



Exploration & Production

## GENERAL SPECIFICATION

### SUBSEA SYSTEMS

#### GS EP SPS 021

#### Subsea mateable electrical/optical connectors

|      |         |                                                             |
|------|---------|-------------------------------------------------------------|
| 06   | 10/2009 | General Technical Update                                    |
| 05   | 10/2008 | General update                                              |
| 04   | 10/2007 | Numbering minor corrections                                 |
| 03   | 10/2006 | General update                                              |
| 02   | 10/2005 | General update – Addition of "EP" root to GS identification |
| 01   | 08/2003 | Change of Group name and logo                               |
| 00   | 10/2002 | First issue                                                 |
| Rev. | Date    | Notes                                                       |

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## 1. Scope

This specification covers minimum requirements for design, fabrication, testing and qualification of the following types of Wet Matable Subsea Connectors and Jumper Assemblies for subsea production equipment:

- Electrical (Low Voltage/Low Power)
- Electrical (Low Voltage/Low Power)/Optical - Hybrid
- Optical.

## 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 - Normative

In the event of a conflict between standards listed below, CONTRACTOR shall seek clarification from COMPANY.

#### Materials Standards

| Reference       | Title                                                                                                                          |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------|
| ASTM D 395      | Standard Test Methods for Rubber Property - Compression Set                                                                    |
| ASTM D 471-98   | Standard Test Method for Rubber Property - Effect of Liquids                                                                   |
| ASTM D 903-93   | Standard Test Methods for Peel or Stripping Strength of Adhesive Bonds                                                         |
| ASTM D 1414-94  | Standard Test Methods for Rubber O-Rings                                                                                       |
| ASTM D 3164-97  | Standard Test Method for Determining Strength of Adhesive Bonded Plastic Lap-shear Sandwich Joints in Shear by Tension Loading |
| BS 903 Part A2  | Physical Testing of Rubber, Method for determination of tensile stress-strain properties                                       |
| BS 903 Part A3  | Physical Testing of Rubber, Determination of tear strength                                                                     |
| BS 903 Part C2  | Physical Testing of Rubber, Determination of volume resistivity                                                                |
| BS 903 Part A26 | Physical Testing of Rubber, Method for determination of hardness (between 10 IRHD and 100 IRHD)                                |
| BS 6899         | Specification for rubber insulation and sheath of electric cables                                                              |
| ISO 1817        | Rubber, vulcanised. Determination of the effects of liquids                                                                    |

## Electrical Standards

| Reference   | Title                                                                                                                                                                                                            |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| IEC 60502-1 | Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1.2 kV) up to 30 kV (Um = 36 kV) - Part 1: Cables for rated voltages of 1 kV (Um = 1.2 kV) and 3 kV (Um = 3.6 kV) |

## Optical Standards: ITU-T Recommendations - Series G - Transmission systems and media, digital systems and networks

| Reference     | Title                                                      |
|---------------|------------------------------------------------------------|
| G.671 (11/96) | Transmission characteristics of passive optical components |

## Standards - Informative

In the event of a conflict between standards listed below, CONTRACTOR shall seek clarification from COMPANY.

## Materials Standards

| Reference        | Title                                                                                           |
|------------------|-------------------------------------------------------------------------------------------------|
| ASTM D 2240-97e1 | Standard Test Method for Rubber Property - Durometer Hardness                                   |
| ISO 8580         | Rubber and plastics hoses - Determination of ultra-violet resistance under static conditions    |
| ISO 6945         | Abrasion resistance of rubber hoses                                                             |
| ISO 1431-1       | Rubber, vulcanised or thermoplastic - Resistance to ozone cracking - Part 1: Static strain test |

## Electrical Standards

| Reference  | Title                                                                           |
|------------|---------------------------------------------------------------------------------|
| ASTM D 877 | Dielectric Breakdown Testing of Dielectric Fluids                               |
| IEC 60270  | Partial Discharge Measurements                                                  |
| IEC 60228  | Conductors of Insulated Cables                                                  |
| IEC 60287  | Electric Cables. Calculation of the Current Rating                              |
| IEC 60811  | Common Test Methods for Insulating and Sheathing Materials of Electrical Cables |

## Optical Standards: ITU-T Recommendations - Series G - Transmission systems and media, digital systems and networks

| Reference                                  | Title                                                                                            |
|--------------------------------------------|--------------------------------------------------------------------------------------------------|
| <a href="#">G.650 (04/97)</a>              | Definition and test methods for the relevant parameters of single-mode fibres                    |
| <a href="#">G.651 (02/98)</a>              | Characteristics of a 50/125 µm Multimode Graded Index Optical Fibre Cable                        |
| <a href="#">G.652 (04/97)</a>              | Characteristics of a Single-mode Optical Fibre Cable                                             |
| <a href="#">G.911 (04/97)</a>              | Parameters and calculation methodologies for reliability and availability of fibre optic systems |
| <a href="#">G.972 (04/97)</a>              | Definition of terms relevant to optical fibre submarine cable systems                            |
| <a href="#">Bellcore Technical Reviews</a> | Series on "passive" optical components                                                           |

## Umbilical Standards

| Reference                   | Title                                                                                                              |
|-----------------------------|--------------------------------------------------------------------------------------------------------------------|
| <a href="#">ISO 13628-5</a> | Petroleum and Natural Gas Industries - Design and Operation of Subsea Production Systems Part 5: Subsea umbilicals |

## Subsea Production Control System Standards

| Reference                   | Title                                                                                                                              |
|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| <a href="#">ISO 13628-6</a> | Petroleum and Natural Gas Industries - Design and Operation of Subsea Production Systems Part 6: Subsea Production Control Systems |

## ROV/ROT Equipment Standards

| Reference                   | Title                                                                                                                                                                      |
|-----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <a href="#">ISO 13628-8</a> | Petroleum and Natural Gas Industries - Design and Operation of Subsea Production Systems - Part 8: Remotely Operated Vehicle (ROV) Interfaces on Subsea Production Systems |
| <a href="#">ISO 13628-9</a> | Petroleum and Natural Gas Industries - Design and Operation of Subsea Production Systems - Part 9: Remotely Operated Tool (ROT) Intervention Systems                       |

## Professional Documents

| Reference      | Title |
|----------------|-------|
| Not applicable |       |

## Regulations

| Reference      | Title |
|----------------|-------|
| Not applicable |       |

## Codes

| Reference      | Title |
|----------------|-------|
| Not applicable |       |

## Other documents

| Reference      | Title |
|----------------|-------|
| Not applicable |       |

## Total General Specifications

| Reference      | Title |
|----------------|-------|
| Not applicable |       |

## 3. Introduction

### 3.1 Abbreviations

|       |                                                |
|-------|------------------------------------------------|
| API   | American Petroleum Institute                   |
| ASTM  | American Society for Testing and Materials     |
| BS    | British Standard                               |
| E     | Rated Voltage                                  |
| FAT   | Factory Acceptance Test                        |
| g     | Acceleration due to gravity                    |
| HP    | Internal Hose Pressure                         |
| HT    | Internal Hose Temperature                      |
| IEC   | International Electrotechnical Commission      |
| ISO   | International Organisation for Standardisation |
| ITU-T | International Telecommunication Union          |
| mm    | Multi-Mode                                     |
| pk-pk | Peak to peak                                   |
| pphm  | Parts per hundred million                      |
| ppm   | Parts per million                              |

|     |                           |
|-----|---------------------------|
| RMS | Root Mean Square          |
| ROT | Remote Operated Tool      |
| ROV | Remote Operated Vehicle   |
| SM  | Single Mode               |
| Um  | Rated Voltage             |
| VAC | Volts Alternating Current |
| VDC | Volts Direct Current      |
| VP  | Vessel Pressure           |
| VT  | Vessel Temperature        |

## 4. Product requirements

### 4.1 General Requirements

The subsea mateable electrical, electrical/optical and optical connectors and cable assemblies shall:

- Be designed for long term subsea use without cathodic protection
- Support electrical insulation from cathodically protected structure
- Be designed for water depth greater than project application
- Utilise electrical connections of a conductive type and optical connections of a low loss design
- Be previously developed and operated with proven components and designs in the same environmental conditions
- Have successfully completed a full qualification test programme
- Have a minimum of dual sealing barriers between seawater and electrical conductors. Both barriers shall be designed for continuous operation in seawater and the selected dielectric fluid. At least one barrier shall be testable during FAT of the product. The other barrier shall be testable during qualification programme
- Be capable of installation/retrieval at subsea depth by diver, ROV/ROT or hydraulic cradle with configuration changes to suit the method of installation
- Ensure electrical and optical contact between the two connector halves shall take place in an insulating fluid filled environment
- Be maintenance free over the connectors design life and when used within its rated number of mate/demate cycles
- Support bulkhead mounting towards a pressure vessel or an oil filled, pressure compensated enclosure, stabplate mounting, individual diver and ROV/ROT installation/retrieval formats and it shall be possible to configure either the plug or the receptacle as the fixed half.
- Be available for termination towards an oilfilled hose (containing electrical conductors/fibres)

- Be robust to withstand the stresses and strains normally experienced during subsea handling and installation by ROV
- Withstand environmental extremes normally experienced during shipping, storage and deployment
- Have a housing and latch mechanism tolerant to silt and fine sand deposits
- Have a latch mechanism provided with visual indicator clearly visible from ROV camera.

## 4.2 Performance

The specific requirements for subsea mateable electrical, electrical/optical, optical connectors and associated jumpers shall be, unless otherwise specified by the project:

| Parameter                                                                               | Performance                                        |
|-----------------------------------------------------------------------------------------|----------------------------------------------------|
| Design life                                                                             | 25 years                                           |
| Water depth                                                                             | 3000 m                                             |
| Minimum External Design Pressure/Test Pressure                                          | 300 bar/450 bar                                    |
| Maximum continuous operational voltage, mated and unmated (at least one connector half) | 1500 VDC, 1000 VAC RMS                             |
| Maximum differential voltage between adjacent pins                                      | 3000 V pk-pk                                       |
| Make/break under power                                                                  | Not required                                       |
| Maximum continuous operational current                                                  | 10A DC, 7A AC RMS                                  |
| Maximum in-rush current                                                                 | 100 A for ½ Sec. duration                          |
| Insulation Resistance - Connector body to conductor/pin                                 | > 10 GΩ@1000V                                      |
| Insulation Resistance - Conductor/pin to conductor/pin                                  | > 10 GΩ@1000V                                      |
| Optical communication wavelength (single-mode)                                          | 1310 nm & 1550 nm                                  |
| Optical communication wavelengths (multi-mode)                                          | 850 nm & 1300 nm                                   |
| Maximum optical attenuation (per mated connector pair) as defined within G.671 (11/96)  | 0.5 dB single-mode<br>1 dB multi-mode              |
| Maximum fusion splice attenuation for similar fibers                                    | < 0.2 Db<br>Bi-directional average reading of OTDR |
| Maximum optical back reflection                                                         | - 45 dB                                            |
| Minimum number of mate/demate cycles                                                    | 100                                                |
| Connector/Jumper assembly maximum handling load - Jumper to Connector Interface         | 2500 N                                             |
| Jumper assembly minimum breaking strength - Jumper to Connector Interface               | 5000 N                                             |
| Maximum ROV Mate Demate Force Required                                                  | 500 N                                              |

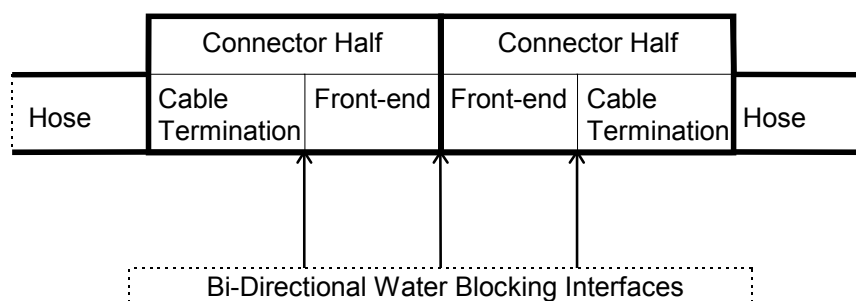
| Parameter                          | Performance     |
|------------------------------------|-----------------|
| Maximum Applied ROV Force (Damage) | 5000 N          |
| Jumper Minimum Bend Radius (MBR)   | 125 mm (inside) |
| Equipment operating temperature    | -5°C to 40°C    |
| Equipment storage temperatures     | -25°C to 50°C   |

### 4.3 Specific design requirements

The connector shall be designed for reliable and repeatable subsea wet mating in configurations suitable for diver or ROV/ROT operations under turbid conditions. The jumper shall include two connector halves and a hose, filled with dielectric fluid in a pressure balanced mode.

The principle of the connector and jumper assembly design shall be as follows:

- Double water blocking barriers shall be provided between seawater and electrical conductors. The integrity of both barriers shall be capable of being tested during Qualification testing and a minimum of one shall be testable during FAT.
- Water blocking from the rear cable termination area of the connector to the front-end of the connector shall be provided.
- Water blocking from the front-end of the connector to the rear cable termination area of the connector shall be provided.



The connector shall provide adequate strain relief means for termination of hose assembly and provide support for each individual wire/fibre terminated within the connector.

The electrical contacts shall be robustly constructed with a minimum allowable diameter for pins of not less than 3 mm diameter irrespective of the current/power requirements. The contacts shall preferably be gold plated.

Should fusion splice be integrated in the connector for optical fibres, it shall be proof tested (straight fibre without torsion) at 450 g minimum, prior to be mechanically reinforced. Reinforcement shall overlap the fiber by at least 10 mm and shall withstand minimum 100 g tension (straight without torsion).

The connector pins shall not allow physical contact with the opposing connector pins during primary engagement to ensure that the connector pins do not experience any primary connector alignment forces.

The design shall cater for applications requiring more than one independent AC electrical circuits to be provided through the same connector allowing for the potential of 180° phase difference between adjacent electrical circuits.

The connector shall be qualified and supplied both in straight and angled termination form.

The connector shall utilise double barrier sealing of the electrical elements for at least one of the two connector halves when in the unmated condition.

A design review shall be performed detailing design, methods of water barriers and insulation towards connections and cabling. All materials shall be identified and verified.

Stroke lengths must be given for electrical engagement, optical engagement and fully engaged.

## 4.4 Operational and installation requirements

### 4.4.1 Intervention

The connector shall be designed such that the configuration may be changed to suit the selected installation method, which shall include:

- Diver
- ROV/ROT
- Hydraulically Operated Cradle
- Stabplate.

The connector jumper assemblies shall meet the requirements of the ROV/ROT Equipment Standards listed above.

All necessary ROV/ROT interface tool nominal and worst case requirements and limitations shall be clearly defined. These shall be, but not necessarily limited to:

- Misalignment
- Mating/demating speeds
- Stroke
- Mating force
- Break-out force
- Tolerances.

All ROV/ROT interface handles shall be coloured Orange.

### 4.4.2 General

The following shall apply:

- The connector shall not require being mated/demated with power applied. The consequence of accidental mate/demate shall be clearly defined.
- As a minimum, one half of the connector pair shall be designed for subsea operation at full rated voltage in the unmated condition.
- The connector, if standing alone, shall be fitted with a robust locking mechanism to prevent accidental or vibration-induced disengagement or malfunction. The device shall have a self evident means to indicate that the connector is fully engaged.

- The connector shall be designed for operation within the presence of sand and silt as defined for qualification. The design shall not be inclined to seizure due to the entrapment of sand particles during mating or demating.
- The connector shall be capable of both vertical and horizontal operation.
- If parts of the connector are connected to a cathodic protection system, prevention of calcite deposits (on exposed working or other relevant surfaces) electro-chemical action in seawater shall be catered for (e.g. Xylan or other coating). The connector design shall accept some calcite deposits without jamming or interfering with mating/demating action.
- The connectors are required to be maintenance-free during subsea operation and lifetime but should be able to be refurbished/maintained during suitable opportunities following retrieval. The recommended maintenance procedures shall be provided. If relevant provision shall be made for renewing the dielectric fluid each time the connector is taken to the surface.
- The connector shall be capable of being water-jetted clean of marine growth in the mated condition only. The potential risks of performing this water-jetting upon an unmated connector shall be clearly defined.
- The connector shall be capable of being acid cleaned with citric acid and brushed with purpose made ROV brushing tool to remove calcite growth.
- Where connector orientation is obtained via keyways within the connector body, prevention of jamming shall be catered for.
- The connector body shall contain clearly visible means of indicating correct alignment prior to engagement.
- All connectors intended to be left unmated during deployment, use and maintenance shall be fitted with protective caps suitable for direct exposure to seawater.
- The connector shall be capable of tolerating worst case, applied mating forces (in the connector axial direction) of greater than 5000 N.
- Transport protection shall be provided for the connector parts and used during transportation.
- All precautions required for air freight of pre-pressurised equipment shall be highlighted and incorporated within the Handling, Packing, Storage and Shipping procedures/guidelines.

#### 4.5 Material requirements

The connector shall be constructed from materials suitable for marine duty for the lifetime specified.

All materials utilised within the connector and jumper assemblies shall be compatible with both fresh water, seawater and the selected dielectric fluid. Qualification testing of new materials to verify compatibility shall be performed. When mounted in a stab plate, the connector is subject to contact with control fluid. Compatibility of all materials with the project control fluid shall be demonstrated by qualification testing.

## 5. Subsea jumper assembly specification

The subsea jumpers shall comprise of dielectric fluid filled hose containing electric wire and optical fibres terminated at each end with the appropriate connector half.

Sufficient over length of electrical wires and optical fibres shall be provided within the jumper assembly to accommodate for maximum elongation of the hose assembly.

The cable assemblies should be designed and installed such that any seawater entering the dielectric fluid moves away from the end terminations by gravity. The cables should be installed into pressure-compensated fluid-filled lines.

All subsea jumpers and hose assemblies shall be pre-charged in order to maintain net positive internal pressure under all conditions of surface and subsea temperature and pressure (including during deployment). The pre-charge pressure shall not cause a strain in the hose material, which adversely affects Ozone or Ultraviolet resistance.

All jumpers shall be coloured Orange.

Compatibility of hose and selected wire and fibre type with pressure compensation fluid shall be demonstrated by qualification tests.

Full details of this interface will be supplied as Project specific data and will include the following:

- Jumper length
- Fluids other than sea water which will surround the jumper
- Wiring details
- Hook-up drawings
- Connector fibre/Pin allocation
- Conductor size
- Conductor insulation requirements
- Wire type and configuration
- Screening requirements
- Connector mounting and compliance requirements
- Any fluids which shall be in contact with the Jumper assembly when used within pressure compensated oil filled enclosure applications.

## 6. Optical fibre specification

Compatibility of selected fibre type with pressure compensation fluid shall be demonstrated.

Selection of fibre and pig tails at the back of the connector shall be such that the specification for fusion splice maximum attenuation is reached.. Protection of the spliced area shall be detailed, together with mounting procedure. Resistance to pulling forces and bendings occurring during manufacturing, integration, installation and operations, shall be justified.

Full details of this interface will be supplied and shall include the following:

- Optical fibre type

- Optical fibre coating
- Optical fibre protective outer jacket.

## 7. Definition of test levels

### 7.1 General

The test requirements defined within this document are structured such that discrete testing of sub-assemblies (connectors and hoses) and completed assemblies (jumpers) shall be possible. Combining of tests in order to minimise test facility time can be evaluated.

In addition to testing and inspection procedures during manufacturing phase there are two generic types of formal testing required, Qualification Testing and Factory Acceptance Testing.

The objective of the **Qualification Tests** is to ensure each new connector/jumper assembly type is fit for it's intended purpose and therefore a one off type test.

The objective of the Factory Acceptance Tests is to demonstrate the quality of each and every connector/jumper assembly.

The Qualification and Factory Acceptance Tests results shall demonstrate compliance with acceptance criteria within the operational conditions.

The acceptance criteria in this specification offer the minimum criteria for testing.

The CONTRACTOR shall submit the Qualification and Factory Acceptance Tests Procedures including all Acceptance Criteria for agreement and approval by COMPANY, well in advance of the commencement of any test programme.

The CONTRACTOR may use other acceptance criteria (values learned by experience) as long as they are set to detect intermittent and lasting defects in materials. However these must be submitted to COMPANY for agreement and approval.

Acceptance criteria shall include test instrument tolerances.

In addition each item undergoing a Qualification Test or Factory Acceptance Test shall be visually examined to ensure that no evidence of damage exists prior to testing and to provide a visual indication of a sound working assembly. The visual inspection shall be repeated after testing is completed. Both pre and post testing visual examinations shall be recorded within the test documentation.

## 7.2 Factory Acceptance Testing

The minimum Factory Acceptance Tests can be divided into the following sections:

| Summary of minimum factory acceptance test requirements (Figure 6.2) |                                           |                           |
|----------------------------------------------------------------------|-------------------------------------------|---------------------------|
| Function                                                             | Test Type                                 | Section                   |
| Electrical                                                           | Contact Resistance (light current only)   | 8.1.1                     |
|                                                                      | Shell Continuity                          | 8.1.2                     |
|                                                                      | Insulation Resistance                     | 8.1.3                     |
|                                                                      | Proof Voltage                             | 8.1.4                     |
| Optical                                                              | Optical Attenuation                       | 8.2.1                     |
| Mechanical                                                           | Helium Leak Test                          | 8.3.1                     |
|                                                                      | Locking Device                            | 8.3.3                     |
|                                                                      | Mating Force (dry mate - no misalignment) | 8.3.4                     |
| Hyperbaric                                                           | Production Hyperbaric Test                | 10.7                      |
| Visual Inspection                                                    | Tolerance Check                           | As per manufacturing file |
|                                                                      | Interface Check                           | As per manufacturing file |
|                                                                      | Verification of Marking                   | As per manufacturing file |
| Batch                                                                | Material Batch (General)                  | 11.1                      |
|                                                                      | Disk Bursting                             | 11.2                      |
|                                                                      | Material Bonding                          | 11.3                      |
|                                                                      | Dielectric Fluid - Moisture Content       | As per specification      |

Each connector and jumper assembly undergoing a Factory Acceptance Test shall be clearly identified with serial number, part number and revision number prior to the commencement of the tests. This information shall be included within the test result documentation.

## 7.3 Qualification Testing

All connector and jumper assembly types to be delivered shall pass a Qualification Test Programme specified by CONTRACTOR and subjected to COMPANY agreement and approval.

These shall be based on the specifications and acceptance criteria, defined in this section, as a minimum.

Each connector and jumper assembly undergoing a Qualification test shall be clearly identified with serial number prior to the commencement of the tests. All detail drawings used to manufacture the Qualification connector shall be listed and stored to enable comparison between the tested items and identical (or close to identical) items manufactured later.

CONTRACTOR shall include in the Qualification documentation evaluations of:

- Operational ambient temperatures versus ambient temperature registered during the tests