



Exploration & Production

GENERAL SPECIFICATION

SUBSEA SYSTEMS

GS SPS 021

Subsea mateable electrical/optical connectors

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00	10/02	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 471-98	Standard Test Method for Rubber Property - Effect of Liquids
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
ASTM D 395	Standard Test Methods for Rubber Property - Compression Set
ASTM D 903-93	Standard Test Methods for Peel or Stripping Strength of Adhesive Bonds
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

**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 1431-1	Rubber, vulcanised or thermoplastic - Resistance to ozone cracking - Part 1: Static strain test

Electrical Standards

Reference	Title
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
ASTM D-877	Dielectric Breakdown Testing of Dielectric Fluids

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

Reference	Title
G.650 (04/97)	Definition and test methods for the relevant parameters of single-mode
G.651 (02/98)	Characteristics of a 50/125 µm Multimode Graded Index Optical Fibre Cable
G.652 (04/97)	Characteristics of a Single-mode Optical Fibre Cable
G.653 (04/97)	Characteristics of a Dispersion Shifted Single-mode Optical Fibre Cable
G.654 (04/97)	Characteristics of a cut-off shifted single-mode optical fibre cable
G.655 (10/96)	Characteristics of a non-zero dispersion shifted single-mode optical
G.911 (04/97)	Parameters and calculation methodologies for reliability and availability of fibre optic systems
G.972 (04/97)	Definition of terms relevant to optical fibre submarine cable systems
Bellcore Technical Reviews	Series on “passive” optical components

Umbilical Standards

Reference	Title
API 17-E	Subsea Production Control Umbilicals
ISO 13628-5	Design and Operation of Subsea Control Umbilicals

Subsea Production Control System Standards

Reference	Title
ISO 13628-6	Subsea Production Control System

ROV/ROT Equipment Standards

Reference	Title
ISO 13628-8	Design and Operation of ROV Interfaces on subsea production systems
ISO 13628-9	Remotely Operated Tool (ROT) Intervention System
API 17-H	Recommended Practice for ROV Interfaces with Subsea Production Equipment

**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 suitable for deepwater applications
- Utilise electrical connections of a conductive type and optical connections of a low loss design
- Be previously developed and operating with proven components and designs
- 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
- 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 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 and optical connectors shall be:

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
Insulation Resistance - Conductor/pin to conductor/pin	> 10 GΩ
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 1 dB multi-mode
Maximum fusion splice attenuation	< 0.05 dB
Maximum optical cross talk between lines	- 60 dB
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

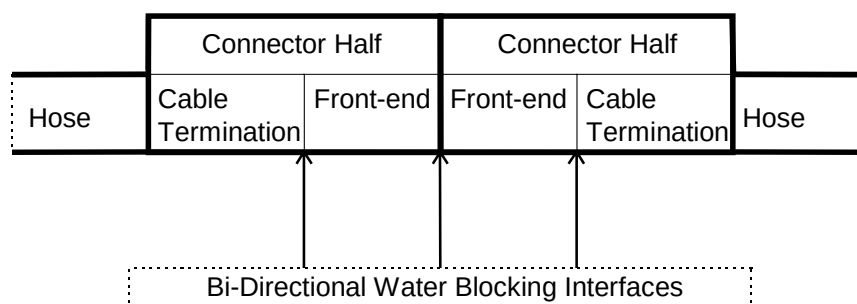
Parameter	Performance
Jumper assembly minimum breaking strength - Jumper to Connector Interface	5000 N
Maximum ROV Mate Demate Force Required	500 N
Maximum Applied ROV Force (Damage)	5000 N
Jumper Minimum Bend Radius (MBR)	125 mm (inside)
Equipment operating temperature	-5°C to 40°C
Equipment storage temperatures	-25°C to 50°C

4.3 Specific design requirements

The connector shall be suitably designed for reliable and repeatable subsea wet mating in configurations suitable for diver or ROV/ROT operations under turbid conditions.

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 Factory Acceptance Testing (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.

The connector pins shall not be capable of 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 by CONTRACTOR. 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 to be mated/demated with power applied. The consequence of accidental mate/demate shall be clearly defined (section 7).
- 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 (section 7).
- 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 a clearly visible means of indicating correct alignment prior to engagement.
- The connector shall be capable of tolerating worst case, applied mating forces (in the connectors 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 within the Handling, Packing, Storage and Shipping procedures/guidelines (Section 7).

4.5 Reliability

The CONTRACTOR shall supply connector histories in the form of:

- Quantity in operation and accumulated operating hours
- Quantity of failures in operation (failures may be further categorised if relevant).

As an alternative to supplying the above information the CONTRACTOR may supply a calculated MTBF figure based upon the products track record.

4.6 Material requirements

The MANUFACTURER shall provide details of the tracking index for the insulating materials.

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.

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.

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.

CONTRACTOR shall ensure compatibility of hose and selected wire and fibre type with CONTRACTOR specified pressure compensation fluid.

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

CONTRACTOR shall ensure compatibility of selected fibre type with CONTRACTOR specified pressure compensation fluid.

CONTRACTOR shall ensure compatibility between fibre and specified/supplied connector pigtails so that the pass criteria of 0.05 dB for a fusion splice shall be achieved.

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

- Optical fibre type



- Optical fibre coating
- Optical fibre protective outer jacket.

7. Approval procedure

The following information is required for submittal by CONTRACTOR for COMPANY approval (unless previously submitted):

- List of materials and material specification for all materials of construction
- The method of corrosion protection
- Evidence of compatibility with COMPANY supplied chemicals list
- Handling, packing, storage and shipping procedures/guidelines
- Qualification testing programme, procedures, data, results and certificates
- Acceptance testing programme, procedures, data, results and certificates
- Documentation list for agreement of document submittal requirements
- Maintenance procedures
- ROV operational characteristics
- Statement covering the consequence of accidental mate/demate with power applied and water-jetting of unmated connectors
- Reliability data.

8. Definition of test levels

8.1 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. The CONTRACTOR may if appropriate, propose for COMPANY approval, the combining of tests in order to minimise test facility time.

In addition to the CONTRACTOR's own internal testing and inspection procedures 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.

8.2 Factory Acceptance Testing

All connectors and jumper assemblies to be delivered shall pass a Factory Acceptance Test to be 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.

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

Summary of minimum factory acceptance test requirements (Fig. 6.2)		
Function	Test Type	Section
Electrical	Contact Resistance (light current only)	9.1.1
	Shell Continuity	9.1.2
	Insulation Resistance	9.1.3
	Proof Voltage	9.1.4
Optical	Optical Attenuation	9.2.1
Mechanical	Helium Leak Test	9.3.1
	Locking Device	9.3.3
	Mating Force (dry mate - no misalignment)	9.3.4
ESS test	Environmental Stress Screening	9.11
Hyperbaric	Production Hyperbaric Test	11.7
Visual Inspection	Tolerance Check	CONTRACTOR Defined
	Interface Check	CONTRACTOR Defined
	Verification of Marking	CONTRACTOR Defined
Batch	Material Batch (General)	12.1
	Disk Bursting	12.2
	Material Bonding	12.3
	Dielectric Fluid - Moisture Content	CONTRACTOR Defined

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.

8.3 Qualification Testing

All connector types and jumper assembly types to be delivered shall pass a Qualification Test Programme to be 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 the ambient temperature registered during the tests
- The sequence of Qualification tests including available facilities
- All deviations from specified requirements within one test and between tests shall be highlighted, justified and explained. The COMPANY shall review all deviations.

The proposed Qualification Test Programme can be divided into the following sections and shall also include an assessment of the CONTRACTORS Quality Assurance System:

Summary of connector qualification tests (Fig. 6.3.1)		
Test Type	Qualification Test	Section
Electrical	Contact Resistance	9.1.1
	Shell Continuity (if applicable)	9.1.2
	Insulation Resistance	9.1.3
	Proof Voltage	9.1.4
	Temperature Rise	9.1.5
	High Voltage Breakdown	9.1.6
Optical	Optical Attenuation	9.2.1
	Optical Crosstalk	9.2.2
	Optical Back Reflection	9.2.3
Mechanical	Helium Leak Test	9.3.1
	Maximum Misalignment	9.3.2
	Locking Device	9.3.3
	Mating Force	9.3.4

Summary of connector qualification tests (Fig. 6.3.1)		
Test Type	Qualification Test	Section
Turbid Tank	Wet Mating Test	9.4.2
	Post Turbid Tank Test Inspection	9.5
Flooded Connector Back-End Test	Flooded Connector Back-End Test	9.6
	Long Term Test	9.7
Environmental Stress Tests	Thermal Shock	9.8
	Mechanical Shock	9.9
	Vibration	9.10

Summary of hose and hose termination qualification tests (Fig. 6.3.2)		
Test Type	Qualification Test	Section
Environmental Stress Tests	Hose Absorption/Compensation	10.2
	Ozone Resistance	10.3
	Ultraviolet Resistance	10.4
	Thermal Shock	10.5
Destructive Testing	Tensile Failure	10.6.1
	Burst Pressure	10.6.2
	Crush Resistance	10.6.3
	Outer Sheath Abrasion	10.6.4
	Hose Kink Testing	10.6.5

Jumper assembly qualification testing (Fig. 6.3.3)		
Test Type	Qualification Test	Section
	Oscillating Jumper Test	11.2
	Jumper Pull Test	11.3
	Drop Test	11.4
	Jumper Handling Simulation Test	11.5
	Simulated Deployment Test	11.6

General material qualification and batch testing (Fig. 7.3.4)		
Test Type	Qualification Test	Section
Material Testing	Material Batch Testing	12.1
	Disc Bursting Test	12.2
	Material Bonding Test	12.3

9. Connector test requirements

9.1 Electrical test requirements

9.1.1 Contact resistance

9.1.1.1 Applicability

FAT and Qualification

9.1.1.2 Objective

To determine the resistance in ohms of the connector contacts.

9.1.1.3 Method

The contact resistance shall either be derived from the voltage drop measured between the points intended for connection of the wiring to the contacts at rated current or by using an ohm-meter giving the same measuring accuracy. Where the termination end of contact is not directly accessible and measuring wires are required, the measuring wires shall be compensated for. In no case shall the resistance of the test cable cause reduced accuracy in the measurement to be significant for the test result.

The measurement will be made using a purpose built ohm-meter. Actual measurements shall be recorded.

For Factory Acceptance Testing, light current testing shall be sufficient to determine contact resistance as full load current limitation may be governed by project wire selection.

9.1.1.4 Light current test (FAT and Qualification)

The contact resistance of individual contacts should be measured with direct current not exceeding 50 mA. During the measurements the open circuit emf of the source should not exceed 20 mVDC.

9.1.1.5 Acceptance criteria

< 30 mΩ

9.1.1.6 Rated current test (Qualification only)

The contact resistance of individual contacts should be measured at the DC current rated value of the connector. During the measurements the open circuit emf of the source should not exceed 2.5 VDC.

9.1.1.7 Acceptance criteria

< 30 mΩ

9.1.2 Shell Continuity

9.1.2.1 Applicability

FAT and Qualification

9.1.2.2 Objective

To determine the resistance between connectors having metallic housings intended to provide electrical continuity when mated.

9.1.2.3 Method

Measurements should be made on mated connectors using equipment as prescribed for test conditions in section 9.1.1.6. Connections for this test should be made to the braid or shell connecting wire for free connectors and to the mounting flange for fixed connectors. Actual measurements shall be recorded.

9.1.2.4 Acceptance criteria

< 0.1 Ω

9.1.3 Insulation resistance

9.1.3.1 Applicability

FAT and Qualification

9.1.3.2 Objective

To quantify the insulation resistance between:

- Individual electrical contacts/cable harness conductors in the connector
- Individual electrical contacts/cable harness conductors and the connector shell.

9.1.3.3 Method

The insulation resistance of individual contacts should be measured with a 1000 VDC megger with a minimum measurement scale of 100 GΩ.

The connector should be mated and the test voltage should be applied for 1 minute. Measurements should be made between all adjacent contact pairs and also outer contact/shell pairs. Actual measurements shall be recorded.

9.1.3.4 Acceptance criteria

> 10 GΩ

9.1.4 Proof voltage test

9.1.4.1 Applicability

FAT and Qualification

9.1.4.2 Objective

To verify that the insulation and contact spacing is sufficient to prevent flashover, current leakage, or insulation breakdown at the connector proof voltage.

9.1.4.3 Method

Proof voltage testing shall be performed in accordance with [IEC 60502-1](#). The selected proof voltage shall be derived from the maximum rated conductor to conductor voltage of 3000 VDC. The same selected proof voltage shall also be applied to the conductor to shell testing.

The selected proof voltage shall be specified by the CONTRACTOR and subject to agreement and approval by the COMPANY.

The proof voltage tests shall be made by applying a voltage equal to the proof voltage rating. The voltage shall be applied between each conductor and the shell (earth) and between all adjacent pairs of conductors. Each voltage check shall be applied for one minute. All results shall be recorded as absolute values.

A number of such tests may be performed during assembly.

9.1.4.4 Acceptance criteria

- No evidence of insulation breakdown
- No evidence of flashover
- Current leakage < Proof Voltage/10 GΩ

9.1.5 Temperature rise test

9.1.5.1 Applicability

Qualification

9.1.5.2 Objective

This test is to verify that the connector will operate as designed (optically/electrically) at the rated current capacity without producing an objectionable over temperature condition.

9.1.5.3 Method

The connector assembly shall be mated and mounted in a framework to allow air circulation around the external shell.

Temperature sensors shall be attached to various locations on the connector to enable monitoring of the temperature variations. The location of sensors shall be:

- Ambient temperature
- As close as possible to the hottest spot in the connector
- At cable termination's
- At the hottest spot on external surfaces at each accessible material type
- As close as possible to the contact surface between male and female.

The measurements shall commence after temperature has established and been stable for ½ hour and the test shall continue for 24 hours with measurement intervals of ½ hour.

Electronic data storage or a chart recorder with a suitable number of channels are preferred to record the temperature rise. Actual current values and voltage drop shall be recorded in parallel with each temperature measurement. After completion of the test, the connector shall be stripped down to its piece parts and examined for effects and evidence of excessive temperatures. All findings shall be recorded within the final qualification report.

9.1.5.4 Acceptance criteria

- No physical damage or burns shall be observed on any of the connector piece parts
- < 30°C temp rise.

9.1.6 High voltage breakdown test (destructive)

9.1.6.1 Objective

This test is to verify the connector voltage limits.

9.1.6.2 Method

The connector halves shall be mated in a tank containing water. Conditioning of connector shall be done prior to the test by gradually increased pressure to 1.5 times design pressure and held for a duration of 5 minutes to allow any voids to be found. The testing may be done at ambient pressure.

The connector plug and receptacle shall be terminated in the normal manner to the respective cables. The water shall provide earth to the electrical test equipment. The connectors shall be mated and electrical tests consisting of insulation resistance test, continuity test, and high voltage test shall be performed.

With the connectors mated the 5 Hz AC voltage shall be increased in stages of one minute each until flashover. The breakdown voltage shall be recorded and the point of failure identified by means of photos.

9.1.6.3 Acceptance criteria

Breakdown at $\geq 8 \cdot U_0$

9.1.6.4 Component HV breakdown test

Component H.V. breakdown tests consisting off single pin breakdown test is preferred, but not mandatory.

9.2 Optical test requirements

9.2.1 Optical attenuation testing

9.2.1.1 Applicability

FAT and Qualification

9.2.1.2 Objective

To determine the optical attenuation between two mated connectors.

9.2.1.3 Method

With a light source, power meter and associated test cabling, a base line optical attenuation measurements shall be performed upon the test set-up at optical wavelengths of:

- 1310 nm and 1550 nm for single-mode
- 850 nm and 1300 nm for multi-mode.

The function of this test is to establish attenuation figures attributable directly to the test set-up without the test connectors under test in circuit.

With the connector in-circuit, the optical attenuation for each optical circuit within the connector shall be measured and recorded. By subtracting the base line optical attenuation the actual attenuation directly attributed to the connector shall be established.

To obtain a spread of test data this test shall be performed ten times in total. Between measurements the connector pairs shall be completely separated and reconnected.

The connectors used to perform this test shall be representative of production spread and therefore shall not be optimised as a matched pair prior to performing this test.

9.2.1.4 Acceptance criteria

- < 0.5 dB @ 1310 nm and 1550 nm for single-mode
- < 1 dB @ 850 nm and 1300 nm for multi-mode

9.2.2 Optical crosstalk attenuation testing

9.2.2.1 Applicability

FAT and Qualification

9.2.2.2 Objective

To determine the optical crosstalk between each optical line within the connector and all other optical lines within the connector. Again the optical cross talk attributable to the test equipment shall be established prior to commencing the test.

9.2.2.3 Method

This test may be combined with the Optical Attenuation Testing test as both utilise the same test equipment.

With a test signal transmitted through one connection in the connector, the level of crosstalk to all other optical connections shall be measured and recorded.

9.2.2.4 Acceptance criteria

> -60 dB attenuation of source signal at all defined wavelengths.

9.2.3 Optical back reflection testing

9.2.3.1 Applicability

Qualification

9.2.3.2 Objective

To determine the optical back reflection of a transmitted signal.

9.2.3.3 Method

The level of back reflection shall be determined utilising return loss test equipment or any other suitable device capable of detecting an attenuation of > -45 dB.

To obtain a spread of test data this test shall be performed ten times in total. Between measurements the connector pairs shall be completely separated and reconnected.

9.2.3.4 Acceptance criteria

> -45 dB signal attenuation of source signal at all defined wavelengths.

9.3 Mechanical tests

9.3.1 Helium leak test

9.3.1.1 Applicability

FAT and Qualification

9.3.1.2 Objective

To verify that water seals are correctly fitted and do not leak.

9.3.1.3 Method

The electrical wires and optical fibres may be substituted by a blank non-porous material and sealed using the cable seal arrangement if approved. The required two independent barriers between wire/fluid filled hose and the seawater shall be separately tested, while double O-rings cannot in most cases be tested separately. A helium leak test shall be carried out on the connector including jumper assembly end fittings and bulkhead cable termination (if applicable to design) to verify all sealing elements. This test is not intended to be performed on hose assemblies due to the absorption/permeation characteristics of the hose.

Helium shall be applied so that it swamps one side of all sealing elements to be tested. The pressure difference between the cavities and the external of the sealing elements shall be at least 1 bar.

The cavity shall be pressurised to 1 bar overpressure through one of the filling points using helium gas (Internal overpressure). A valve shall be closed trapping gas in the cavity. Using a chart recorder temperature and pressure shall be recorded at regular intervals over a period of 24 hours (qualification test) or 2 hours (FAT). Alternatively, a helium detector connected to the lowest pressure shall be used to detect the leakage rate.

Leak tests using leak detection fluid or Helium leak detection equipment shall be carried out at accessible seals on the connector.

9.3.1.4 Acceptance criteria (Qualification test)

Internal pressure drop of < 0.1 bar over the 24 hour period.



9.3.1.5 Acceptance criteria (FAT)

Internal pressure drop of < 0.05 bar over the 2 hour period.

9.3.2 Maximum misalignment

9.3.2.1 Applicability

Qualification

9.3.2.2 Objective

To demonstrate the correct operation of the connector at specified worst-case misalignment during mating.

9.3.2.3 Method

This test shall be performed with a bulkhead mount and free connector configuration. The free connector shall be mounted in a pneumatically actuated frame, simulating the normal mounting method. The mounting frame assembly shall be designed to have the minimum recommended clearances towards the connector to enable it to align. The receptacle unit and its mounting bracket shall be offset from its central axis position to the max. misalignment position and mated a specified number of times. This shall include any angular and rotational misalignment. The alignment indicator shall be observed. Any locking device tightened to specified load shall be included in the test.

To demonstrate the operation at any combination of misalignment, testing of all mechanical mechanisms is required. The testing submerged in turbid sea water (see Turbid Tank Test) at 1.5 times design pressure under misalignment is preferred, but not mandatory.

The connector shall be mated at maximum speed and the forces measured.

The insulation resistance, contact resistance and optical attenuation shall be measured before and after the test. The results and observations shall be recorded.

The maximum misalignment tolerance shall be established prior to commencing the test. At least 8 matings shall be at max. misalignment, two at + x-axis and two at - x-axis, two at + y-axis and two at - y-axis. Where rotational orientation mechanism is included, at least 8 matings shall cover max. orientation misalignment combined with max. misalignment in x- and y-axis.

9.3.2.4 Acceptance criteria

Mating and demating force: as agreed with COMPANY.

No damage shall be observed.

The connector shall be verified to function as per specification (electrically and optically) after misalignment testing.

9.3.3 Locking device

9.3.3.1 Applicability

FAT and Qualification

9.3.3.2 Objective

For connectors equipped with locking devices the objective of this test is to verify correct operation of the locking mechanism and that no mechanical damage occurs to the connector due to the locking mechanism.

9.3.3.3 Method

The connector shall be checked for satisfactory positive location, the locking mechanism undone and the connector separated. This procedure shall be repeated several times after which the locking device shall be inspected for damage on both halves of the connector.

The procedure shall also include all reasonable attempts to mate and lock the connector halves together with incorrect orientation (qualification only).

The connector pair shall be engaged and the locking device tightened to specified load. The testing in turbid water is preferred, but not mandatory for Qualification. Production FAT testing shall be performed as a dry test.

9.3.3.4 Acceptance criteria

An evaluation assessing the ease with which the locking device is activated shall be part of the final qualification report.

No damage observed to either half of the connector pair due to incorrect orientation of connectors.

The correct operation of the locking device shall be recorded as part of the Production FAT.

9.3.4 Mating Forces

9.3.4.1 Applicability

FAT and Qualification

9.3.4.2 Objective

To measure the forces required for subsea (ROV) mating and evaluate the influence of sand/silt. Testing shall be performed in a turbid water tank. Testing under pressure is preferred, but not mandatory.

9.3.4.3 Method

This test shall be performed with a bulkhead mount and free connector configuration.

The following measurements of force shall be performed for qualification:

- Engagement force - dry and wet
- Disengagement force - dry and wet
- Force at maximum mating speed - dry
- Max. misalignment forces - dry

The mating and demating forces shall be recorded (without misalignment) during the FAT for all production units. It is preferred that the FAT test is performed as a wet test under pressure, but not mandatory.



9.3.4.4 Acceptance criteria

Mating and demating force recorded are within the specified operational characteristics.

No damage observed to either half of the connector pair.

9.4 Turbid tank tests

9.4.1 Introduction

9.4.1.1 Test equipment requirements

- **Pressure vessel**

A pressure vessel filled with chilled, simulated seawater is required. An externally controlled mating frame for the mating of the two connector halves shall be installed inside the pressure vessel. The mating frame movement shall be in the both vertical, horizontal and assumed "worst" direction axis and fully engage/disengage both aligned connector halves at the maximum misalignment tolerances. When the connectors are fully disengaged a minimum separation distance of 100 mm between connectors shall be achieved.

The rate of change of pressure during pressurisation/depressurisation shall be approximately 35 bar/min.

- **Simulated seawater data**

While the turbid tests are being performed the water shall be continuously agitated to ensure that the solids remain in suspension and are evenly distributed. Salinity to be approx. 35000 ppm (sea salt plus mains water) containing approximately 1.5 per cent weight sand and silt in suspension. The distribution of particle size should be approximately flat between 2-500 microns. Typically 1% river silt (2-50 microns) and 0.5% builders' soft and sharp sand (50-500 microns) may be used.

The temperature of the seawater shall be maintained between 0°C and 4.5°C throughout the test.

The composition and temperature of the sea water shall be established and recorded prior to the sequence of tests. The seawater conductivity and temperature shall be measured prior to commencing the test and on completion of the test.

Seawater Characteristics to be recorded:

- Seawater Conductivity (Ω^{-1})
- Salinity (ppm)
- Silt (%)
- Sand (%)
- Temperature (°C)

- **Mounting**

One connector half (the one designed to move) shall be positioned in the mating frame. Alternatively, the connector half not designed to move may be positioned in the mating frame, however an evaluation report to eliminate any operational malfunction caused by the difference is then required as part of the Qualification testing documentation.

9.4.1.2 Physical assessments

- **Engagement and disengagement**

Mating pairs should be fully engaged and separated in the normal manner and the forces required measured. These forces should preferably be measured using simple techniques and should include the forces required to lock the connector, if applicable to the connector design.

- **Locking device evaluation**

If the connector is equipped with a locking device, the connector pair should be engaged and the locking device tightened to the specified load. The connector should be checked for satisfactory positive location, the locking mechanism undone and the connector separated. This procedure should be repeated several times after which the locking device should be inspected for damage to both halves of the connector. A subjective evaluation of the ease with which the locking device is activated should also be made.

9.4.2 Turbid tank wet mating test

9.4.2.1 Applicability

Qualification

9.4.2.2 Objective

To verify the connector performs as specified for a minimum of 100 mate/demate cycles within a turbid environment.

9.4.2.3 Method

The connector shall be vertically mounted in a special test rig for performing mating operations in a manner that simulates normal mounting. Initially the following test should be conducted:

- **Pre and post turbid tank testing**

- Contact resistance
- Shell continuity (if applicable)
- Insulation resistance
- Proof voltage
- Optical attenuation and back reflection.

The test rig with connectors should then be immersed in the pressure vessel with circulating seawater suspended with sand and silt. The following tests are performed after each demate/mate operation:

- **Intermediate testing**

- Contact resistance
- Shell continuity (if applicable)
- Insulation resistance
- Optical attenuation and back reflection.

During each demate operation the connectors shall remain fully separated (minimum 100 mm) for a period of no less than 1 minute.

The first mating shall be performed at ambient pressure, the next mating at approx. 0.5 times design pressure, and the next two matings at connectors design pressure. The remaining matings shall be performed at approx. 1.5 times connectors design pressure. The pressure shall then be released (to ambient) and the connector shall be examined externally for damage/defects.

Measurements shall be performed and recorded during each of the first five matings. Thereafter measurements shall be performed and recorded at each 5th mating until the specified total number of matings has been achieved. The minimum number of matings shall be no less than 100.

Vessel water initial and final temperature shall be recorded (at beginning and at the end of test).

Turbid tank test sequence		
Mating Cycle	Pressure	Test Type
0	Ambient - Dry	Pre/Post
1	Ambient - Wet	Intermediate
2	0,5 x Design Pressure	Intermediate
3 and 4	1 x Design Pressure	Intermediate
5	1.5 x Design Pressure	Intermediate
10, 15, 20, 25 - 100	1.5 x Design Pressure	Intermediate
101	Ambient - Dry	Pre/Post

9.4.2.4 Acceptance criteria

The connector's electrical and optical performance shall remain within specification.

No damage observed to connector during post test visual examination.

9.4.3 Turbid tank partial mating test

9.4.3.1 Applicability

Qualification

9.4.3.2 Objective

To verify the connector performs as specified for a minimum of 20 mate/demate cycles that are interrupted at various stages within a turbid environment.

9.4.3.3 Method

The connector shall be mounted in a special test rig for performing mating operations in a manner that simulates normal mounting. Initially the following test should be conducted:

- **Pre and post partial mating turbid tank testing**
 - Contact resistance
 - Shell continuity (if applicable)
 - Insulation resistance

- Proof voltage
- Optical attenuation and back reflection

The test rig with connectors should then be immersed in the pressure vessel with circulating seawater suspended with sand and silt. The following tests are performed after the operations where the connectors are fully mated.

- **Intermediate testing**

- Contact resistance
- Shell continuity (if applicable)
- Insulation resistance
- Optical attenuation and back reflection

10 mating operations shall be interrupted at different stages in the operation, ranging as widely as possible, and then fully demated.

10 mating operations shall be interrupted at different stages in the operation, ranging as widely as possible, then partially demated, then fully mated and then fully demated.

All mating may be performed at ambient pressure, and the connector shall afterwards be examined externally for damage/defects.

The total number of matings shall be no less than 20.

9.4.3.4 Acceptance criteria

The connector's electrical and optical performance shall remain within specification.

No damage observed to connector during post test visual examination.

9.5 Post turbid tank testing connector inspection

9.5.1 Applicability

Qualification

9.5.2 Objective

To establish the level of wear and contamination external and internal to the connector after completion of the turbid tank testing.

9.5.3 Method

Both halves of the connectors under test shall be stripped down and the following inspections/tests performed.

- Visual inspection for damage and wear
- Assessment of accumulation of solids on critical interface surfaces
- Analysis of contamination of dielectric fluid within primary and secondary fluid filled chambers (water, salt, silt and sand content)
- Insulation resistance of dielectric fluid.

9.5.4 Acceptance criteria

No damage observed to connector (excluding wear upon interfacing surfaces).

The accumulation of solids on the external body of the connector shall not interfere with the correct operation of the connector.

Water, Salt and Silt content of fluid filled enclosures to be quantified and the SUPPLIER shall assess the impact of this upon the operation of the connector over its lifetime.

Insulation resistance of dielectric fluid samples to quantified.

9.6 Flooded connector back-end test

9.6.1 Objective

To verify that the connector will continue to operate even if salt water breaches the oil filled hose. During this test the conductor insulation and the connector to conductor sealing mechanism shall be the only barriers between the seawater and the live conductor.

9.6.2 Method

The free half of the connector pair shall be terminated to individual wires in the approved manner. The specified method of water blocking between the wire insulation jacket and the connector shall be fitted, duplicating the actual termination itself. An 8 hour helium leak check shall then be performed in accordance with section 9.3.1.

The bulkhead portion of the connector shall be assembled to the pressure vessel cover and the free half of the connector mated to it such that the connector resides within the pressure vessel.

Prior to commencing the pressure testing and on completion of the pressure testing (pre and post) the following tests shall be performed:

- Contact resistance
- Shell continuity (if applicable)
- Insulation resistance
- Optical attenuation and back reflection.

The complete assembled unit will be loaded into a pressure vessel, which will be filled with sea water.

Pressure shall be cycled between ambient and overpressure corresponding to 1.5 times design hydrostatic pressure. Gradient during pressurisation and depressurisation shall be approximately 35 bars per minute. Pressure and temperature within the pressure vessel shall be continuously recorded throughout the test.

At the end of the test while pressure is still 1.5 times design hydrostatic pressure, insulation resistance, optical attenuation and back reflection shall be measured and recorded.

The following hydrostatic pressure sequence will be performed:

Flooded connector back-end test sequence		
Step	Pressure	Test Type
0	Ambient - Dry	Pre/Post
1	Ambient - Wet allow connector to soak for a period > step 2	None
2	Increase pressure from ambient to 1.5 x design pressure at approx. 35 bar/min rate of change	None
3	Hold at 1.5 x design pressure for period > step 1	None
4	Decrease pressure from 1.5 x design pressure to ambient at approx. 35 bar/min rate of change	None
5	Hold at ambient pressure period > step 1	None
6	Repeat steps 2 to 5 for a total of 25 cycles. Test on final hold at 1.5 x design pressure	IR and Optical
7	Ambient - Dry	Pre /Post

9.6.3 Acceptance criteria

The connectors electrical and optical performance shall remain within specification.

9.7 Long term flooded connector back end test

9.7.1 Applicability

Qualification

9.7.2 Objective

To verify the long term performance of the electrical system with the rear of the connector flooded in seawater, replicating the effects of a breached oil filled hose.

9.7.3 Method

The test shall be performed with the same test-set-up as defined for the flooded connector back end testing but shall be maintained at a constant pressure of 1.5 x design pressure and only the electrical Insulation performance shall be monitored.

Insulation measurements shall be performed daily (excluding weekends) until completion of the 1000 hours with all results documented and included within the final qualification report.

In order to minimise test equipment utilisation alternative test configurations may be proposed for approval by the COMPANY.

9.7.4 Acceptance criteria

The connectors electrical insulation remains > 10 GΩ.

9.8 Thermal shock tests

9.8.1 Applicability

Qualification

9.8.2 Objective

To verify that thermal shock produces no detrimental effects on the connector.

9.8.3 Method

Each connector half shall be subjected to the following tests in the unmated conditions.

The tests are to be performed at atmospheric pressure.

9.8.3.1 High temperature

The temperature shall be raised to 70°C and maintained for a period of four hours. The connectors shall then be rapidly cooled by immersion in a water bath, the temperature of which shall be between 0°C and 4.5°C.

Repeat the above sequence twice more.

Allow the connector to return to ambient room temperature.

Inspect the assembly for physical damage together with electrical insulation measurements (unmated and mated) and optical attenuation and back reflection measurements (mated).

9.8.3.2 Low temperature

The temperature of each assembly shall be lowered to -40°C and maintained for a period of four hours.

The connectors shall then be rapidly brought to ambient by immersion in a water bath, the temperature of which shall be between 0°C to 4.5°C.

Repeat the above sequence a further two times and allow the connector to return to ambient room temperature. Inspect and test as above.

9.8.4 Acceptance criteria

The connector will be considered acceptable if no physical damage is observed and the results of the electrical and optical testing are within the connectors design specification.

9.9 Mechanical shock test

9.9.1 Applicability

Qualification

9.9.2 Objective

To verify that the connectors (with electrical cables and optical fibres) are sufficiently rugged to withstand rough handling and the loads which may be generated when integrated within a system.

9.9.3 Method

Each half of the connector pair shall be subjected to three (3) shocks in a horizontal direction and three (3) shocks in a vertical direction. The profile of the shocks shall be of a half sine period of 11 ms at 30 g.

After completion of the shocks the connectors shall be mated and tested for:

- Contact resistance
- Shell continuity (applicable)
- Insulation resistance
- Optical attenuation and back reflection.

9.9.4 Acceptance criteria

No damage shall be observed on either half of the connectors and both connectors mate together. Damage to the protective cover, if used, is permissible.

Results of the electrical and optical testing are within the connectors design specification.

9.10 Vibration test

9.10.1 Applicability

Qualification

9.10.2 Objective

To verify that the connectors (with electrical cables and optical fibres) are sufficiently rugged to withstand vibrations, which may be induced from flow in pipes including transients, rotating machinery and rough handling loads which may be generated in transit.

9.10.3 Method

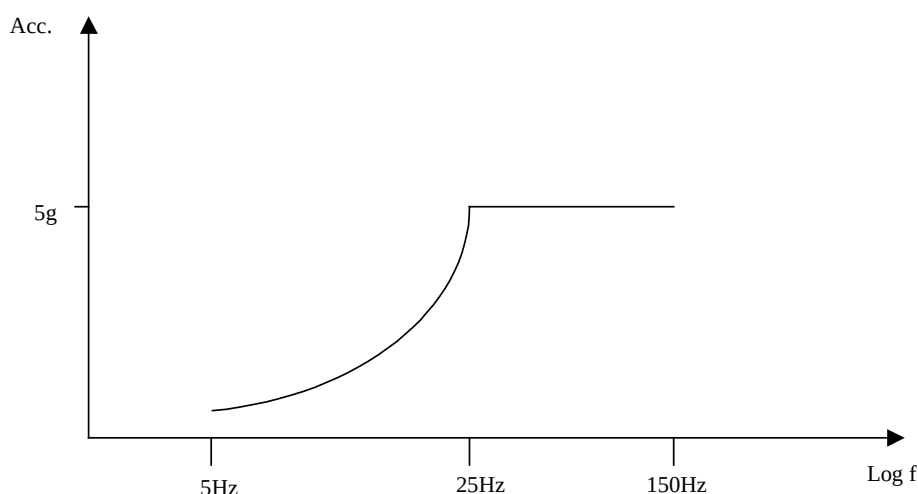
The connector half that is normally permanently attached to subsea equipment shall be fixed the vibration equipment in a similar manner as intended for normal operation. The retrievable half of the connector shall interface to the fixed half of the connector as intended for normal operation.

The electrical cables and optical fibres may be anchored to the test fixture if required.

The following excitation shall be applied to three mutually perpendicular axes. The axes shall be selected to maximise the probability of detecting faults in the design. The excitation level shall be:

- 5 Hz to 25 Hz $\pm$ 2 mm displacement
- 25 Hz to 150 Hz 5 g acceleration
- Sweep rate maximum one octave per minute

A double sweep from 5 Hz to 150 Hz and back to 5 Hz shall be performed.



Note: Some vibration test equipment rigs have problems with large displacement amplitudes. Therefore the excitation is specified with constant amplitude (± 2 mm) in the region below 25 Hz as otherwise the displacement amplitude would be prohibitively large for 5 g acceleration at these low frequencies. The maximum sweep rate is specified as one minute per octave; i.e. one minute minimum between each doubling of the frequency. The sweep rate must be low enough to allow any resonances to build up amplitude.

Monitoring of contact resistance and optical attenuation shall be continuous throughout the duration of the test and at a sufficiently high sample frequency to detect intermittent contacts, increased contact resistance and changing optical attenuation.

As an example, current subsea electrical communication frequency requirements are approximately 100 kHz and optical data rates are approximately 2 Mb/s.

After completion of the testing both connectors shall be visually inspected for damage and tested for:

- Contact resistance
- Shell continuity (if applicable)
- Insulation resistance
- Optical attenuation and back reflection.

9.10.4 Acceptance Criteria

No damage shall be observed on either half of the connectors.

No intermittent contacts or increased attenuation (electrical or optical) detected during vibration.

Results of the electrical and optical testing during and after vibration are within the connectors design specification.

9.11 Environmental stress screening

9.11.1 Applicability

FAT

9.11.2 Objective

The purpose of this test is to disclose potential failures due to flaws in workmanship.

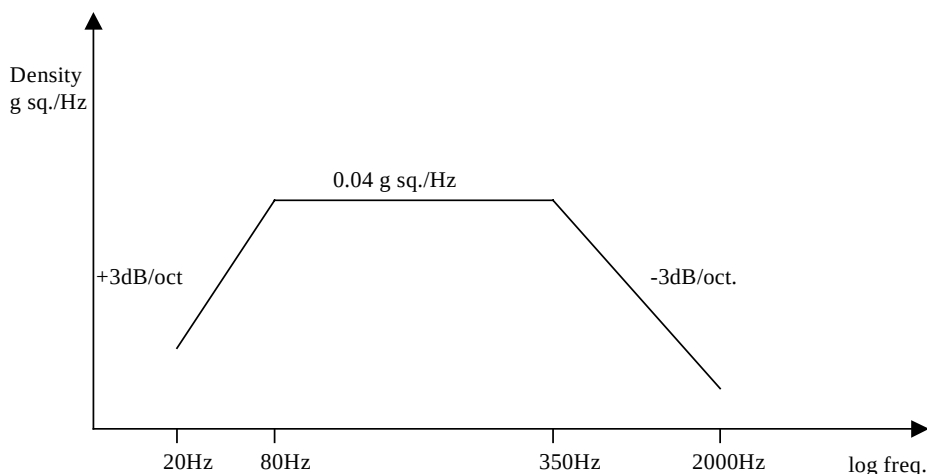
9.11.3 Method

The connector half that is normally permanently attached to subsea equipment shall be fixed the vibration equipment in a similar manner as intended for normal operation. The retrievable half of the connector shall interface to the fixed half of the connector as intended for normal operation.

The electrical cables and optical fibres may be anchored to the test fixture if required.

The random vibration shall be applied for a total of 10 minutes with the following characteristics:

- 20-80 Hz at 3 dB per octave rise
- 80-350 Hz at 0.04 g squared/Hz
- 350-2000 Hz at 3 dB per octave rolloff
- Composite excitation level shall be 6 grms.



Note: The random vibration is specified as spectral energy density over a frequency range. The integral of the density profile is a measure of the total energy (or load on the equipment). The integral of the above curve is approximately 6 grms.

After completion of the testing both connectors shall be visually inspected for damage and tested for:

- Contact resistance
- Shell continuity (if applicable)
- Insulation resistance
- Optical attenuation and back reflection.

9.11.4 Acceptance Criteria

No damage shall be observed on either half of the connectors.

No intermittent contacts or increased attenuation (electrical or optical) detected during vibration.

Results of the electrical and optical testing during and after vibration are within the connectors design specification.

10. Hose and hose termination testing

10.1 Introduction

The purpose of this section is to allow the CONTRACTOR to perform qualification testing on a hose and its associated termination as a stand-alone item independent of the connector qualification program.

10.2 Absorption/Compensation test

10.2.1 Applicability

Qualification

10.2.2 Objective

To determine the compensation and ageing characteristics of a conduit hose filled with insulating oil and immersed in seawater at hydrostatic operating pressure. Ageing is accelerated using high temperature.

10.2.3 Method

A hose assembly consisting of at least a two metre length of hose, a pressure transducer (for monitoring hose internal pressure) and end caps, shall be filled with the relevant compensation fluid and pressurised to the CONTRACTOR's specified internal pressure. The hose termination fittings shall be as per the type used in jumper assemblies. The assembly shall be placed within a pressure vessel and pressurised to the rated design pressure. The seawater temperature within the vessel shall be set to whichever temperature is highest: 55°C or CONTRACTOR's max. temperature at the hottest spot, ref. Temperature Rise Test (section 9.1.5).

At the end of the test period allow the hose to return to ambient room temperature, release the water pressure and remove the assembly from the test vessel. Inspect the hose for damage and defects. A written report shall be made evaluating the test results.

The oil insulation resistance shall be recorded prior to and after the test.

Monitor and record the following conditions daily over a period 14 days (336 hours):

- The Vessel Pressure (VP)
- The internal Hose Pressure (HP)
- The Vessel Temperature (VT)

Electronic data storage or a chart recorder with a suitable number of channels are preferred to record the values. The recording shall be set up to detect any large deviation in the conditions of the test and to detect any important intermittent deviation in the recorded results. Alternatively, manual instruments with recordings at the beginning and at the end of each working day are required.

10.2.4 Acceptance criteria

The hose shall be free from damage or defects. All observations shall be documented within the qualification report.

The insulation resistance of the compensating fluid within the hose shall not significantly change.

A net positive pressure is maintained within the hose throughout the test duration.

10.3 Ozone resistance

10.3.1 Applicability

Qualification

10.3.2 Objective

To verify hose resistance to damage from Ozone.

10.3.3 Method

A hose assembly consisting of at least a two metre length of hose, a pressure transducer (for monitoring hose internal pressure) and end caps, shall be filled with the relevant compensation fluid and pressurised to the CONTRACTORS specified internal pressure. The hose termination fittings shall be as per the type used in jumper assemblies. The hose shall then be coiled to its minimum bend radius and held in position via cable ties.

The assembly shall be placed within an ozone test chamber and exposed to 50 pphm (parts per hundred million) ozone concentration for a minimum duration of 72 hours at 40°C Ambient. The hose pressure shall be monitored at the start and finish of the test and chamber temperature shall be monitored during the test.

10.3.4 Acceptance criteria

The hose shall be free from damage or defects. All observations shall be documented within the qualification report.

The hose pressure shall not significantly change between test start and finish. All deviations shall be explained within the qualification report.

10.4 Ultraviolet resistance

10.4.1 Applicability

Qualification

10.4.2 Objective

To verify hose resistance to damage from ultraviolet light.

10.4.3 Method

A hose assembly consisting of at least a two metre length of hose, a pressure transducer (for monitoring hose internal pressure) and end caps, shall be filled with the relevant compensation fluid and pressurised to the CONTRACTOR's specified internal pressure. The hose termination

fittings shall be as per the type used in jumper assemblies. The hose shall then be coiled to its minimum bend radius and held in position via cable ties.

The assembly shall be placed within a test chamber and exposed to an ultraviolet light source with a wavelength of approximately 350 nm at an irradiance level of approximately 50 W/m² for a minimum duration of 500 hours. Throughout the test the temperature shall be maintained at a constant 70°C Ambient. The hose pressure shall be monitored at the start and finish of the test and chamber temperature shall be monitored during the test.

10.4.4 Acceptance criteria

The hose shall be free from damage or defects. All observations shall be documented within the qualification report.

The hose pressure shall not significantly change between test start and finish. All deviations shall be explained within the qualification report.

10.5 Thermal shock test

10.5.1 Applicability

Qualification

10.5.2 Objective

To verify that thermal shock produces no detrimental effects on the hose assembly.

10.5.3 Method

A hose assembly consisting of at least a two metre length of hose, a pressure transducer (for monitoring hose internal pressure) and end caps, shall be filled with the relevant compensation fluid and pressurised to the CONTRACTOR's specified internal pressure. The hose termination fittings shall be as per the type used in jumper assemblies. The hose shall then be coiled to its minimum bend radius and held in position via cable ties.

The tests are to be performed at atmospheric pressure.

10.5.4 High temperature

The temperature shall be raised to 70°C and maintained for a period of four hours. The hose assembly shall then be rapidly cooled by immersion in a water bath, the temperature of which shall be between 0°C and 4.5°C.

Repeat the above sequence twice more. Allow the hose assembly to return to ambient room temperature.

Inspect the assembly for physical damage. Record all observations.

10.5.5 Low temperature

The temperature of the hose assembly shall be lowered to -40°C and maintained for a period of four hours.

The hose assembly shall then be rapidly brought to ambient by immersion in a water bath, the temperature of which shall be between 0°C to 4.5°C.

Repeat the above sequence a further two times. Allow the hose assembly to return to ambient room temperature.



Inspect the assembly for physical damage. Record all observations.

10.5.6 Acceptance criteria

The hose assembly will be considered acceptable if no physical damage is observed.

The hose pressures measured pre and post thermal shock shall not significantly. All deviations shall be explained within the qualification report.

The internal pre-charge pressure recorded, prior to and on completion of the thermal shock testing shall not significantly change. All deviations shall be explained within the qualification report.

10.6 Destructive testing

10.6.1 Tensile failure

10.6.1.1 Applicability

Qualification and Batch

10.6.1.2 Objective

To establish/verify the failure load of the hose and or associated hose fittings.

10.6.1.3 Method

A hose assembly consisting of at least a two metre length of hose, hose fittings and end caps, shall be filled with the relevant compensation fluid and pressurised to the CONTRACTOR's specified internal pressure. The hose termination fittings shall be as per the type used in jumper assemblies.

The test shall be performed as a simple pull test with force applied at 0 degree to the termination. The tensile load shall be increased in a gradual manner until failure of the hose or hose fittings occur. At the point of failure the following parameters shall be recorded:

- The hose elongation
- The applied tensile load at point of failure

When performing this as a batch test there shall be no requirement for oil filling of the hose.

10.6.1.4 Acceptance criteria

The hose assembly will be considered acceptable if the point of failure is greater than the CONTRACTOR specified minimum breaking strength (which shall be greater than 5000 N).

10.6.2 Burst pressure

10.6.2.1 Applicability

Qualification and Batch

10.6.2.2 Objective

To establish/verify the pressure containment performance of hose and associated hose fittings.

10.6.2.3 Method

A hose assembly consisting of at least a two metre length of hose, hose fittings and end caps shall be internally pressurised with water until failure of hose or hose fittings occurs. The pressure at which failure occurs shall be recorded.

10.6.2.4 Acceptance criteria

The hose assembly will be considered acceptable if the point of failure is greater than the CONTRACTOR specified burst pressure.

10.6.3 Crush resistance

10.6.3.1 Applicability

Qualification

10.6.3.2 Objective

To establish any detrimental effects that may occur due to the hose being crushed flat and to ascertain if the hose is usable after such an incident.

10.6.3.3 Method

A sample of hose shall be selected and the outer hose diameter recorded. The area which has been measured shall then be compressed with a weight sufficient to allow the hose to collapse in the centre. The weight shall remain in place for 24 hours after which the weight shall be removed. The outer diameter of the hose shall be measured 60 seconds after removal of weight and again after 4 hours.

The following parameters shall be recorded:

- Initial outer diameter of the hose
- Outer diameter of hose 60 seconds after removal of weight
- Outer diameter of hose 4 hours after removal of weight
- Weight required to collapse hose.

10.6.3.4 Acceptance criteria

The hose assembly will be considered acceptable if no visible damage is apparent and the hose returns to its original form.

10.6.4 Outer sheath abrasion resistance

10.6.4.1 Applicability

Qualification

The aim of this test is to establish the abrasion resistance of the hose assembly to ensure that it is sufficiently durable for site handling.

The CONTRACTOR shall define appropriate test methods for approval by the COMPANY.

10.6.5 Hose kink test

10.6.5.1 Applicability

Qualification

10.6.5.2 Objective

To establish the bend radius at which the oil filled hose collapses and to ascertain if the hose recover after such an incident.

10.6.5.3 Method

A hose assembly consisting of at least a two metre length of hose, hose fittings and end caps, shall be filled with the relevant compensation fluid and pressurised to the CONTRACTOR's specified internal pressure. The hose termination fittings shall be as per the type used in jumper assemblies.

The hose shall be then positioned in a loop such that the bend radius can be adjusted. The loop shall then be tightened to the point at which the hose collapses. The bend radius at which the collapse occurs shall be recorded.

Alternatively the CONTRACTOR may define an alternative test method for approval by the COMPANY.

10.6.5.4 Acceptance criteria

The hose assembly will be considered acceptable if no visible damage is apparent and the hose returns to its original form.

The point at which the hose collapses shall be less than 125 mm.

11. Jumper assembly testing

11.1 Introduction

To verify that the completed jumper assembly comprising of connectors, hose, hose termination fittings, electrical cables and optical fibres perform as intended when integrated together.

All jumper testing shall be performed with a 20 m jumper assembly terminated at both ends with connectors and oil filled to the CONTRACTOR specified pre-charge pressure. In addition to this two bulkhead connector assemblies shall also be required.

Note: For qualification of jumpers significantly longer than the length defined within this document, alternative test methods may be more applicable or appropriate. The CONTRACTOR shall highlight any concerns or additional testing that may be required to the COMPANY.

11.2 Oscillating jumper test

11.2.1 Applicability

Qualification



11.2.2 Objective

To verify that the wiring/fibre attachment, wire/fibre assemblies and hoses are sufficiently durable.

11.2.3 Method

The test shall utilise a bulkhead mounted connector mounted securely within a salt water test tank, with one end of the jumper assembly mated. The jumper should be moved in a conical rotation, which describes a solid angle of 30° at a distance conforming to the minimum design bending radius in the data sheet. The rotation shall be achieved by supporting the jumper through a ring mounted on a rotating mechanical arm. This mechanical arm shall rotate on its axle around the connector's own axis.

The frequency should be approximately four rotations per minute lasting for thirty days, (equivalent 170,000 cycles). Insulation, continuity and optical attenuation and back reflection shall be monitored once per day.

11.2.4 Acceptance criteria

No cable damage shall be observed.

Results of the electrical and optical testing are within the jumper design specification.

11.3 Jumper pull test

11.3.1 Applicability

Qualification

11.3.2 Objective

To ensure that the connector and associated jumper assembly are constructed with sufficient strain relief and mechanical strength to withstand the forces it might at worst case be subjected to, such as a snagged jumper during assembly. The test shall verify the pull strength to be greater than the CONTRACTOR stated working maximum.

11.3.3 Method

The test shall be performed as a simple pull test with force applied at 0 degree to the termination. With maximum force applied the total elongation of the cable/hose shall be recorded.

Insulation resistance, contact resistance, optical attenuation and back reflection shall be verified before and after testing.

11.3.4 Acceptance criteria

No damage shall be observed.

Results of the electrical and optical testing are within the connectors design specification.

The jumper shall return to the original length (pre pull test) after sufficient relaxation period.

11.4 Drop test

11.4.1 Applicability

Qualification

11.4.2 Objective

To verify that the jumper assembly is sufficiently rugged to withstand rough handling, and the loads which may be generated in an accidental drop.

11.4.3 Method

Protective covers are mounted, if required, and one end of the jumper assembly raised to an elevation of 2 meters above a concrete floor. The floor may be covered with a 5 mm rubber mat. The jumper assembly shall then be dropped onto the floor, then mated and tested for:

- Contact resistance
- Shell continuity
- Insulation resistance
- Optical attenuation and back reflection

This test shall be repeated for the second connector on the other end of the jumper.

11.4.4 Acceptance criteria

No damage shall be observed on either connectors and both connectors mate with test bulkhead connector. Damage to the protective cover, if used, is permissible.

Results of the electrical and optical testing are within the connectors design specification.

11.5 Jumper handling simulation test

11.5.1 Applicability

Qualification

11.5.2 Objective

To verify that the assembled connector and associated jumper assembly is sufficiently designed to withstand normal handling loads during workshop handling and installation.

11.5.3 Method

The 20 meter jumper assembly shall be coiled in a figure of eight pattern such that the minimum bend radius is achieved. The jumper should then be uncoiled and laid out straight. This procedure shall then be repeated.

After completion of the testing the jumper shall be visually inspected for damage and tested for:

- Electrical continuity
- Insulation resistance
- Optical attenuation and back reflection.

11.5.4 Acceptance criteria

No damage shall be observed on either half of the connectors.

Results of the electrical and optical testing are within the connectors design specification.

11.6 Simulated deployment testing

11.6.1 Applicability

Qualification

11.6.2 Objective

To simulate deployment of jumper assembly and verify cable and fibre management allows sufficient free movement of conductors and fibres to accommodate changes due to expansion and contraction of the jumper during pressure changes.

11.6.3 Method

Prior to performing the hyperbaric testing of the jumper assembly shall have completed all production leak testing.

With the test pressure vessel dry, two bulkhead connectors shall be mounted on the pressure vessel flange and the jumper assembly mated.

During this test the following parameters shall be recorded at each hold point within the pressure cycling sequence.

- Loop resistance
- Insulation resistance
- Optical attenuation

In addition to the above the jumper pre-charge pressure shall be recorded both pre and post hyperbaric testing.

Simulated deployment test sequence	
Step	Pressure
1	Ambient - Dry test
2	Ambient - Wet allow to soak for 1 hour and test
3	Increase pressure from ambient to design pressure at approx. 35 bar/min rate of change
4	Design Pressure - Allow to soak for 1 hour and test
5	Decrease pressure from design pressure to ambient at approx. 35 bar/min rate of change
6	Ambient - Allow to soak for 1 hour and test
7	Repeat Steps 3-6 a further four times



11.6.4 Acceptance criteria

The jumpers electrical and optical performance shall remain within specification throughout the testing.

Both pre and post hose pre-charge pressure measurements shall be the same.

11.7 Production hyperbaric test

11.7.1 Applicability

FAT

11.7.2 Objective

To verify correct operation of each production connector/jumper assembly at the specified design pressure. This test shall be performed as part of the Factory Acceptance Testing. The COMPANY shall advise the CONTRACTOR on a data sheet, if Production Hyperbaric testing shall be performed at either the product design pressure or the project specific test pressure.

11.7.3 Method

Prior to performing the hyperbaric testing of the connectors both halves of the connector and jumper assemblies shall have completed all production leak testing.

With the test pressure vessel dry, the bulkhead portion of the connector shall be mounted on the pressure vessel flange and the free half of the connector dry mated.

During this test the following parameters shall be recorded after each demate/mate cycle:

- Contact resistance
- Shell continuity (if applicable)
- Insulation resistance
- Optical attenuation

In addition to the above the jumper pre-charge pressure shall be recorded both pre and post hyperbaric testing.

Production hyperbaric test sequence	
Step	Pressure
1	Ambient - Dry test
2	Ambient - Wet allow connector to soak for 1 hour
3	Ambient - Wet demate-mate test
4	Increase pressure from ambient to design pressure at approx. 35 bar/min rate of change
5	Hold at design pressure for 4 hours
6	Design Pressure - Wet demate-mate test
7	Decrease pressure from design pressure to ambient at approx. 35 bar/min rate of change
8	Hold at ambient pressure 1 hour
9	Ambient - Wet demate-mate test
10	Ambient - Dry test

11.7.4 Acceptance criteria

The connectors electrical and optical performance shall remain within specification throughout the testing.

Both pre and post hose pre-charge pressure measurements shall be the same.

12. Material testing

12.1 Material batch tests

12.1.1 Applicability

Batch

12.1.2 General

The polymeric and elastomeric materials used in connector construction shall be assessed by documentation or performing a number of evaluation tests. This shall establish the material compatibility in their respective environments and also, where applicable, the electrical performance characteristics. The use of elastomers in the connector construction serves two functions, namely for environmental protection and electrical insulation. The environmental protections are designed to provide oil resistance and mechanical sealing performance.

12.1.3 Tests required

The following tests or equivalent shall be documented or performed on elastomers:

Immersion test [ASTM D-471](#) - Mineral oil, Seawater, gel, methanol, citric acid, xylene

Others. To be defined by COMPANY on a per project basis

Intermittent exposure test [ASTM D-471](#) - Fluids to be defined by COMPANY on a per project basis

Rubber O-rings [ASTM D-1414](#)

Compression set [ASTM D-395](#) method B

Bonded/sandwich [ASTM D-3164](#)

Tear Strength [BS 903](#) Part A3

Tensile Strength [BS 903](#) Part A2 (peel or stripping)

Volumetric Resistivity [BS 903](#) Part C2

Hardness [BS 903](#) Part A26 or [ASTM D-2240](#)

Elongation at Break [BS 903](#) Part A2

Cable stripping [BS 6899](#) Method F

All results shall be recorded on material data sheets.

12.1.4 Acceptance criteria

- As agreed with COMPANY
- Where a maximum value is given result must be +0% -20%
- Where a minimum value is given result must be -0% +20%.

12.2 Disc bursting test

12.2.1 Applicability

Batch

12.2.2 Objective

To verify that the insert moulding material (e.g. epoxy) used to produce the specimen connectors is sufficiently strong to be acceptable for use in this application. If no insert moulding material is used in the manufacture of the specimen connector, the disc bursting test is not required.

12.2.3 Method

For each batch of inserts produced, a disc must be cast from the same material and cured under the same conditions as the inserts.

The disc is then machined to a nominal thickness of 3.5 mm.



The exact thickness is recorded and the disc subjected to hydrostatic pressure until failure. Calculations relating thickness and diameter to bursting pressure will determine the material strength and ascertain if expected results are being attained.

The calculation used is:

$$\text{Breaking stress} = \frac{0,657 p}{t^2}$$

Where p = bursting pressure [psi]

t = thickness of disc [inches]

12.2.4 Acceptance criteria

The tested strength shall be related to the design strength not lower than 1087.5 psi. The required design strength shall be subject to COMPANY approval.

12.3 Material bonding tests

12.3.1 Applicability

Qualification

12.3.2 Objective

The objective of the tests is to test the quality of bonding between materials that comprise the water block system.

12.3.3 Method

Three batch specimens each shall be obtained for the following standard tests.

- Peel Strength [ASTM D903-98](#)
- The intentions of the standard should be adhered to within the bounds of economy. A simple spring balance and lead screw drive at 6 inches/minute will suffice. The peel strength shall be reported in kg/mm
- Lap Shear Strength [ASTM D3164-97](#)
- Comment as above. The shear strength shall be reported in MPa
- Water Immersion
- The specimens are prepared as for the above test D3164 and then immersed in salt water 60°C for 72 hours. The lap shear test is performed and any reduction in strength observed.

12.3.4 Acceptance criteria

The MANUFACTURER shall quote typical values that experience shows are acceptable before the start of the tests.