TECHNICAL SPECIFICATION

# HIGH PRESSURE METAL/POLYMER FLEXIBLE PIPE
## FOR USE IN OIL AND GAS OPERATIONS AS FLOWLINES AND RISERS

DDD 39.40.20.30-Gen.

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**DESIGN AND ENGINEERING PRACTICE**

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

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# 1. INTRODUCTION

## 1.1 GENERAL

This specification gives basic requirements for metal/polymer flexible pipe intended to be used for the transmission of well fluids such as oil, gas and water at high pressures under static and dynamic loading conditions in non-sour and sour services.

Any other use shall be subject to approval of the principal, who is recommended to consult SIPM.

Unless otherwise authorized by SIPM, the distribution of this specification is confined to companies forming part of or managed by the Royal Dutch/Shell Group and to contractors and manufacturers/suppliers nominated by them.

As a rule the requirements of this specification shall be adhered to.

However, national and/or local regulations may exist in which some of the requirements are more stringent.

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, economic and legal aspects.

In all cases the contractor shall inform the principal of any deviation from the requirements of this specification 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 specification as closely as possible.

All publications referred to in this specification are listed in (13.).

Where cross references are made, the number of the section or sub-section referred to is shown in brackets.

## 1.2 DEFINITIONS

For the purpose of this specification, the following definitions shall hold:

**Shall** and **Should** - the word 'shall' is to be understood as mandatory and the word 'should' as strongly recommended to comply with the requirements of this specification.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction.
The Principal will generally specify the technical requirements.
The Principal may also include an agent or consultant, authorized to act for the Principal.

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

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

The Purchaser is the party which buys flexible pipe for its own use or on behalf of the owner.

* For Group operating companies having a service agreement with SIPM or SICM, the term Principal shall be taken as referring to the equipment engineering department of SIPM - EP.

## 2. PURCHASING

### 2.1 GENERAL

An enquiry for flexible pipe will be by means of a requisition using the requisition sheet DEP 39.40.20.93-Gen. The manufacturer shall respond with a Manufacturing Procedure Specification (MPS) as described in (4.1), which shall form the basis for the purchase order. Inspection requirements shall be discussed at a pre-production meeting after issue of the purchase order.

The intended service for the flexible pipe shall be clearly stated in the requisition.

A list of minimum requirements to be specified in the requisition is given in Appendix I.

Minor changes to this specification may be proposed by the manufacturer in the quotation stage for review by the principal. Any deviations from the requisition should be clearly stated in the quotation.

In case of conflict between documents relating to the inquiry or order, the following priority of documents shall apply:

1. purchase order and variations thereto
2. requisition sheet and project specification
3. this specification
4. the manufacturing procedure specification as approved by the principal prior to manufacturing (see 4.1)

### 2.2 QUALIFICATION PROCEDURES

Metal/polymer flexible pipes for use by Shell Group operating companies shall be qualified by passing the qualification criteria of a set of tests defined by SIPM-EP resulting in the qualification of a particular product prior to pruchsing. Details need to be defined in detail in the purchase order, e.g. all layers involved, materials and dimensions of materials and dimensions of the final product.

The qualification tests and criteria for static applications are subject of a separate document 'Static Qualification Tests for Metal/Polymer Flexible Pipe'. On request this document can be made available by SIPM-EP.

The qualification tests and criteria for dynamic applications are currently in development.

## 3. BASIC DESIGN

This specification applies to metal/polymer flexible pipe consisting of an extruded polymer tube to contain pressurized fluid, that is reinforced by means of spirally wound strips and/or wires around or inside the polymer tube.

The extruded polymer tube shall be reinforced such that burst due to the pressure of the transported fluids and collapse due to external (e.g. hydrostatic) pressure or sudden depressurization are prevented.

The selection of construction materials and the design of the metal/polymer flexible pipe shall be such that deterioration by corrosion, ageing is prevented. Especially the influences of the transported fluid and the external environment shall be thouroughly investigated.

Metal/polymer flexible pipes are composed of a number of extruded polymer layers and spirally applied metallic layers as follows:

Item I: Internal carcass:

- Prevents collapse of the internal polymer layer under external hydrostatic pressure and/or externally applied crushing loads and/or gas pressure between the polymer layers due to diffusion.
- Protects the internal polymer layer from damage during TFL operations in some applications.

Item II: Internal polymer layer:

- Forms the pressure seal in the flexible pipe
- Improves the insulation in some applications.

Item III: Hoop stress resisting layer(s):

- Provides reinforcement of the internal polymer layer against internal pressure induced hoop stress and/or externally applied crushing loads.
- Prevents extrusion and/or creep of the internal polymer layer under internal pressure.

Item IV: Tensile stress resisting layer(s):

- Provides reinforcement of the internal polymer layer against internal pressure and/or externally applied axial loads.

Item V: External polymer layer:

- Prevents corrosion as a result of ingress of water.
- Contains lubricants, in particular for dynamic applications.
- Prevents lubricant degradation as a result of ingress of water in particular for dynamic conditions.

Item VI: External carcass:

- Prevents damage of the external polymer layer due to external forces and impact mainly for topsides applications.

All the foregoing layers except for Items I and VI may consist of a number of sub-layers depending upon the particular application.

Non-metallic spirally applied tapes may also be included in the pipe structure to aid manufacture.

In addition intermediate polymer layers and/or anti-friction non-metallic tapes and/or additional lubricant may be included for dynamic applications.

The manufacturer shall prevent the build up of gas pressure between the external and internal polymer layers as a result of diffusion through the internal polymer layer by incorporating a suitable gas relief system in the design.

Both ends of the metal/polymer flexible pipe shall be provided with end fittings. The flange or coupling type shall be specified in the requisition.

The strength and the integrity of the end fittings shall be greater than of the pipe body.

The end fitting shall be resistant against corrosion, either by way of material selection, or by means of the combination of a suitable coating and cathodic protection.

This specification details the properties of the end fitting materials and any of the above layers when present in the structure.

Metal/polymer flexible pipes shall be designed on the basis of 3:1 safety factors between the guaranteed values and the maximum service pressures both with regard to burst and collapse strength.

## 4. MANUFACTURE

### 4.1 MANUFACTURING PROCEDURE SPECIFICATION

The manufacturer shall supply to the principal a Manufacturing Procedure Specification (MPS), detailing step by step, on a layer by layer basis the manufacture of the complete flexible pipe, i.e. all layers, sub-layers, lubricants, tapes and any other items forming an integral part of the final product.

The MPS shall include reference to specifications and sources of all materials used in the manufacture of the flexible pipe. This clause applies both to the materials used for the manufacture of the layers described in (1.2) and to materials such as lubricants, corrosion coating materials, anti-friction tapes, and non-metallic tapes.

The manufacturer shall state in the MPS all parameters related to the quality of the final product as defined in the specification which can be monitored during manufacturing, to enable definition of the inspection of these items. Both nominal values and ranges of these parameters shall be stated.

The layout of the MPS shall enable the principal to easily and unambiguously define the responsibilities of the principal's designated inspector during the manufacture.

The MPS shall be approved by the principal prior to commencement of the manufacture of the flexible pipe.

### 4.2 PRODUCTION RECORD

The manufacturer shall record length of fabrication on completion of each operation and shall ensure that the exact location of all join-up welds, polymer repair areas (where applicable) etc. are documented on Production Record.

### 4.3 MANUFACTURE PREPARATION

All the materials proposed to be used for manufacturing shall be stored by the manufacturer in such a manner that they are not detrimentally affected by environmental or other injurious conditions. Any materials so affected shall be subject to rejection by the principal and, if so rejected, shall be replaced by the manufacturer at the manufacturer's expense.

The materials used for manufacture shall be in accordance with (5.) and (6.). Proposals for alternative materials by the manufacturer may be considered. However, the use of such alternatives shall always be subject to approval by the principal.

Suppliers of base materials as proposed by the flexible pipe manufacturer shall be approved by the principal. Any materials used without the principal's approval shall render both materials and production subject to rejection by principal. Any materials and/or product shall be replaced and/or reproduced at manufacturer's expense.
All materials to be used for manufacturing the flexible pipe structure and end fittings shall be tested by the pipe manufacturer in his works. The tests and test criteria shall be in accordance with this specification and shall be approved by the principal prior to manufacture.

The manufacturer shall ensure that all machinery and instruments are calibrated in accordance with this specification and all relevant standards appertaining to the manufacture and testing of the flexible pipe.

### 4.4 SPIRAL APPLICATION OF METALLIC AND NON-METALLIC LAYERS

The manufacturer shall ensure that the spiral application and forming equipment functions satisfactorily and all items subject to wear are renewed as and when required. The manufacturer shall demonstrate that the spiral application equipment will produce a satisfactory end product prior to manufacture.

The manufacturer shall ensure that all interlocking layers are fully interlocked and set in the mid position.

The manufacturer shall ensure that all metallic material is coated with a uniform layer of an approved lubricant prior to application to prevent damage during manufacture.

If, at the justifiable discretion of the principal, it is considered that metallic material prior to use for manufacture has become contaminated with deleterious substances, manufacturer shall steam clean, air blow dry and re-lubricate the metallic material prior to use.

## 4.5 EXTRUSION OF POLYMERS

The manufacturer shall ensure that each of the extruded inner polymer layers is applied in a continuous operation.
The manufacturer shall ensure that all extrusions are onto a clean and dry underlying layer.
The manufacturer shall demonstrate the method of removing rejected extruded layers and shall receive principal's approval prior to manufacture.
The manufacturer shall clearly define the extrusion and repair method for thin intermediate polymer layers.

## 4.6 APPLICATION OF LUBRICANTS AND CORROSION PROTECTION COATINGS

The manufacturer shall specify the method of application of all lubricants and corrosion protection coatings for approval by the principal. In particular the manufacturer shall ensure that all lubricants and corrosion protection coatings are fully compatible with all elements of the metal/polymer flexible pipe, including the plasticizer of the polymer sheath.

## 4.7 END FITTINGS

The manufacturer shall specify the manner and method for manufacturing the end fittings in the MPS and shall receive approval from the principal prior to manufacture.

## 4.8 GAS RELIEF

The manufacturer shall specify the manner and method for the incorporation of the gas relief system.

## 4.9 HEAT TREATMENT

All heat treatments shall be carried out in accordance with the relevant material standards.

## 4.10 WELDING

The manufacturer shall submit to the principal the method and manner to be used for joining and/or repair of each individual metallic component to be joined during production of the flexible pipe.

The manufacturer shall submit to purchaser the type of welding equipment, materials and consumables proposed to be used by manufacturer for executing welding and shall receive approval from purchaser prior to use.

The manufacturer shall prove by testing that the welding equipment, materials and consumables, methods, manners and procedures proposed shall result in an acceptable standard of product in accordance with this specification and in a manner acceptable to purchaser.

All pre-production testing shall be certified by manufacturer and certificates issued and submitted to purchaser prior to production welding.

The manufacturer shall not change purchaser approved methods, equipment, materials, consumables, parameters and/or test methods without first pre-testing the changes and shall receive approval from purchaser prior to use of such changes.

The manufacturer shall be required to impose strict quality control and supervision during each weld, both visually and by means of non-destructive testing.

Join-up welds of stainless steel wires or strips shall be made using gas tungsten arc welding

(GTAW) only. Pure argon shall be used as shielding gas.

The manufacturer shall not use welding techniques during manufacture or installation of the end fittings, unless prior approval has been obtained from the principal.

## 4.11 JOIN-UP OF THE INTERNAL CARCASS

A procedure for joining up the internal carcass shall be submitted to the principal for approval prior to manufacture.

## 4.12 SURFACE TREATMENT

The manufacturer shall specify the surface treatment of the end fitting parts prior to manufacture. The external surface of the end fittings shall be protected by means of a coating system. This system shall be approved by the principal prior to manufacture.

## 5. MATERIALS

All materials shall be supplied by subsuppliers approved by the principal.

5.1 MATERIAL SELECTION

ITEM I

The material of the internal carcass shall be selected by the principal and shall be one of the following:

Option 1: Carbon steel ASTM A106

This carbon steel shall not contain more than 0.020% phosphorous and 0.020% sulphur. The carbon equivalent (C.W. IIW) shall not exceed 0.45%.

C.W. = C + Mn/G + (Cr + Mo + V)/5 + (Ni + Cu)/15

Option 2: Carbon steel ASTM A106, resistant to hydrogen induced cracking (HIC) and sulphide stress cracking (SSC)

The chemical analysis shall be as follows:

| Element | Check analysis (%) |
|---|---|
| Carbon (C) | 0.16 max. |
| Manganese (Mn) | 1.30 max. |
| Phosphorous (P) | 0.020 max. |
| Sulphur (S) | 0.003 max. |
| Silicon (Si) | 0.45 max. |
| Copper (Cu) | 0.40 max. |
| Carbon Equivalent (C.E. IIW) | 0.39 max. |

Moreover, the manganese shall be minimized and if possible maintained less than 1%. Calcium treatment of the melt is mandatory, the Calcium content (check analysis) shall be not less than 1.5 times and not greater than 3.5 times the Sulphur content measured.

Option 3: Austenitic stainless steel UNS S31603 (AISI 316L)

Option 4: Duplex stainless steel UNS S31803 (DIN 1.4462)

Option 5: Austenitic stainless steel UNS N08028

ITEM II

The internal polymer layer shall be Polyamide 11 extruded from virgin material. The combination of polyamide and plasticizer agent shall be qualified by the Principal.

ITEM III

High strength low alloy steel (HSLA) resistant to HIC and SSC. The chemical analysis of carbon steel shall be as for Item I, option 1.

ITEM IV

High strength low alloy steel (HSLA) resistant to HIC and SSC. The chemical analysis of carbon steel shall be as for Item I, option 1.

ITEM V

The external polymer layer shall be Polyamide 11, extruded from virgin material.

ITEM VI

The material of the external carcass shall be selected by the principal and shall be one of the following:

Option 1: Carbon steel ASTM A106

Option 2: Austenitic stainless steel UNS S30403 (AISI 304L)

Option 3: Austenitic stainless steel UNS S31603 (AISI 316L)

Option 4: Austenitic stainless steel UNS S31254

END FITTINGS

The material of the end fittings shall be selected by the principal and shall be one of the following:

High strength low alloy steel UNS G41300 (AISI 4130)

High strength stainless steel UNS N06625 (Alloy 625)2

5.2 CHEMICAL ANALYSIS

Certificates of heat analyses in accordance with DIN 50049 3.1.B shall be provided by the manufacturer for hydrogen induced cracking and/or sulphide stress cracking resistant materials mentioned in (5.1), Item I Option 2, Item III and Item IV

The manufacturer shall furnish a report of the chemical product analysis of one main spool of metal strip or wire per heat and of every batch of polymer of each of the components of the flexible pipe.

If any product analysis fails to conform to the specified requirements either the main spool (see 4.3) shall be rejected, or the analysis shall be repeated in duplicate. If both recheck analyses conform to the requirements, the lot shall be accepted.

Any product analysis made by the manufacturer shall be available to the purchaser.

Chemical analyses shall be determined by any of the procedures commonly used for determining chemical compositions such as emission spectroscopy, X-ray emission, atomic absorption, combustion techniques or wet analytical procedures. The calibration methods used shall be in accordance with established standards.

# 6. PROPERTIES AND TESTING OF MATERIALS

## 6.1 MECHANICAL AND PHYSICAL PROPERTIES

### 6.1.1 Properties of metallic materials

The requirements with respect to tensile properties, hardness values, charpy impact values and minimum bending radii shall be as defined in the following table (materials are defined in (5.)):

| | SMYS MPa | UTS MPa | elong. % | Charpy V J | bend R mm | HV max |
|---|---|---|---|---|---|---|
| Item I | | | | | | |
| C-steel 241 | 413 | 25 | --- | 0.5 | --- | |
| C-steel (HIC, SSC) | 241 | 413 | 25 | --- | 0.5 | 248 |
| UNS S31603 | 215 | 510 | 40 | --- | 0.5 | 248 |
| UNS S31803 | 450 | 680 | 25 | --- | 0.5 | 300 |
| UNS N08028 | 220 | 500 | 40 | --- | 0.5 | 248 |
| Items III and IV | | | | | | |
| HSLA (HIC, SSC) | 650 | 780 | 1 | --- | 4 t | 248 |
| Item VI | | | | | | |
| C-steel | 241 | 413 | 25 | --- | 0.5 | 248 |
| UNS S30403 | 200 | 490 | 40 | --- | 0.5 | 248 |
| UNS S31603 | 215 | 510 | 40 | --- | 0.5 | 248 |
| UNS S31254 | 300 | 650 | 35 | --- | 0.5 | 248 |
| End fittings | | | | | | |
| UNS G41300 | 358 | 540 | 18 | 46 (61) | --- | 248 |
| UNS N06625 | 360 | 540 | 18 | 46 (61) | --- | 345 |

For the above table the following definitions apply:

| | | |
|---|---|---|
| HSLA | : | High strength low alloy |
| SMYS | : | Specified minimum yield strength |
| UTS | : | Ultimate tensile strength |
| elong. | : | Elongation at fracture |
| Charpy V | : | Impact value, giving minimum value single specimen and (in brackets) minimum average value of three specimens. |
| Test temperature | : | minimum operating temperature minus 10 °C or the minimum ambient temperature minus 10 °C, whichever is the lowest. Longitudinally taken specimens, taken from 1/4 of the cross-section. |
| bend R | : | Minimum bending radius without any sign of fracture, bending about an axis perpendicular to the longitudinal direction of the wire and parallel to the shortest cross-sectional dimension. |
| t | : | thickness of the strip |
| HV | : | Vickers hardness, measured with 10 kg load |

### 6.1.2 Properties of polymeric materials

**Polyamide 11**
The relative viscosity of polyamide 11 when tested in accordance with Aquitaine Total Organic recommendations shall be not less than 1.36 and not greater than 1.46.

The moisture content of polyamide 11 prior to being extruded shall be less than 0.08%.

**Epoxy resin**
The epoxy resin material used to fill the annulus of the end fittings shall be obtained from a source approved by the principal. The epoxy resin shall be capable of achieving a compressive strength of forty (40) MPa.

**Other polymeric materials**
Properties and testing of other materials are to be agreed between the manufacturer and the principal.

## 6.2 MECHANICAL TESTING

### 6.2.1 General

The required frequency of all tests is given in Appendix II.

Any materials failing to meet the criteria laid down in this specification and relevant standards shall be rejected.

Any test specimens showing defective machining or flaws may be discarded and another specimen substituted. When the elongation of any tensile specimen is less than that specified and if any part of the fracture is outside of the middle third of the gauge length as indicated by scribe scratches on the specimen before testing, a re-test shall be allowed.

A test certificate (less than one year old) of verification of testing machines in accordance with BS 891, BS 427 and BS 1610 shall be provided by manufacturer to principal prior to manufacture.

### 6.2.2 Mechanical testing of metallic parts

Tensile testing, hardness testing and impact testing of metallic parts shall be carried out in accordance with ASTM A370 when possible. All tests shall be carried out with final products in the case of wires and strips, and on the base material of the forgings (end fittings).

### 6.2.3 Tensile testing of polymeric components

Tensile testing of polymeric components shall be carried out on five (5) samples taken from the outer surface of each end of each layer produced on the longitudinal axis. The samples shall be stored at 20 degrees Celcius for a minimum of six hours prior to tensile testing. The average value of the ultimate elongation shall be greater than 180%.

### 6.2.4 Compression testing of the epoxy resin

Compression testing of the epoxy resin used to fill the end fittings shall be carried out in accordance with ASTM D695-84.

## 7. FACTORY ACCEPTANCE TESTS

### 7.1 GAUGING

A gauging pig shall be passed through each individual length of pipe prior to pressurizing for pressure testing. The pig shall pass through the bore undamaged. If damage does occur, the cause shall be investigated.

The gauging pig shall have dimensions as specified in the requisition.

### 7.2 HYDROSTATIC PRESSURE TEST

The flexible pipe shall be subjected to a hydrostatic pressure test for a minimum duration of 24 hours at a pressure of 1.5 times the design pressure.

The test pressure, the temperature of the test water and the ambient temperature shall be recorded continuously for the complete duration of the pressure test.

The pressure test shall be executed using testing equipment as approved by principal.

The manufacturer shall carry out the pressure test in a safe working area that shall be adequately marked and restricted for the duration of the test.

Water used for the pressure test shall have a maximum chloride content of 20 ppm.

Pressure loss, corrected for temperature fluctuation and line relaxation effects shall be zero. Alternatively a pressure relaxation curve may be proposed in the MPS for approval by the principal.

Pressure loss, as defined in 6.2.6, during testing shall result in a re-test. In the event of pressure loss during the re-test the pipe shall be rejected. The manufacturer shall be required to carry out a full investigation of the pressure loss and shall submit findings and propose corrective actions to principal. A further re-test may be allowed at the discretion of the principal.

### 7.3 ELECTRICAL CONTINUITY AND RESISTANCE TESTING

The manufacturer shall determine electrical continuity between the two end fittings of each pipe length before and after the pressure test for acceptance by the principal.
The electrical resistance measured between the inner carcass and the end fittings shall be greater than one (1) megaohm when measured at one point five (1.5) volts.

The electrical resistance measured between the end fittings shall be less than ten (10) ohms per kilometer length of pipe.

The manufacturer shall record continuity and resistance measurements and submit same to the principal.

### 7.4 GAS RELIEF SYSTEM

The manufacturer shall demonstrate that the system meant to relief pressure built up in the annulus between the two polymer layers functions properly.

## 8. DIMENSIONS AND TOLERANCES

The basic requirements of the flexible pipe shall be derived from the specification included in the requisition.

The thickness of polymer layers shall be specified in the MPS for approval by the principal.

The thickness of metallic and non-metallic wires and strips shall be specified in the MPS for approval by the principal.

The external diameter of the flexible pipe after application of each layer shall be specified in the MPS for approval by principal.

The dimensional tolerances of internal and external carcass strip materials shall be + or -5% of the thickness.

The dimensional tolerances of wire and strip materials shall be + or -3% of the thickness.

The tolerances of the polyamide layer thicknesses shall be 20%.

The dimensional tolerances of the outer diameters of the layers shall be as follows:

| | | | | |
|---|---|---|---|---|
| Item I | +1% | and | -1% | of outer diameter |
| Item II | +2% | and | -2% | of outer diameter |
| Item III | +2.5% | and | -2.5% | of outer diameter |
| Item IV | +2.5% | and | -2.5% | of outer diameter |
| Item V | +2.5% | and | -2.5% | of outer diameter |
| Item VI | +3% | and | -3% | of outer diameter |

The internal diameter of Items I and VI shall be specified in the MPS for approval by the principal.

## 9. PRODUCT INSPECTION

### 9.1 PLANT ACCESS

The inspector representing the principal shall have free entry at all times while the work on the contract for the principal is being performed, to all parts of the manufacturer's works which will concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being manufactured in accordance with his specifications. All inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified on the purchase order, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

The manufacturer shall notify the principal of any changes in the manufacturing schedule at least 5 (five) working days before such a change.

### 9.2 VISUAL INSPECTION

The flexible pipe shall be visually inspected by the manufacturer during its complete manufacture. Observation of any occurrences which might effect the quality of the flexible pipe in an unfavorable manner, shall be reported to the principal and recorded on the flow chart.

Any holidays, discolouring, indentations, scores, laminations, abraded or damaged areas noted in or on the internal polymer layer, shall be reason to deem this layer suspect and shall lead to rejection.

Excessive holidays and/or damaged areas occurring in the outer polymer layer shall render this layer suspect and liable to rejection.

### 9.3 DIMENSIONAL CHECKS

The manufacturer shall check the following dimensions of the flexible pipe by means of established techniques, and shall submit records to the principal at the end of each layer application. These records shall be included in the PRODUCTION RECORD.

#### 9.3.1 Outside diameter

The outside diameter of each completed layer shall be measured and recorded every 5 metres. Two orthogonal diameters shall be recorded in each case.

#### 9.3.2 Pitch

The pitch shall be checked against the axial length of every twenty (20) spirals in accordance with the MPS.

#### 9.3.3 The thickness

The thickness of the extruded polymer layers of the items II and V shall be checked by means of a calibrated ultrasonic thickness instrument with an absolute accuracy of at least 0.05 mm.

Thickness checks of the extruded polymer sheaths shall be taken every 5 (five) metres at four equidistant locations around he circumference of the polymer layer.

#### 9.3.4 TFL inspection

For TFL applications, a go/no gauge shall be mounted in the bore of the internal carcass during manufacture to continuously check the dimensional tolerances of the internal diameter.

### 9.4 BEND TEST

The manufacturer shall take one sample of the fabricated pipe from each length produced up to and including item III, and shall submit the sample to bending down to the minimum

bending radius at -18°C (minus eighteen degrees Celsius) with no sign of cracking in the polymer layers. The manufacturer shall prepare a sample for inspection of the layering of the inner carcass (item I) the internal polymer layer (item II) and the hoop stress resisting layer (item III). Any defect noted indicative of any malfunction of machinery and/or materials shall be reason for further investigation and may subject the complete pipe to rejection by the principal.

9.5 POLYMER INTEGRITY

The first applied inner and outer polymers layers shall be subjected to an electrical insulation check using an approved holiday detector regulated to a voltage capable of detecting a 1 mm diameter hole.

The holiday detector shall be calibrated prior to the start of extrusion. It shall be shown that holiday detection can be carried out effectively on the coating of the required thickness. Calibration shall be witnessed by the principal. The detector shall be provided with an audible alarm.

9.6 END FITTINGS INTEGRITY

End fittings shall be inspected radiographically to ensure that the internal cavity is effectively filled with epoxy resin without the presence of voids.

## 10. WORKMANSHIP AND REPAIR OF DEFECTS

### 10.1 COMPLIANCE

The manufacturer is responsible for complying with all the provisions of this specification. The principal may make any investigation to satisfy himself of the compliance by the manufacturer and may reject any material which does not comply with this specification.

### 10.2 WORKMANSHIP

The manufacturer shall take all reasonable precautions to minimize damage during manufacture and/or storage.

The occurrence of sharp edges on the internal and external carcasses Items I and VI shall be prevented.

Caterpillar tensioners shall not damage the extrusions and cause thickness reductions below the specified limits.

The outside diameter of the completed flexible pipe shall be uniform and within the specified tolerances.

There shall be no voids in the end fitting epoxy filling.

The manufacturer shall ensure that only the minimum number of internal carcass join up welds is incorporated in the flexible pipe. Carcass for flexible pipe dynamic applications shall be manufactured in continuous lengths.

### 10.3 REPAIR OF DEFECTS

Defects found in the internal pressure bearing polymer layer Item II shall not be allowed. Any defect in this layer shall result in complete removal of the layer.

Minor defects in the polymer layer Item V may be repaired. A repair procedure shall be submitted to the principal prior to the manufacture of the flexible pipe. All repairs shall be inspected by the principal.

The method of repair for intermediate polymer layers shall be submitted to the principal prior to manufacture.

Any defects in welds shall be repaired by cutting out of the weld and heat affected zone area and re-welding according to the agreed procedure.

Surface protection coating damaged during assembly shall be repaired by means of a suitable procedure, to be agreed prior to manufacture.

The repair of voids in the end fitting epoxy filling is not permitted.

The manufacturer shall announce all repairs to the principal.

## 11. MARKINGS

### 11.1 NAME PLATE

A name plate shall be attached securely to both pipe ends clearly displaying the following information:

- manufacturers name
- nominal bore
- design pressure
- test pressure
- burst pressure
- minimum bend radius
- maximum operating temperature
- flow direction (arrow)
- Shell purchase order and item number
- manufacturing date

### 11.2 MARKING ON EXTERNAL LAYER

The manufacturer shall clearly mark the external layer with circumferential lengths marks 5 mm wide every 10 metres. The marking system shall resist installation abrasions and shall be satisfactory for a long term subsea service.

The manufacturer shall clearly mark the external layer of flexibles intended for dynamic application with a continuous line 5 mm wide parallel to the longitudinal axis of the flexible pipe. The marking system shall resist abrasions during installation etc. and shall be satisfactory for a long term subsea environment.

## 12. DOCUMENTATION AND REPORTING

All relevant documentation shall be provided to the principal by the manufacturer prior to the principal giving approval for each stage of manufacture or testing.

A list of relevant documentation shall be agreed between the principal and the manufacturer during the pre-production meeting. The list shall include the following:

- material test certificates both from manufacturers and from tests performed on the manufacturers work sites,
- calibration certificates for all instruments,
- manufacturing, production and test data for each operation/ inspection procedure for the pipe structure, the end fittings and the assembly,
- as-built drawings of the pipe identifying all points of interest including weld locations, polymer repairs, extrusion interruptions, etc.,
- QC documents.

All documentation shall be provided to the principal in accordance with a mutually agreed schedule.

Approval or otherwise of documentation by the principal shall be given within a time period mutually agreed prior to manufacture.

All documentation and communications shall be in the English language.

The manufacturer shall issue a weekly status report in a format to be agreed by the principal prior to manufacture.

## 13. REFERENCES

In this specification reference is made to the following publications.

NOTE: The latest issue of each publication should be used together with any amendments/supplements/revisions.

It is particularly important that the effect of revisions to international, national or other standards shall be considered when they are used in conjunction with DEPs, unless the standard referred to has been prescribed by date.

### DEPs

| | |
|---|---|
| Metal/polymer flexible pipe(Requisition sheet) | DEP 39.40.20.93-Gen. |

### USA STANDARDS

| | |
|---|---|
| Methods and definitions for mechanical testing of steel products. | ASTM A 370-77 |
| Test method for compressive properties of rigid plastics. | ASTM D 695-84 |

*Issued by:*
*American Society for Testing and Materials,*
*1916 Race Street, Philadelphia, 19103, USA.*

### BRITISH STANDARDS

| | |
|---|---|
| Vickers hardness test | BS 427 |
| Rockwell hardness test | BS 891 |
| Method of load verification of testing machines. | BS 1610 |

*Issued by:*
*British Standards Institution,*
*2 Park Street, London,*
*W1A 2BS, England.*

## 14. APPENDICES

## APPENDIX 1 CHECKLIST FOR PURCHASING METAL/POLYMER FLEXIBLE PIPE

I.1 REQUISITION SHEET CHECKLIST

The purchaser is advised to use the following checklist to generate information to be included in the requisition.

General

- Static or dynamic,
- Subsea or topsides,

Dimensions:

- Nominal bore,
- Length,

Intended service:

- Working pressure,
- Design pressure,
- Minimum burst pressure,
- Maximum service temperature (internal and external),
- Fluids to be transported (oil, gas),
- GOR,
- Maximum watercut,
- $CO_2$-content of gas,
- $H_2S$-content of gas, if $p(H_2S) > 35$ mbar, then specify 'sour service application',
- Service life,
- Water depth,

Selected materials:

- Internal carcass material,
- External carcass material (if applicable),
- End fitting body,

End fittings:

- Type of fitting/flange,
- Type of coating,

Special requirements:

- Legislation,
- Insulation,
- Pressure drop,
- Acid injection application,

Test parameters final product:

- Hydrostatic test pressure,
- Gauging pig diameter,
- Bend test radius.

## I.2 PURCHASE ORDER CHECKLIST

It is advised to include the following information in the purchase order, in addition to the information provided in the requisition:

Dimensions (all including tolerances):

Item I:

- Strip thickness,
- Strip width,
- Carcass internal diameter,
- Carcass external diameter,

Item II (each layer):

- Layer thicknesses
- External diameter after completion of layer

Item III (each wire):

- Number of wires,
- Spiral pitch,
- Wire thickness,
- Wire width,
- Radius of rounding of of the wire cross-section,
- External diameter after completion of layer,

Item IV (each wire):

- Number of wires,
- Spiral pitch,
- Wire thickness,
- Wire width,
- External diameter after completion of layer,

Item V:

- Layer thickness,
- External diameter after completion of layer,

Item VI:

- Layer thickness,
- Internal diameter of layer,
- External diameter after completion of layer.

Further data approved after submittal in or with the MPS:

Non-metallic tapes:

- Materials,
- Dimensions,

Lubricants:

- Specification/product name,
- Quantities to be applied,

Gas relief system:

Anti-corrosion additives:
- Specification of products,
- Quantities to be applied,

Anti-friction additives:

- Specification of products,
- Quantities to be applied.

**APPENDIX 2 TEST FREQUENCIES**

| Type of test | Ref. section | Frequency | Remarks |
|---|---|---|---|
| POLYMERIC COMPONENTS | | | |
| Alloy identification | 6.2 | one per batch | polymer sheath material |
| Viscosity | 6.1.2.1 | one per batch | polymer sheath material |
| Moisture content | 6.1.2.1 | one per batch | polymer sheath material |
| Tensile test | 6.2.3 | five samples of each end of each layer | polymer sheaths |
| Compressive strength | 6.2.4 | one per batch | epoxy resin |
| Holiday test | 9.2 | continuous | polymer sheets audible alarm required |
| Thickness measurement | 9.3 | at least every ten metres | polymer sheaths |
| METALLIC COMPONENTS | | | |
| Chemical composition check analysis | 5.2 | one per heat | all metals |
| End fittings | | | |
| Tensile test | 6.2.2 | two per heat | end fitting body material |
| Charpy V-notch | 6.2.2 | three per heat | end fitting body material |
| Hardness test | 6.2.2 | five per heat | end fitting body material |
| Radiography | 9.6 | each end fitting | |
| Wires and strips | | | |
| Tensile test | 6.2.2 | one per main spool | min. three tests |
| Weld tensile test | 6.2.2 | every weld )* | items III and IV |
| Magnetic particle inspection | | every weld | all ferritic wires |
| Dye penetrant inspection | | every weld | items I and VI, non-ferritic materials |
| Bend test | 9.4 | three per coil | all wires |
| Hardness test | 6.2.2 | five per coil | all wires |
| Dimensions | 9.3 | beginning, end and middle of each coil | all wires |

)* Before each weld is made a test weld is to be made, cut out and tested

**TEST FREQUENCIES (cont'd)**

| Type of test | Ref. section | Frequency | Remarks |
|---|---|---|---|
| PRODUCT TESTS | | | |
| Dimensions | 9.3 | every 5 m | items I - VI |
| Gauging test | 7.1 | once | |
| Hydrotest | 7.2 | once | |
| Electrical continuity | 7.3 | one per completed length | |
| Electrical resistance | 7.3 | once | between inner carcass and each end fitting |
| | 7.3 | once | between the two end fittings |
| Laying/bending test | 9.4 | once | |