANY

The following non-exhaustive list of non-conformances shall render the product unacceptable:

- Micro-cracks
- Traces, coloured spots or surface roughness which are indications of contamination by rough material
- Surface irregularities such as corrugation or undulation (inappropriate control of the extrusion head or defective-pulling crawler).
- Air bubbles in the pressure sheath
- Longitudinal tool marks (solid residue or any foreign matter in the extrusion head).
- Remaining thickness of the layer excluding the flaw dimension less than 1.1 times the minimal thickness.

The mechanical characteristics of the virgin material used for the pressure sheath shall be checked. In the case of Polyamide and Polyethylene, five samples shall be taken at the beginning and the end of the extrusion process.

As required by [API 17J](#), all samples shall be stored at ambient temperature for a minimum of 6 hours prior to testing.

These samples shall be stretched in accordance with the detailed procedure of the elongation test specified in [ASTM D638](#). Values between 90% and 110 % of the nominal value indicated in the MQP are acceptable.

10.2.3 Pressure and tensile armours winding

The welding approval test shall be performed on the welding station forming part of the wiring machine. A similar test shall be performed during the spooling phase. There must be no indication of cracks.

For flexible pipe structures with armours at 55°, in addition to the pitch length the wire gap distribution shall be measured and compared with the allowable value indicated in the MQP.

Wire gap measurement shall be done at least every 10 meters using automatic electronic tools instead of manual measurement.

10.2.4 Anti-wear and insulation layers

Performance of multiple insulation layers thicker than 33 mm (i.e. six single layers) requires qualification and check to ensure that laying tension is fully transmitted through the insulation layers to the armour without damage nor sliding.

10.2.5 End fitting

All areas of the pressure sheath shall be continuously supported by a steel support.

If because of the end fitting build up, a not supported area is identified, it shall remain below 2 millimetres.

In all cases detailed calculation shall be provided for COMPANY approval to determine the allowable gap with respect to the sheath thickness.

Measures taken to ensure that the final product gap remains below allowable shall be detailed and validated.

Direct contact of the pressure sheath with the injected epoxy is not allowed.

The minimum holding points for the end fitting mounting are defined below:

- Machining on pressure sheath
- Position conical ring part, before bending back the wires
- After bending back the wires, before resin injection operation.
- Resin injection and compression resistance test on samples.

10.2.6 Venting valves

It is mandatory to test each venting valve before installing them on the end fitting in order to record the opening pressure of the relief valve, plus the tolerance of the measurement.

10.3 Factory Acceptance Tests (FAT)

Unless otherwise stated below, the [API SPEC 17J](#) requirements shall be satisfied in terms of test procedure and test pressure.

10.3.1 Gauge test

The minimum diameter of the gauging pig shall be 95% of the nominal ID.

During the test, the pumped volume of water, the ambient and the internal temperatures shall be checked and recorded.

10.3.2 Internal hydrostatic pressure test

The equipment required for the test shall be calibrated before each test with a dead-weight pressure balance (stamp date not older than six months).

A variation of the pressure shall be applied and tested before start off the hydrostatic test.

A redundant mechanical calibrated pressure equipment shall be connected to the line as well.

The entrapped air content shall not exceed 0.2% of the calculated capacity of the pipeline section under test for a smooth bore and 0.5 % for a rough bore line

10.3.3 External hydrostatic pressure test

When required by the deep water application, the test of the external sheath sealing on the back space of an end fitting shall be carried out with equipment calibrated with a dead-weight pressure balance (stamp date not older than 3 months).

The procedure shall be the same as for the internal pressure test.

10.4 Delivery

10.4.1 Documentation

Each delivery shall be accompanied by a document containing all necessary information, such as:

- type and number of reels,
- length of flexible line on each reel,
- weight of each reel,
- factory acceptance tests, etc.

10.4.2 Marking

Each flexible line shall be identified with two markings:

- Identification code
- Length markings.

Markings shall be in paint that shall have a composition compatible with the external sheath, with good adherence and anti-fouling properties.

10.4.2.1 Identification code

The indication shall identify the transported fluid and line diameter.



The fluid shall be reported by white bands:

- Oil: 1 thick band of 60 mm
- Gas: 2 narrow bands of 30 mm, 30 mm apart
- Water: 3 narrow bands of 30 mm, 20 mm apart.

At the location of the fluid identification, a diameter mark shall be painted on two white rectangular areas, with dimensions varying with the diameter, one for each side of the line.

The area dimensions are 80 x 150 mm for diameters less than 12" and 200 x 200 mm for larger diameters.

The marking interval shall be every 20 m from 35 m up to 215 m and every 100 m above 215 m.

10.4.2.2 Length markings

One bright yellow band shall be painted around the pipe every 10 m.

For every 50 m, the number of tens shall be painted, then the number of hundreds and thousands.

10.4.3 Packaging

The reel characteristics shall be in accordance with the laying requirements.

The end fittings shall be sealed with blind flanges.

The lines shall be reeled under tension and protected against UV.

Free venting shall be obtruded and a label with instructions for fitting shall be applied.

On each side of the reels, an identification plate shall indicate:

- Place and country of delivery
- Job name
- Line name or code
- Reel number/Total number of reels for the job
- Customer name
- Contract reference
- Diameter and length
- Net and gross weights.

All additional equipment shall be adequately protected and properly boxed for delivery. All boxes shall be properly identified (see above list of indications), and a boxing list shall be provided.

Accessories and spare parts (bolts and gaskets) shall be delivered together with the associated flexible lines.

Appendix 1 Stress ratio format

Results of each structure stress analysis shall be documented as outlined below.

For each layer of the proposed structures, the stress ratio shall be tabulated according to tables 1, 2 and 3 below and compared to the allowable ratio for each of the following load cases:

- factory test pressure
- installation
- hydrotest offshore
- in operation / design.

Line Description and Structure number	Internal Pressure (bar)	External Pressure (bar)	Axial Tension (kN)	Bending Moment (kN.m)

Table 1: Loads

Line Description and Structure number	Stress in Pressure vault (MPa)	Ratio UTS (%)	Ratio YS (%)

Table 2: Stress in Pressure vault wires

Line Description and Structure number	Stress in Tensile Armour (MPa)	Ratio UTS (%)	Ratio YS (%)

Table 3: Stress in tensile armour wires

Allowable stress ratios according to APi 17J:

-x% per reference to the minimum UTS

-y% per reference to the minimum YS