SEPS SP-1001

Power connectors, penetrators and jumper assemblies with rated voltage from 3 kV (U_{max} = 3.6 kV) to 30 kV (U_{max} = 36 kV)

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FOREWORD

The intent of this document is the development of a standard that will be accepted globally. Presently discussions are underway with IEC and IEEE about the possibility of their development of this document into a joint IEC/IEEE standard.

This, document, SEPS-SP -1001, has been compiled and approved by the following members of the SEPS JIP on behalf of their respective companies.

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1 SCOPE

This document is valid for high voltage, single and three-phase wet-mateable and dry-mateable AC connectors, penetrator and jumper assemblies with rated voltage in the range of 3.6 kV < $U_m \leq$ 36 kV.

For the sake of simplicity, the subsea high voltage single and three-phase wet-mateable and dry-mateable AC connectors and AC penetrator assemblies will be referred to herein as "Connector Assembly" except where otherwise specified.

Note: The Connector Assemblies covered by the scope of this document are referred to as High Voltage connector assemblies according to the IEC. It should be noted that in some countries this voltage range is considered to be a medium voltage.

This document presents design, Factory Acceptance Tests (FAT'S), qualification process, transportation/installation and operational requirements.

2 NORMATIVE REFERENCES

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API:

ANSI/API Spec 6A	Specification for Wellhead and Christmas Tree Equipment
API RP 17Q	Subsea Equipment Qualification-Standardized Process for Documentation

ASTM:

ASTM D1141 - 98 (2008)	Standard Practice for the Preparation of Substitute Ocean Water

CEN:

EN 10204	Metallic products – Types of inspection documents

ICEA:

ICEA S-93-639 NEMA WC 74	5 to 46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy
ANSI/ICEA T-27-581 NEMA WC 53	Standard Test Methods for Extruded Dielectric Power, Control, Instrumentation, and Portable Cables for Test
ICEA S-96-659 (2001-5000V cables)	Non-shielded power cables rated 2001 – 5000 V

IEC:

IEC 60038	IEC Standard Voltages
IEC 60059	IEC Standard Current Ratings
IEC 60060-1	High-voltage test techniques. Part 1: General definitions and test requirements
IEC 60270	High-Voltage Test Techniques - Partial Discharge Measurements
IEC 60183	Guide to the selection of high-voltage cables
IEC 60502-2	Power cables with extruded insulation and heir Accessories for Rated Voltages from 1 kV (U_m = 1.2 kV) up to 30 kV (U_m = 36 kV) - Part 2: Cables for rated voltages from 6 kV (U_m = 7.2 kV) and up to 30 kV (U_m = 36 kV)

IEC 60721-3-2	Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 2: Transportation
IEC 60885-2	Electrical Test Methods for Electric Cables - Part 2: Partial Discharge Tests
IEC 60986	Short-Circuit Temperature Limits of Electric Cables with Rated Voltages from 6 kV (U_m = 7.2 kV) Up To 30 kV (U_m = 36 kV)
IEC 61238-1	Compression and Mechanical Connectors for Power Cables for Rated Voltages up to 30 kV (U_m = 36 kV) - Part 1: Test Methods and Requirements
IEC 61442	Test Methods for Accessories for Power Cables with Rated Voltages from 6 Kv (U_m = 7.2 kV) Up To 30 kV (U_m = 36 kV)
IEC 62262	Degrees of Protection Provided by Enclosures for Electrical Equipment Against External Mechanical Impacts (IK Code)

IEEE:

IEEE 386	Separable Connector Systems for Power Distribution Systems Above 600 Volts
IEEE 4	Standard Techniques for High Voltage Testing
IEEE 592	Standard for Exposed Semiconducting Shields On High Voltage Cable Joints (Splices) and Separable Connectors

ISO:

ISO 10423	Wellhead and Christmas Tree Equipment
ISO 12103-1 A4	Coarse Test Dust

NORSOK:

NORSOK M-001	Materials Selection
NORSOK M-710	Qualification of Non-Metallic Sealing Materials and Manufactures

3 DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

Term	Definition
Ambient pressure (AP)	Ambient topside air pressure
Cable termination	Device fitted to the end of a cable to ensure electrical connection with other parts of the system and to maintain the insulation up to the point of connection
Connector assembly	Any assembly of wet and/or dry mate connectors, penetrators, cable terminations, cable pigtails or jumper cables between subsea components – or any combination of these
Connector	Fully insulated termination permitting the connection and the disconnection of a cable to other equipment
Design pressure	Maximum differential pressure that a penetrator can work with at worst case operating conditions. Two figures shall be specified, for differential pressure in both directions; internal-ambient and ambient-internal
Dry mateable connector	Connector designed to be submerged in sea water, but connected/disconnected in a dry (topside/onshore) environment only
Dummy Connector	Device allowing connection to a connector half for protection when unmated. Normally no cable is attached to the dummy connector, internal connection between phases may however be established to allow continuity testing. Electrical rating, including acceptable voltage test level shall be clearly specified in the dummy connector data sheet, and marked on the item
Factory Acceptance Tests	A sequence of tests to be performed on each connector assembly at the supplier installation before delivery
Hose	A flexible tube or pipe, usually oil filled, which acts as mechanical protection of the jumper cable. The oil-filled hose may also constitute a water sealing barrier

Term	**Definition**
Hydrostatic pressure	Hydrostatic pressure corresponding to the designed water depth
Jumper assembly	Cable connection terminated at each end to either a connector or a penetrator, including protective, oil filled hose and hose terminations. Other common designations are electrical flying lead and electrical jumper lead
Onshore protection cap	Device connected to a connector half during handling, transportation and storage. The cap shall protect against water and dust ingress and the sealing surfaces against mechanical damages. Onshore protection caps are not allowed for subsea installation
Penetrator	A device that enables one or several conductors to pass through a partition such as a wall or a tank, and insulates the conductors from it. The means of attachment, flange or fixing device, to the partition forms part of the penetrator. Penetrators include bulkhead mounted connector assembly components. *Bushing* is an alternative commonly used term
Qualification Process	A sequence of tests that are performed to verify and ratify that the design of a component is in accordance with the requirements as set out in the connector assembly datasheet. If any relevant parameter is outside the envelope of a previously qualified connector assembly datasheet, a new qualification process shall be performed
Rapid Gas Decompression	An extreme depressurisation event from high pressure (thousands of psi) to low pressure (hundreds of psi down to atmospheric) in order of seconds, or instantly, that can occur in a production system with presence of gas. Also known as explosive decompression.
Rated current, I_r	Maximum r.m.s. value of current which the connector assembly can carry continuously at rated frequency and at maximum ambient temperature, as given by the temperature Class

Term	**Definition**
Rated thermal short-time current, I_{th}	r.m.s. value of a symmetrical current which the connector assembly withstands thermally for the rated duration (t_{th}) immediately following continuous operation at rated current and frequency, with maximum temperatures of ambient sea water/operational media
Rated dynamic current I_d	Peak value of a current that the connector assembly withstands mechanically
Subsea Protection cap	Device connected to a connector half for protection when unmated subsea. Provides mechanical protection and prevents marine growth on critical/sealing surfaces
Water sealing barrier	Part of a connector assembly that prevents intrusion of sea water into the connector assembly internals
Wet mateable connector	Connector designed to be submerged in sea water, and can also be connected/disconnected in a submerged condition

3.2 Abbreviations

AP	Ambient Pressure
API	The American Petroleum Institute
ASTM	American Society for Testing and Materials
CEN	European Committee for Standardization
CP	Cathodic Protection
CR	Contact Resistance
DP	Design Pressure
EN	European Norm
FAT	Factory Acceptance Tests
FEA	Finite Element Analysis
g	Acceleration due to Gravity
HP	Hydrostatic Pressure
ICEA	Insulated Cable Engineers Association
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IR	Insulation Resistance
ISO	International Organization for Standardization
PD	Partial Discharge
PMI	Positive Material Identification
PSL	Product Specification Level
RGD	Rapid Gas Decompression
ROT	Remotely Operated Tool
ROV	Remotely Operated Vehicle
U_o	Rated power frequency voltage between a conductor and earth or metallic screen for which the connector assembly is designed
U	Rated power frequency voltage between conductors for which the connector assembly is designed
U_m	Maximum value of the “highest system voltage” for which the connector assembly may be used
UV	Ultraviolet

4 DEVELOPMENT, DOCUMENTATION & MARKING REQUIREMENTS

4.1 Design documentation

Design documentation to be provided shall be titled and contain information as described by the following table. Design documentation shall be revised such that it represents the present technology readiness level of the component.

The documentation requirements listed below are typical and shall not be limited to the following items:

Preferred document	Document content
Design specification	Including design data sheet, operations interface specification, mechanical, electrical and thermal design specification, cathodic protection requirements. Intended installation and intervention procedures
Design drawings	Detailed, scaled mechanical drawings including weights, dimensions, cross sections and material and parts lists
Materials specification	Materials selection report including material list and properties. Compatibility details, test procedures and report
Design analysis report	Report containing mechanical, electrical and materials calculations and theoretical studies
Cleaning & spillage requirements	Procedure with regards to cleaning and spillage requirements.
Handling, transport and storage	Document containing intended handling, transport and storage procedures

4.2 Qualification Process documentation

Detailed specification for each technical qualification sequence and test is required. This specification should include procedures, instruments, connection diagrams and all relevant environmental, mechanical and electrical parameters used. In addition, a test report shall be provided demonstrating the outcome of each test within each sequence. Test reports shall be compiled in the format required by API RP 17Q - Subsea Equipment Qualification - Standardized Process for Documentation.

4.3 FAT documentation

Factory acceptance tests (FAT) which, shall be undertaken for every component intended for field use. Documentation shall be supplied as follows:

Preferred document	**Document content**
FAT Test procedure	A detailed test specification for each FAT test, embracing complete test procedures with all relevant environmental, mechanical and electrical parameters, instruments and connection diagrams used
FAT Test report	A test report shall be provided demonstrating the outcome of each test within the test sequence. The test report shall be compiled in a format as recommended by Section 4.2 Qualification Process Documentation

4.4 As built documentation

Further to successful technical qualification, each connector assembly shall be supplied with detailed as built documentation. The following documents shall be supplied, as a minimum, and shall contain information as detailed:

Preferred document	**Document content**
Design report	Including design data sheet, operations interface specification, mechanical, electrical and thermal design analyses, and cathodic protection influence report
Design drawings	Detailed, scaled mechanical drawings including weights, dimensions, cross sections and material and parts lists
Materials specification	Materials selection list and properties. Compatibility detail, test procedures and report
Operation and Maintenance manual	Installation, operation, Intervention and Maintenance information. Subsea water-jet and Subsea citric acid and brush cleaning detailed procedures
Traceability report	Individual component and materials traceability
Handling and storage report	Handling, Shipping, Storage and Preservation requirements

4.5 Design analysis

The connector assemblies shall be subject to a design analysis covering as a minimum:

- Electrical, thermal and mechanical finite element analysis, voltage stress calculations, covering qualification test and intended operational conditions. The analysis shall include worst case design loads (test, storage, handling, installation/retrieval and operation) including fault scenarios. The analysis shall include the heat generated by the losses in the connector assembly itself. The complete connector shall be analyzed. The analysis should also include possible nonlinear material properties. The analysis shall verify that the worst case design loads do not exceed electrical, thermal or mechanical limitations for any material.

- Design analysis shall include calculations to verify suitability of the pressure compensating system. The analysis shall include design test, storage, transportation, installation/retrieval and operational conditions. Any hysteresis shall be included.
- The material properties and limitations used in the analysis shall be identified and documented based on qualified, recognised and repeatable fabrication processes. This is also applicable for bonding between materials.
- The connector assembly design shall be subject to a Design Failure Mode Effect and Criticality Analysis.

4.6 Data sheet

A data sheet shall be created for each connector assembly. As a minimum, characteristic data for the connector assembly shall be documented in the format given in Appendix 1.

4.7 Equipment Marking

4.7.1 Connectors and penetrators

The connector and/or penetrators shall be legibly and durably marked in a visible place with the following:

- Name, logo or registered mark of the manufacturer or supplier
- Model / serial number
- Rated voltage, Uo/U (U_m)
- Rated current, I_r
- Environmental class
- Design pressure
- Water depth

4.7.2 Jumper assemblies

The jumper assemblies shall be legibly and durably marked on the outer surface at each end with the following information as a minimum:

- Name, logo or registered mark of the manufacturer or supplier
- Model / serial number
- Rated voltage, Uo/U (U_m)
- Rated current
- Type of cable insulation
- Number and size of conductor
- Water depth
- Environmental class

5 PERFORMANCE CRITERIA

5.1 General requirements

The performance criteria for HV connector assemblies are those requirements attested by the qualification process with which the component complies. Based upon the design analysis and the qualification process, a data sheet shall be submitted giving the design specification for the component.

5.2 Environmental conditions

This standard establishes three temperature classes of connector assemblies:

- Class I: standard applications
- Class II: medium temperature applications
- Class III: high temperature applications

The specific values stated in each connector class shall be used in the qualification process to qualify the connector assembly according to the special application requirements. For some of the test sequences, different steps are defined for the three classes.

	Class I	**Class II**	**Class III**
Parameter	**Performance Criteria**	**Performance Criteria**	**Performance Criteria**
Water depth	3000 m	3000 m	3000 m
Minimum ambient temperature	-5 ^{0}C	-5 ^{0}C	-5 ^{0}C
Maximum ambient sea water temperature Note 2	20 ^{0}C	20 ^{0}C	20 ^{0}C
Maximum ambient internal temperature Note 2	+60 ^{0}C	+80 ^{0}C	+110 ^{0}C
Handling and storage temperature	-25 to 60 ^{0}C	-25 to 60 ^{0}C	-25 to 60 ^{0}C
Rapid gas decompression rate Note 3	20 bar/min (290 psi/min)	20 bar/min (290 psi/min)	69 bar/min (1000 psi/min)

Note 1: The specified maximum ambient temperatures do not take into account the heat generated by the connector assembly itself.

Note 2: Internal refers to inside housing to which the connector assembly is attached.

Note 3: RGD requirement is only applicable for connector assemblies that are in contact with production fluids. Detailed test conditions shall be agreed between the manufacturer and purchaser.

5.3 Electrical characteristics

Parameter	**Performance Criteria**
Rated voltage U_m	3.6 kV ≤ U_m ≤ 36 kV
Steady state frequency range	15 – 200 Hz
Un-terminated connectors/penetrators	> 100 GΩ
Terminated connector assemblies	> 20 GΩ

5.4 Mechanical characteristics

Parameter	**Performance Criteria**
Minimum mate/de-mate operations	100
Minimum surface recoveries	50
Impact protection class (according to IEC 62262)	IK 10

6 DESIGN REQUIREMENTS

6.1 General functional requirements

The following requirements apply to all types of connectors:

- Designed for a service life time of 30 years.
- Designed to be maintenance free throughout service life.
- Designed such that maximum loading may be applied and sustained without compromising performance characteristics.
- Designed for a minimum of two years storage onshore as part of the design service life.
- Designed for a minimum of one year storage subsea with subsea protection cap and a minimum 30 day storage subsea without protection as part of the design service life.
- Designed for an average number of turn-on/turn-off cycles of a minimum of 100 per year without impacting the design life of the component.

6.2 Electrical properties

6.2.1 Ratings

6.2.1.1 Voltage ratings

The values of U_m for connector assemblies shall be according to the standard values of the highest voltage for the equipment, as defined in IEC 60038.

Table 1 – Voltage ratings

U_0/U (U_m)	Rated voltage (kV)					
U_0/U	1.8/3	3.6/6	6/10	8.7/15	12/20	18/30
U_m	3.6	7.2	12	17.5	24	36

Note: For systems with a rated "maximum" voltage, U_m, of 36 kV, the standard voltage ratings (i.e. U_0/U (U_m)) shown in the table above apply on systems with a nominal operating phase-to-phase voltage of 33 kV as well as 30 kV. The same U_0 of 18 kV shall be selected for the multiplier value referenced in the testing section for both systems with a nominal operating phase-to-phase voltage of 33 kV as well as 30 kV. No special labelling and/or marking are required to denote the higher phase-to-phase operating voltage of 33 kV. Reference IEC 60183 Amendment 1.

6.2.1.2 Current ratings

The rated current I_r of connector assemblies shall be in accordance with current classes given in IEC 60059.

Table 2 – Current ratings

Rated current (A)												
100	200	250	315	400	500	630	800	1000	1250	1600	2000	2500

Rated current shall normally be specified for rated frequency in sea water at 20 ˚C for Class I and in the relevant fluid/gas at 80 ˚C/110 ˚C for class II and class III connector assemblies respectively. For connector assemblies operating in other conditions, the rated current and corresponding operational ambient conditions shall be clearly specified in the data sheet. For penetrators and bulkhead mounted connectors, rated current may be given by operational conditions in the tank/housing to which it is mounted; these conditions shall be clearly specified in the data sheet.

If the optional extended temperature rise test is performed, the current carrying capacity vs. ambient temperature characteristics shall be included in the datasheet.

6.2.1.3 Short circuit current rating

Unless otherwise specified, the standard value of the rated thermal short-time current (I_{th}) shall be 25 times the rated current (I_r), t_{th} being 1 s.

Unless otherwise specified, the standard value of the rated dynamic current I_d, shall have amplitude of the first peak equal to 2.5 times I_{th}.

The maximum permissible short circuit temperature of the conductors shall be calculated in accordance with IEC 60986 and/or be verified by the FEA.

6.2.2 Earthing

Connector assemblies shall have means for earthing of housings and cable screens. The earthing connection shall be Cu, with a cross section area similar to that of the cable screen, however the cross section area should be a minimum of 6 mm^2.

6.2.3 Dummy connectors

Electrical voltage rating, including acceptable voltage test level shall be clearly specified in the dummy connector data sheet, and marked on each item.

6.3 Mechanical properties

6.3.1 Pressure ratings

Pressure retaining components (penetrators, bushings, bulkhead mounted connectors etc.) should be categorized and qualified to standardised pressure classes, in accordance with ISO 10423 / API 6A as shown in Table 3 below:

Table 3 – Pressure ratings

Pressure classes according to ISO 10423							
Pressure (bar)	138	207	345	690	1035	1380	1861
Pressure (psi)	2000	3000	5000	10000	15000	20000	27000

6.3.2 Rapid gas decompression

Operational changes in pressures and tolerance to rapid gas decompression (RGD) shall be documented where applicable. Tolerance to RGD shall be stated in the data sheet.

6.3.3 External forces

Rotational forces, vibrations, tensions, compressions shall not impair the function or quality of the connector assembly, throughout design service life.

A retaining mechanism for securing sheaths, screens and armour shall be incorporated in the connector assembly design, in order to verify mechanical and electrical suitability.

The connector assembly shall have an impact protection rating, IK10, according to IEC 62262.

6.4 Material properties

The connector assemblies shall meet the following requirements:

- The connector assembly shall comprise proven materials and components, which are qualified and suitable for relevant equipment, applications and environments, and the design life. The connector assembly shall be compatible with relevant and interfacing fluids/materials as per operational requirements, throughout design service life.

- The chemical resistance of all materials shall be documented.
- All polymeric materials shall be compatible with the service environment.
- The connector assembly shall be designed to be cathodically protected or made of a sea water resistant material. Due consideration shall be given to chosen materials and system design; to ensure correct material protection in order to reduce the possibility of corrosion, calcareous build-up and hydrogen embrittlement.
- Any dielectric oil shall be carefully selected, also considering density relative to water, such that potential migration and/or ingress of water do not gather in critical areas within the connector assembly, leading to reduction in the design service life.
- A materials selection report including qualification test reports shall be prepared and presented to the purchaser, before construction of connector assemblies.
- Each connector assembly and its individual parts shall be documented as 100% traceable, enabling comparison and rectification on similar connector assemblies. Hence, materials, manufacturing records and recording of test results shall ensure full traceability for each connector assembly. The materials shall be delivered with certificates type 3.1 according to EN 10204.
- The composition of all metallic components shall be verified by positive material identification (PMI) according to the manufacturer’s procedure. The PMI shall be performed as late as possible in the assembly process and the result documented.

6.5 Connector Specific requirements

6.5.1 General requirements

The following requirements apply to all types of connectors:

- Connectors shall be designed for a minimum of 100 maintenance free mate/de-mate cycles, post FAT /delivery.
- Physical contact between electrical contacts of opposing connector assembly halves during primary engagement of the connector assembly shall not be possible. This is to prevent damage due to exposure to primary alignment forces.

Connector assemblies shall be designed:

- To be capable of vertical, tilted and horizontal operation inclusive of mating and de-mating.
- With clearly visible indications of correct rotational and axial alignment prior to and during mating. The connector assembly shall also have self-evident means to indicate that the connector assembly is fully mated; i.e. a positive fully mated indication shall be part of the design. Visual indication shall be clearly visible from a ROV camera.
- With a robust locking mechanism to prevent accidental or vibration-induced de-mating or malfunction.
- To have a housing and latch mechanism tolerant to silt and fine sand deposits.

6.5.2 Wet mateable connectors

Additional requirements for wet mateable connectors:

- Designed to withstand calcium deposits, marine growth and debris without jamming, and without interfering with mating, de-mating and operation.
- Designed for operation within the presence of sand and silt, and tolerant to silt and fine sand deposits (e.g. mating areas, housing and locking mechanism). The connector assembly design shall not be susceptible to damage by sand particles during mating or de-mating.
- The connector assembly shall be designed for water-jet cleaning of marine growth in the mated condition, or with a dummy connector/protection cap installed. The potential risks of performing this water jetting shall be clearly defined and documented.
- The connector assembly shall be designed for acid cleaning with citric acid and brushed with a purpose made ROV brushing tool to remove calcium growth. All applicable limitations shall be specified e. g. maximum concentrations and durations when using citric acid.

6.5.3 Dry mateable connectors

Additional requirements for dry mateable connectors:

- Dry mateable connectors shall be suitable for mating/de-mating in harsh offshore conditions, e.g. in a humid and salt atmosphere.
- Means for testing seals between the connector halves after mating shall be considered.

6.6 Penetrator specific requirements

6.6.1 Penetrators for pressure compensated equipment

Penetrators used as equipment penetrations for pressure compensated housings shall be designed for a minimum differential pressure in the range –10 to +10 bar in the specified temperature range.

6.6.2 Penetrators subject to differential pressure

The following requirements are additionally required for penetrators which are exposed to differential pressure above what is normally seen for pressure compensated assemblies.

Components intended for differential pressure service shall be designed and tested mechanically (in addition to tests specified in this document) according to the design code applicable for the equipment to which it is mounted. If not specified, ISO 10423 should be used as a reference, where PSL 3G and PR2 should be the level of technical qualification/documentation.

The applicable temperature range shall be clearly specified and related to the pressure rating requirements.

6.7 Seals

- In general all connector assemblies shall incorporate a minimum of two water sealing barriers between sea water and electrical conductors/live parts and between other non-isolating media (inside housings, e.g. motor cooling liquid) and electrical conductors/live parts. The seals shall be independently installed (different seal surfaces). Each barrier shall be testable during qualification testing; at least one barrier shall be testable during FAT.
- Each sealing barrier shall be separately designed and qualified for continuous exposure to sea water (at required hydrostatic design pressure). Failure of one of the sealing barriers shall not jeopardise the function or integrity of the remaining sealing barrier. The connector assembly shall operate within its specified electrical requirements with only one seal in operation.
- Seals shall be of a subsea field proven type and designed and qualified for continuous subsea operation for all operating conditions.
- Materials used shall be compatible with all applicable interfacing materials and fluids, also if one sealing barrier should fail.
- The sealing components of the connector assembly shall not deform the cable insulation or the outer semi-conductive layer in such a way as to lower the electric or mechanical strength of the cable.
- The principle with two water sealing barriers is also applicable to dummy connectors (main connector disconnected).
- Use of test ports for testing of seals should be minimized. Where test ports are introduced, careful consideration shall be made in order not to introduce new potential leakage paths and reduce the main seals integrity level.
- The supplier shall demonstrate that the sealing system fulfils the design life time of the connector assembly. Any diffusion shall be quantified and it shall be verified that the diffusion rates are acceptable.
- Connector assemblies that are exposed to production fluids shall be qualified as gas tight to PSL 3G and PR2 as per ISO 10423 or ANSI/API Spec 6A. The connector assembly shall have two independent barriers for gas sealing. Each of the two barriers shall be separately designed and qualified for continuous gas exposure at the required pressure.

6.8 Electric field control

Electric field control shall be applied when the cable has an outer semiconductor insulation layer.

6.9 Jumper assemblies

- Jumper assemblies shall be flexible. Details on minimum bending radius and the force required to achieve this shall be specified in the data sheet.

- All jumper assemblies shall be oil filled and pressure balanced to reflect the operational conditions.
- Jumper assemblies shall have a tension strength element included in order to avoid tensional forces in the cables.
- Electrical cables should in general be type tested in accordance with IEC 60502-2, ICEA S-93-639, ICEA S-96-659 and ANSI/ICEA T-27-581.

6.10 Reconditioning

It shall be possible to refurbish the connector assembly following retrieval. Provision shall be made for replacing critical parts each time the connector assembly is retrieved. Potentially, the refurbishment could be performed on the offshore vessel.

The connector assembly cable termination shall allow reconnection of electrical cable conductors without degradation to the performance of the terminals.

6.11 Storage and Transportation

Storing and transportation shall be considered during the design of the connector assembly. Special consideration shall be given to shock and vibration, pre-pressurised equipment, minimum bending radius of electrical jumpers and protection of those parts easily susceptible to damage. Onshore protection caps shall be provided.

7 TESTING

7.1 Test Requirements

Testing shall take two forms:

- Technical qualification of new technologies and designs.
- Factory acceptance testing (FAT) of every component intended for field use.

7.1.1 General requirements

Test procedures and acceptance criteria shall reflect the conditions, interfaces and environment during intended operation, installation and recovery/re-installation plus all temporary phases. The design limits shall be determined through testing, both to establish actual safety factors and to verify nominal values.

Each item undergoing a qualification test or FAT 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. Visual inspection shall be repeated after testing is completed. Both the pre and post testing visual examinations shall be recorded within the test documentation.

Each mate/de-mate and lock/unlock process shall be undertaken as described within the relevant test procedure, and the details tabulated and logged.

The results of the following tests shall be tabulated, logged and graphed together each time they are undertaken and throughout all testing sequences in order to highlight anomalies:

- Contact resistance test
- Insulation resistance test
- Partial discharge test (PD inception voltage as applicable)

Where applicable, temperature differences shall be accounted for.

Sensors, as required, shall be included in the test setup, to monitor the applicable parameters, e.g. pressures and temperatures. Sensors should also enable measurements of differential pressures between pressure compensated areas and the pressure vessel, and forces resulting from mating/de-mating and locking/unlocking; if not performed as discrete tests.

It shall be possible to de-mate/mate, lock/unlock wet-mate connector assemblies while submerged and under pressure.

Connector assemblies shall be fitted with a sample of the intended cable during testing.

7.1.2 Electrical test requirements

In general the electrical tests described in this chapter are adopted from land based international standards for cables and connector systems and subsea industry requirements.

Normative reference is made to relevant parts of the following standards:

- IEEE 4 Standard Techniques for High Voltage Testing.
- IEEE 386 Separable Connector Systems for Power Distribution Systems above 600 Volts.

- IEEE 592 Standard for Exposed Semiconducting Shields on High Voltage Cable Joints (Splices) and Separable Connectors
- IEC 60502-2 Power Cables with Extruded Insulation and Their Accessories
- IEC 61442 Test Methods for Accessories for Power Cables with Rated Voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)
- IEC 60270 High-Voltage Test Techniques - Partial Discharge Measurements
- IEC 61238-1 Compression and Mechanical Connectors for Power Cables for Rated Voltages up to 30 kV (Um = 36 kV) - Part 1: Test Methods and Requirements

The electrical tests in this chapter cover relevant test requirements for subsea connector assemblies from the above standards.

7.1.3 Artificial sea water

For tests performed in artificial sea water, the following requirements shall be met:

- Artificial sea water shall be according to ASTM D1141-98.
- Salinity to be approx. 35000 ppm (sea salt plus mains water) containing approximately 1.5 per cent by weight sand and silt.
- The particle size distribution shall be according to ISO 12103-A4, Coarse test dust.
- The composition and temperature of the sea water shall be established, recorded and verified prior to testing, and circulation shall be provided and maintained during testing.
- The water shall be continuously agitated while performing the tests to ensure that solids remain in suspension and are evenly distributed.

7.2 Technical qualification testing – connectors and penetrators

7.2.1 Test specimens

The same connector assembly should be used throughout qualification testing without refurbishment. Alternatively, it shall be validated that parallel testing of several connector assemblies or discrete testing of subassemblies provides the same confidence level as one connector assembly throughout qualification testing. Such validation shall be presented to purchaser for acceptance. Any replacement or modifications of parts (e.g. boot seals, seal rings) during the qualification test program shall be agreed with the purchaser and recorded.

Technical qualification testing shall be undertaken such that all aspects of the connector assembly are thoroughly tested. Testing may compromise the integrity of the component or part being tested, and may be destructive. The assemblies tested shall not be used in operation.

Where possible and applicable, all tests shall be undertaken with connector assemblies located in the worst case environmental media and ambient temperature for which it is designed.

Manufacturers shall also verify that manufacture and assembly of all parts can be repeated with sufficient quality.

7.2.2 Technical qualification test sequences

Technical qualification testing shall be undertaken sequentially in order to target specific aspects of the connector assembly. Sequence shall be as follows:

Table 4 – Qualification Test Sequence

Step	Test	Application		Reference
		Connectors	Penetrators	
0	Material testing [1)]	x	x	7.4.27
1	Prototype manufacturing acceptance test	x	x	7.2.3
2	Mate/de-mate operation test	x		7.4.22
3	Electrical and thermal qualification test – connectors	x		7.2.4
4	Electrical and thermal qualification test - penetrators		x	7.2.5
5	Electrical short circuit qualification test	x	x	7.2.6
6	Hyperbaric qualification test	x	x	7.2.7
7	Pressure cycling test – penetrators		x	7.2.8
8	Combined pressure and temperature cycling test – penetrators [2)]		x	7.2.9
9	Extended static pressure test – penetrators [3)]		x	7.4.17
10	Rapid gas decompression qualification test [4)]	x	x	7.2.10
11	Mechanical and environmental stress test	x	x	7.2.11
12	Hyperbaric Long term qualification test – connectors	x		7.2.12
13	Long term pressure cycling qualification test - penetrators		x	7.2.13
14	Inner barrier qualification test – connectors	x		7.2.14
15	Inner barrier qualification test – penetrators		x	7.2.15
16	Impulse withstand voltage test	x	x	7.4.7
17	HV breakdown test	x	x	7.4.22
18	Dismantling and examination	x	x	7.4.23

1) Material testing is normally performed on material samples and, as such, step 0 is not part of the sequence applicable to an assembled connector or penetrator.
2) Applicable to penetrators exposed to process fluid/gas

3) Optional – to be performed if agreed between manufacturer and purchaser. When to perform the test in the test sequence is also subject to agreement.
4) Applicable to connector assemblies exposed to process fluid/gas. Test requirement to be determined via analysis of likely operational environment and agreed between the purchaser and manufacturer.

CR, IR and PD tests at the start of a new test sequence are not necessary if already performed at the end of the previous sequence. If dismantling of a connector assembly has been performed, the below listed tests shall be performed prior to starting the next test sequence.

- Contact resistance
- Insulation resistance
- PD test to 1.73 x Uo
- PD test to 2.5 x Uo
- HV AC test to 2.5 x Uo (hold time 1 hour)
- PD test to 1.73 x Uo
- PD test to 2.5 x Uo

7.2.3 Prototype manufacturing acceptance test sequence

7.2.3.1 Objective

The scope of this test is to highlight any manufacturing defects within the connector assembly and to ensure a healthy product at the start of the qualification process.

7.2.3.2 Sequence

Step	Test	Test level	Reference
1	Helium leak test	See test method	7.4.1
2	Static pressure test - penetrators	See test method	7.4.16
3	Contact resistance	See test method	7.4.2
4	Insulation resistance	See test method	7.4.8
5	PD test	1.73 x U_0 (10 pC)	7.4.5
6	PD test	2.50 x U_0 (200 pC)	7.4.5
7	High voltage AC test	4 x U_0 (1 hour)	7.4.6
8	PD test	1.73 x U_0 (10 pC)	7.4.5
9	PD test	2.5 x U_0 (200 pC)	7.4.5

7.2.3.3 Acceptance criteria

Acceptance criteria defined in the referenced test procedure shall be fulfilled.

7.2.4 Electrical and thermal qualification test - connectors

7.2.4.1 Objective

The scope of this test is to ensure that the connector assembly can effectively deal with load changes, both at and without hyperbaric pressure. Information about capability for operation in air will also be determined.

7.2.4.2 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Temperature rise test	See test method	7.4.12
5	Thermal cycles	15 cycles at AP	7.4.14
6a	Thermal cycles – Class I and II	50 cycles at 1.1 x HP	7.4.14
6b	Thermal cycles – Class III	300 cycles at 1.1 x HP	7.4.14
7	Contact resistance	See test method	7.4.2
8	Insulation resistance	See test method	7.4.8
9	PD test	1.73 x U_0 (10 pC)	7.4.5
10	High voltage AC test	2.5 x U_0 (1 hour)	7.4.6
11	PD test	1.73 x U_0 (10 pC)	7.4.5

7.2.4.3 Acceptance criteria

The electrical performance of the connector assembly shall remain within specified design limits throughout the test sequence. Acceptance criteria defined in the referenced test procedure shall also be fulfilled.

7.2.5 Electrical and thermal qualification test – penetrators

7.2.5.1 Objective

The objective of these tests is to ensure that the connector assembly can effectively deal with load changes, both with and without differential pressure.

7.2.5.2 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8

Step	Test	Test level	Reference
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Temperature rise test	See test method	7.4.12
5	Thermal cycles	15 cycles at AP	7.4.14
6a	Thermal cycles – Class I and II	50 cycles at 1.1 x DP (internal - ambient)	7.4.14
6b	Thermal cycles – Class III	150 cycles at 1.1 x DP (internal - ambient)	7.4.14
7	Insulation resistance	See test method	7.4.8
8	Helium leak test	See test method	7.4.1
9a	Thermal cycles – Class I and II	50 cycles at 1.1 x DP (ambient - internal)	7.4.14
9b	Thermal cycles – Class III	150 cycles at 1.1 x DP (ambient - internal)	7.4.14
10	Helium leak test	See test method	7.4.1
11	Contact resistance	See test method	7.4.2
12	Insulation resistance	See test method	7.4.8
13	PD test	1.73 x U_0 (10 pC)	7.4.5
14	High voltage AC test	2.5 x U_0 (1 hour)	7.4.6
15	PD test	1.73 x U_0 (10 pC)	7.4.5

7.2.5.3 Acceptance criteria

The electrical performance of the connector assembly shall remain within the specified test and design limits throughout the test sequence. Acceptance criteria defined in the referenced test procedure shall additionally be fulfilled.

7.2.6 Electrical short circuit qualification test sequence

7.2.6.1 Objective

The objective of this test sequence is to ensure that the connector assembly is capable of withstanding the maximum design short circuit current without any degradation or damage.

7.2.6.2 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2

Step	Test	Test level	Reference
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Thermal short circuit test	See test method	7.4.10
5	Dynamic short circuit test	See test method	7.4.11
6	Contact resistance	See test method	7.4.2
7	PD test	1.73 x U_0 (10 pC)	7.4.5
8	High Voltage AC test	2.5 x U_0 (1 hour)	7.4.6
9	PD test	1.73 x U_0 (10 pC)	7.4.5

7.2.6.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within specified test and design limits throughout the test sequence. Acceptance criteria defined in the referenced test procedure shall additionally be fulfilled.

7.2.7 Hyperbaric qualification test - connectors

7.2.7.1 Objective

The objective of this test sequence is to ensure the connector assembly can tolerate repetitive surface recovery cycles without degradation or damage. This test is in general applicable to both connectors and penetrators; the test may however be combined with/replaced by 7.2.8 for penetrators. The actual cable and all pressure compensating systems shall be included in the test.

7.2.7.2 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Mate / de-mate		
5	Pressure cycling (De-mated)	30 cycles to 1.1 x HP. Hold time per cycle shall be 5 minutes.	N/A
6a	De-mate/Mate – wet mateable connectors only	30 repetitions at 1.1 x HP	

Step	Test	Test level	Reference
6b	De-mate/Mate – dry mateable connectors only	10 repetitions at AP	
7	Pressure cycling (Mated)	30 cycles to 1.1 x HP Hold time per cycle shall be 5 minutes.	N/A
8	Contact resistance	See test method	7.4.2
9	Insulation resistance	See test method	7.4.8
10	PD test	1.73 x U_0 (10 pC)	7.4.5
11	High Voltage AC test	2.5 x U_0 (1 hour)	7.4.6
12	PD test	1.73 x U_0 (10 pC)	7.4.5

Note: Pressurisation and depressurisation rate should be minimum35 bar/minute.

7.2.7.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within specified test and design limits throughout the test sequence. No leakage, degradation or damages shall be observed. Acceptance criteria defined in the referenced test procedure shall additionally be fulfilled.

7.2.8 Pressure cycling test - penetrators

7.2.8.1 Objective

The objective of this test is to demonstrate that the penetrator is capable of handling varying pressure loads in the worst case operational conditions. The penetrators shall be installed at actual operational conditions (media and max/min temperature).

7.2.8.2 Sequence

The test sequence specified below shall be performed both at maximum and minimum ambient temperature, with differential pressure applied in both directions (internal-ambient and ambient-internal), in total four test sequences. This test should be conducted with the relevant cable and associated pressure compensators installed.

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Static pressure test	See test method	7.4.16

5	Pressure cycling	100 cycles to 1.1 x DP Hold time per cycle shall be 5 minutes.	N/A
6	Static pressure test	See test method	7.4.16
7	Insulation resistance	See test method	7.4.8
8	Contact resistance	See test method	7.4.2
9	PD test	1.73 x U_0 (10 pC)	7.4.5
10	High Voltage AC test	2.5 x U_0 (1 hour)	7.4.6
11	PD test	1.73 x U_0 (10 pC)	7.4.5
12	Helium leak test	See test method	7.4.1

7.2.8.3 Acceptance criteria

No leakage/no pressure drop during hold time (pressure drop shall be explainable). The connector assembly as specified above shall remain within specification and without reduction throughout the testing. No degradation or damage shall be observed. The acceptance criteria given in the referenced sections shall also be met.

7.2.9 Combined pressure and temperature cycling test - penetrators

7.2.9.1 Objective

This test is applicable to penetrators exposed to process gas/fluids in service. The objective of the test is to demonstrate that the penetrator is capable of handling varying pressure loads during varying temperature conditions.

7.2.9.2 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Static pressure test	See test method	7.4.16
5	Pressure/temperature cycling		7.4.18
6	Static pressure test	See test method	7.4.16
7	Insulation resistance	See test method	7.4.8
8	Contact resistance	See test method	7.4.2

9	PD test	1.73 x U_0 (10 pC)	7.4.5
10	High Voltage AC test	2.5 x U_0 (1 hour)	7.4.6
11	PD test	1.73 x U_0 (10 pC)	7.4.5
12	Helium leak test	See test method	7.4.1

7.2.9.3 Acceptance criteria

No leakage/no pressure drop during the cycles (pressure drop shall be explainable). The connector assembly as specified above shall remain within specification and without reduction throughout the testing. No degradation or damage shall be observed. The acceptance criteria given in the referenced sections shall also be met.

7.2.10 Rapid gas decompression test sequence

7.2.10.1 Objective

The objective is to verify that the connector assembly can withstand the specified decompression rate. This test sequence applies only to those components designed for exposure to production fluids, and shall be performed only if agreed between the manufacturer and purchaser. Detailed test conditions shall be agreed between the manufacturer and purchaser.

7.2.10.2 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0	7.4.5
4	Rapid gas decompression test – General	See test method	7.4.25
5	Rapid gas decompression test – Elastomeric materials	See test method	7.4.26
6	Contact resistance	See test method	7.4.2
7	Insulation resistance	See test method	7.4.8
8	PD test	1.73 x U_0 (10 pC)	
8	High Voltage AC test	2.5 x U_0 (1 hour)	7.4.6
9	PD test	1.73 x U_0 (10 pC)	7.4.5
10	Helium leak test	See test method	7.4.1

7.2.10.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within specified test and design limits throughout the test sequence. Acceptance criteria defined in the referenced test procedure shall additionally be fulfilled.

7.2.11 Mechanical and environmental stress test sequence

7.2.11.1 Objective

The objective of this test sequence is to ensure that the connector assembly is capable of withstanding the mechanical and environmental stresses and conditions it may experience during its design lifetime.

7.2.11.2 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Thermal shock test	See test method	7.4.9
5	Contact resistance	See test method	7.4.2
6	PD test	1.73 x U_0 (10 pC)	7.4.5
7	Bending moment and free fall tests	See test method	7.4.15
8	PD test	1.73 x U_0 (10 pC)	7.4.5
9	Vibration test	See test method	7.4.19
10	PD test	1.73 x U_0 (10 pC)	7.4.5
11	Cable Pull Test	See test method	7.4.21
12	PD test	1.73 x U_0 (10 pC)	7.4.5
13	Cleaning and spillage test	See test method	7.4.20
14	Contact resistance	See test method	7.4.2
15	Insulation resistance	See test method	7.4.8
16	PD test	1.73 x U_0 (10 pC)	7.4.5
17	High voltage AC test	2.5 x U_0 (1 hour)	7.4.6
18	PD test	1.73 x U_0 (10 pC)	7.4.5

7.2.11.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within specified test and design limits throughout the test sequence. No degradation or damages shall be observed. Acceptance criteria defined in the referenced test procedure shall additionally be fulfilled.

7.2.12 Hyperbaric long term qualification test – connectors

7.2.12.1 Objective

The objective of the tests is to ensure that the connector assembly is able to withstand life time operational conditions, without degradation or damage.

7.2.12.2 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	De-mate/Mate		
5	Long term pressure test	Long term test at HP (constant pressure) and elevated temperature.	N/A
6a	De-mate/Mate – wet mateable connectors only	30 repetitions	7.4.22
6b	De-mate/Mate – dry mateable connectors only	10 repetitions	7.4.22
7	Contact resistance	See test method	7.4.2
8	Insulation resistance	See test method	7.4.8
9	PD test	1.73 x U_0 (10 pC)	7.4.5
10	High voltage AC test	2.5 x U_0 (1 hour)	7.4.6
11	PD test	1.73 x U_0 (10 pC)	7.4.5

The elevated temperature shall primarily be determined from material limitations as defined in the material selection report. However, the design analysis results shall also be evaluated when determining the elevated temperature. The test duration and temperature shall be documented with justification that it is representative of the design life.

7.2.12.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within specified test and design limits throughout the test sequence. No degradation or damages shall be observed. Acceptance criteria defined in the referenced test procedure shall additionally be fulfilled.

7.2.13 Long term qualification test – penetrators

7.2.13.1 Objective

The objective of the test is to ensure that the connector assembly is able to withstand long term service at operational conditions, without degradation or damage. Test conditions shall be representative for the life time of the product (accelerated test).

7.2.13.2 Sequence

The test sequence specified below shall be performed with differential pressure applied in both directions (internal-ambient and ambient-internal), in total two test sequences.

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Static pressure test	See test method	7.4.16
5	Long term test at elevated temperature	Constant pressure, DP	N/A
6	Static pressure test	See test method Use 24 hours hold time in step 7 of the test procedure	7.4.16
7	Contact resistance	See test method	7.4.2
8	Insulation resistance	See test method	7.4.8
9	PD test	1.73 x U_0 (10 pC)	7.4.5
10	High voltage AC test	2.5 x U_0 (1 hour)	7.4.6
11	PD test	1.73 x U_0 (10 pC)	7.4.5

The elevated temperature and test duration shall primarily be determined from material limitations as defined in the material selection report. However, the design analysis results shall also be evaluated when determining the elevated temperature. The test duration and temperature shall be documented with justification that it is representative of the design life.

7.2.13.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within specified test and design limits throughout the test sequence. Acceptance criteria defined in the referenced test procedure shall additionally be fulfilled.

7.2.14 Inner barrier qualification test– connectors

7.2.14.1 Objective

The objective of the test is to ensure that the connector assembly is able to withstand operational conditions with the outer sealing barrier removed, without degradation or damage. The inner barrier shall be exposed to the applicable fluid or gas resulting from a removed outer barrier.

7.2.14.2 Sequence

Test sequence shall be according to 7.2.7 Hyperbaric qualification test - connectors.

7.2.14.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within specified test and design limits throughout the test sequence. Acceptance criteria defined in the referenced test sequence shall additionally be fulfilled.

7.2.15 Inner barrier qualification test sequence – penetrators

7.2.15.1 Objective

The objective of the test is to ensure that the connector assembly is able to withstand operational conditions with the outer sealing barrier removed, without degradation or damage. The inner barrier shall be exposed to the applicable fluid or gas resulting from a removed outer barrier.

7.2.15.2 Sequence

Test sequence shall be according to 7.2.8 Pressure cycling test - penetrators.

7.2.15.3 Acceptance criteria

The electrical performance and mechanical integrity of the connector assembly shall remain within specified test and design limits throughout the test sequence. No leakage, degradation or damages shall be observed. Acceptance criteria defined in the referenced test sequence shall additionally be fulfilled.

7.3 Factory acceptance testing

7.3.1 FAT test requirements

Factory acceptance testing shall be non-destructive, and not in any way compromise the integrity of the product being tested. Required test procedures, sequences and acceptance criteria are described and specified within this document.

7.3.2 FAT test sequence – connectors and penetrators

Unless otherwise agreed between the manufacturer and purchaser, electrical tests as specified in Table 5 shall be performed where "Electrical tests" are specified in the test sequence:

Table 5 – Electrical tests – FAT

Test	Reference
Contact resistance	7.4.2
Insulation resistance	7.4.8
Shell continuity test	7.4.3
Screen continuity test	7.4.4

Rate of pressure change shall be a minimum of 35 bar/min.

Acceptance criteria for FAT testing shall be as per the referenced test procedures.

Step	Test	Test level	Connectors	Penetrators	Reference
1	Helium leak test	See test method	x	x	7.4.1
2	Electrical tests	See test methods	x	x	Table 5
3	PD test	1.73 x U_0 (10 pC)	x	x	7.4.5
4	Mate/de-mate Connectors only	1 operation in air - no misalignment	x		N/A
5	Mate/de-mate Connectors only	1 operation in each extreme misalignment condition – in air	x		
6	Electrical tests	See test methods	x		Table 5
7	Submerse in environmental media	Soak for one hour	x		N/A
8	Electrical tests	See test methods	x		Table 5
9	Pressurise	To 1.1 x HP Hold time 1 hour.	x		N/A
10	Electrical tests	See test methods	x		Table 5
11	De-mate/mate Wet mate connectors only	1 operation at 1.1 x HP	x		

Step	Test	Test level	Connectors	Penetrators	Reference
12	Depressurise	To AP Hold time 1 hour	x		N/A
13	De-mate/mate Connectors only		x		
14	Electrical tests	See test methods	x		Table 5
15	Static pressure test Penetrators only	See test method		x	7.4.16
16	Contact resistance	See test method	x	x	7.4.2
17	PD test	1.73 x U_0 (10 pC)	x	x	7.4.5
18	PD test	2.5 x U_0 (200 pC)	x	x	7.4.5
19	High voltage AC test	2.5 x U_0 (30 min)	x	x	7.4.6
20	PD test	1.73 x U_0 (10 pC)	x	x	7.4.5
21	PD test	2.5 x U_0 (200 pC)	x	x	7.4.5

7.3.3 FAT Test sequence — complete jumper assemblies

The test sequence specified in this section is applicable to complete connector assemblies, including jumper assemblies. Individual component testing on each connector/penetrator shall be completed in accordance with section 7.3.2 prior to this test sequence. Leak testing of the complete jumper assembly, including hose and hose terminations, shall also be completed.

Test set-up shall allow electrical testing at the specified test pressure.

Unless otherwise agreed between manufacturer and purchaser, electrical tests as specified in Table 5 shall be performed where “Electrical tests” are specified in test sequence.

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

Rate of pressure change shall be a minimum of 35 bar/min.

Step	Test	Test level	Reference
1	Electrical tests at ambient pressure, dry	See test methods	Table 5
2	PD test at ambient pressure, dry	1.73 x U_0 (10 pC)	7.4.5
3	Submerge connector assembly and allow to soak for 15 minutes		
4	Increase pressure from ambient to 0.3 x HP Hold pressure for 10 minutes	35 bar/min	
5	Decrease pressure to ambient pressure Wait 10 minutes before next pressure cycle	35 bar/min	
6	Increase pressure from ambient to 0.7 x HP Hold pressure for 10 minutes	35 bar/min	
7	Decrease pressure to ambient pressure Wait 10 minutes before next pressure cycle	35 bar/min	
8	Increase pressure from ambient to 1.1 x HP Hold pressure for 15 minutes	35 bar/min	
9	Electrical tests at 1.1 x HP	See test methods	Table 5
10	PD test at 1.1 x HP	1.73 x U_0 (10 pC)	7.4.5
11	Decrease pressure to ambient pressure Wait 15 minutes	35 bar/min	
12	Electrical tests at ambient pressure	See test methods	Table 5
13	PD test at ambient pressure	1.73 x U_0 (10 pC)	7.4.5
14	PD test at ambient pressure	2.5 x U_0 (200 pC)	7.4.5
15	High voltage AC test	2.5 x U_0 (30 min)	7.4.6
16	PD test at ambient pressure	1.73 x U_0 (10 pC)	7.4.5
17	PD test at ambient pressure	2.5 x U_0 (200 pC)	7.4.5

Acceptance criteria for FAT testing shall be as per the referenced test procedures.

Regarding the hose pre-charge pressure measurements after hyperbaric testing, it is acknowledged that potential ambient and pressure chamber temperature fluctuations could affect this reading, however, positive pre-charge integrity must be confirmed at a level sufficient to compensate for calculated fluid loss at installation.

7.4 Test Procedures

7.4.1 Helium leak test

7.4.1.1 Objective

The objective of the helium leak test is to verify that all sealing barriers are correctly fitted and do not leak. Each of the two required barriers shall be independently tested.

7.4.1.2 Method

Helium shall be applied so that it swamps one side of the sealing barrier/termination chamber to be tested. Helium leakages shall be sensed on the other side of the sealing barrier/termination chamber with a mass spectrometer - having accuracy better than $1\ 10^{-9}$ mbar l/s. Temperature (ambient) and pressure (vacuum) shall be continuously recorded.

An outline procedure/sequence should be as follows:

- Connect the test equipment on one side of the sealing barrier/termination chamber to be tested, and let the test equipment run until the background helium level indication is stable and low enough to allow reading in the acceptance criteria range.
- Purge helium systematically at the other side of the sealing barrier/termination chamber to be tested, where it shall be assured that helium fully surrounds each seal.
- The mass spectrometer helium rate before and after each purging shall be recorded.

Note: Correct use of Helium vacuum techniques will reveal a single seal leakage almost immediately, after a short period of Helium purging (typically << 1 min.). If Helium is exposed for longer periods (typically > 5 min.), diffusion through soft materials (seals, membranes, non-metallic parts) may take place - which would then complicate the interpretation of test results. The test procedure should cater for diffusion effects, and the test equipment supply/return lines should be short – contributing to a successful test performance. When testing across a double/multi seal barrier or double/multi string welded seam, a leak indication will be delayed - and it could be very difficult to discriminate a leak from diffusion.

If use of Helium vacuum techniques are not possible due to design, alternative helium leak test methods may be applied further to documented equivalence with relevant recognised international standards.

7.4.1.3 Acceptance Criteria

The reading shall not increase with more than $5\ 10^{-8}$ mbar l/s during purging with helium.

7.4.1.4 Documentation

A detailed test procedure shall be provided, describing how each barrier shall be tested. The procedure shall be supported with drawings defining each sealing barrier.

7.4.2 Contact Resistance Test

7.4.2.1 Objective

The objective of the test is to determine the resistance of the connector assembly.

7.4.2.2 Method

The contact resistance shall be measured at each contact interface during the assembly. The resulting total resistance (cable termination to cable termination) shall also be measured – for all connector assemblies. The values measured during the prototype manufacturing acceptance tests and the initial test after manufacturing shall be used as references for all subsequent tests. The CR test shall be performed in accordance with IEC 61238-1. The current used shall be a minimum of 10% of the rated current, however, not lower than 10 A. Any subsequent increase in contact resistance shall be explained.

The contact resistance shall be measured and documented at each contact interface together with the total resistance of the connector assembly (cable termination to cable termination).

7.4.2.3 Acceptance Criteria

- Individual contact interface: Maximum 20 mV (rms) voltage drop across each contact interface at rated current (extrapolation acceptable).
- Resulting total resistance (cable termination to cable termination): Maximum ± 10 % change from prototype assembly

7.4.3 Shell continuity test

7.4.3.1 Objective

The objective of the test is to determine the resistance between connector assembly metallic housings, intended to provide electrical continuity when mated.

7.4.3.2 Method

Testing shall be performed in accordance with IEC 61238-1.

7.4.3.3 Acceptance Criteria

Maximum 100 mV voltage drop across each contacting interface with applied current of 10 A.

7.4.4 Screen continuity test

7.4.4.1 Objective

The objective of the test is to determine the resistance between the power cable screen and the connector/penetrator assembly, intended to provide electrical continuity (defined path for charging/fault currents).

7.4.4.2 Method

Testing shall be conducted in accordance with IEC 61238-1.

Two types of measurement shall be made:

- Cable screen to connector/penetrator;
- Cable screen to cable screen, either side of the mated connector.

7.4.4.3 Acceptance Criteria

Maximum 20 mV voltage drop across each contacting interface with applied current of 20A.

7.4.5 Partial discharge test

7.4.5.1 Objective

The objective of the test is to determine that the PD level for the connector assembly is below the acceptance criteria, and hence verify the insulation quality of the connector assembly.

7.4.5.2 Method

The test shall be performed on each circuit with the voltage applied between the cable conductor (pin) and the earthed metallic screen and housing, with all other circuits earthed. This procedure shall be repeated on each circuit. The partial discharge test shall be performed in accordance with the procedures outlined in IEEE Standard 386 and IEC 60270 and IEC 60885-2.

PD test @ 1.73 U_0: Voltage shall be raised gradually to and held, for not more than 1 min. at $2xU_0$ before the voltage is lowered to $1.73xU_0$ and PD measurement is performed.

PD test @ $2.5xU_0$: Voltage is gradually raised to $2.5xU_0$ where PD measurement is performed.

7.4.5.3 Acceptance Criteria

PD level < 10 pC @ 1.73 x U_0

PD level < 200 pC @ 2.50 x U_0

7.4.6 High voltage AC test

7.4.6.1 Objective

The objective of the test is to verify the insulation level of the connector assembly. The test shall hence verify the electrical withstand level of the connector assembly and prove the ability to withstand the electrical stresses it is exposed to.

7.4.6.2 Method

The high voltage test shall be performed in accordance with IEC 60060-1 and 61442 and IEEE Std 4.

The test shall be performed on each circuit with the voltage applied between the cable conductor (pin) and the earthed metallic screen and housing, with all other circuits earthed. These procedures shall be repeated on each test circuit.

Test voltage and duration shall be as specified in the various test sequences in this document.

7.4.6.3 Acceptance criteria

No breakdown of insulation or flashover shall occur.

7.4.7 Impulse Withstand Voltage Test

A standard lightning-impulse (1.2/50) withstand voltage (BIL) test, in accordance with IEC 60060-1 and IEEE 386 requirements, shall be conducted on connectors and penetrators with $U_m \geq 7.2$ kV. Unless otherwise agreed between the manufacturer and purchaser, impulse voltage peak levels shall be according to
Table 6.

Table 6 – Impulse Withstand voltage test levels

U_m (kV)	3.6	7.2	12	17.5	24	36
$U_{peak,impulse}$ (kV)	20	40	60	75	95	145

7.4.8 Insulation resistance test

7.4.8.1 Objective

The objective of the test is to measure the Insulation Resistance of the connector assembly.

7.4.8.2 Method

The insulation resistance against earth shall be measured on each electrical contact individually. All other electrical contacts and conductive parts shall be earthed. The insulation resistance shall be recorded after 1 and 10 minutes. Test voltages are set out below.

Table 7 – Insulation Resistance voltage test levels

Max system voltage U_m	Minimum test voltage
$U_m < 7200$ V	2500 V DC
$U_m \geq 7200$ V	5000 V DC

7.4.8.3 Acceptance Criteria

Acceptance criteria:

- IR > 100 GΩ (stable reading) after 10 minutes for un-terminated connectors/ penetrators.
- IR > 20 GΩ (stable reading) after 10 minutes for terminated connectors/penetrators.

7.4.9 Thermal Shock test

7.4.9.1 Objective

The objective of the test is to verify that the connector assembly is able to withstand thermal shocks. These may result from deck storage, and insertion into sea water.

7.4.9.2 Method

The connector assembly shall be tested in its unmated condition, at atmospheric pressure. Three high temperature tests and three low temperature tests shall be conducted.

High Temperature: The temperature shall be raised to 60˚C and maintained for a period of four hours. The connector assembly shall then rapidly be cooled by immersion in water, which shall have a temperature between 0 and 5 ˚C. Water volume shall be sufficient to ensure a rapid cooling. Allow the connector assembly to return to ambient room temperature.

Low Temperature: The temperature of each assembly shall be lowered to -25 ˚C, or lower for intended arctic conditions, and maintained for a period of four hours. The connector assembly shall then be rapidly heated by immersion in water, which shall have a temperature between 0 and 5 ˚C. Water volume shall be sufficient to ensure rapid heating. The connector assembly shall be allowed to return to ambient room temperature.

7.4.10 Thermal short circuit tests

7.4.10.1 Objective

The objective of the test is to ensure that the connector assembly is able to withstand the rated thermal short-time current (I_{th}) which the connector assembly is designed to withstand. There shall be no degradation of conductor contacts or insulation materials. Reference IEC 61442 sections 11 & 12.

7.4.10.2 Method

The test method shall be as in IEC 61442 for Thermal short-circuit test. One end shall be connected to the test generator and the other end to a short circuiting bar. Maximum short circuit temperature for the materials shall be defined.

The connector assembly shall be subjected to two short circuits at the maximum permissible short-circuit temperature of the connector/penetrator and subsequent connected cable. Temperature rise shall be within a period of 5 seconds. The second short circuit shall be applied when the assembly has cooled to within 10 °C of its temperature prior to the first test.

7.4.10.3 Acceptance Criteria

There shall be no degradation of conductor contacts or insulation materials.

7.4.11 Dynamic short circuit tests

7.4.11.1 Objective

The objective of the test is to ensure that the connector assembly is able to withstand the rated dynamic short circuit current without degradation or damage due to mechanical forces.

The test is project specific and only relevant if the peak current is >80kA (single phase) and 63kA (three phase)."

7.4.11.2 Method

The test requires a three phase assembly as installed subsea, to be regarded as a valid test.

The test methods shall be as specified in IEC 61442. One end shall be connected to the test generator and the other end to a short circuiting bar. The waveform shall be recorded.

The connector assembly shall be subjected to two short circuits.

7.4.11.3 Acceptance Criteria

There shall be no degradation of conductor contacts or insulation materials.

7.4.12 Temperature rise test

7.4.12.1 Objective

A temperature rise test at rated current and frequency shall be performed before thermal cycling tests commence. The objective is to locate and determine the highest local temperatures within the connector assembly and to determine the current to be used for the heating cycle test.

7.4.12.2 Method

Temperature sensors shall be attached to various locations on the connector assembly to enable monitoring of temperatures. Temperature sensors shall as a minimum be located as follows:

- Ambient temperature
- At the point where the highest local temperature is expected
- At cable terminations
- At the anticipated hottest spot on external surfaces of each accessible material type
- As close as possible to the contact surface between male and female

The current shall be maintained until thermal stability is achieved. This is defined as when three consecutive measurements of temperature rise, taken at 5 min intervals, do not differ by more than 2 K. The current shall be maintained for a period of 1 h after stability is reached. The current shall then be increased to reach a stable temperature 5-10 °C above steady state temperature at rated current. The temperature rise test shall be performed

- In air at ambient temperature and
- In the relevant operational environment (fluid, gas..) at the maximum ambient temperature. The current determined from this test shall be used as basis for the thermal cycles test, ref 7.4.14.

Electronic data storage or a chart recorder with a suitable number of channels shall be used to record temperature. Actual current values and voltage drop shall be recorded in parallel with each temperature measurement. All findings shall be recorded within the final qualification report.

7.4.13 Extended temperature rise test

7.4.13.1 Objective

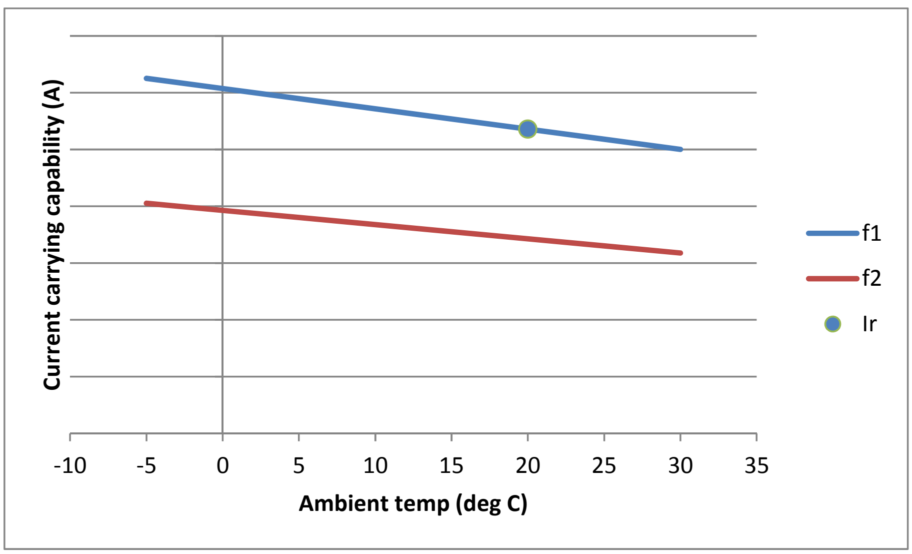
The objective of this test is to characterise the connector assembly with respect to current loading capability at various ambient temperature and frequency conditions. The test represents an extension of the temperature rise test in 7.4.12 and can be performed as part of this. The test is optional and shall only be performed if agreed between the manufacturer and purchaser.

7.4.13.2 Method

The extended temperature rise test shall be performed at conditions as agreed between the manufacturer and purchaser. Two possible methods for characterization are described below:

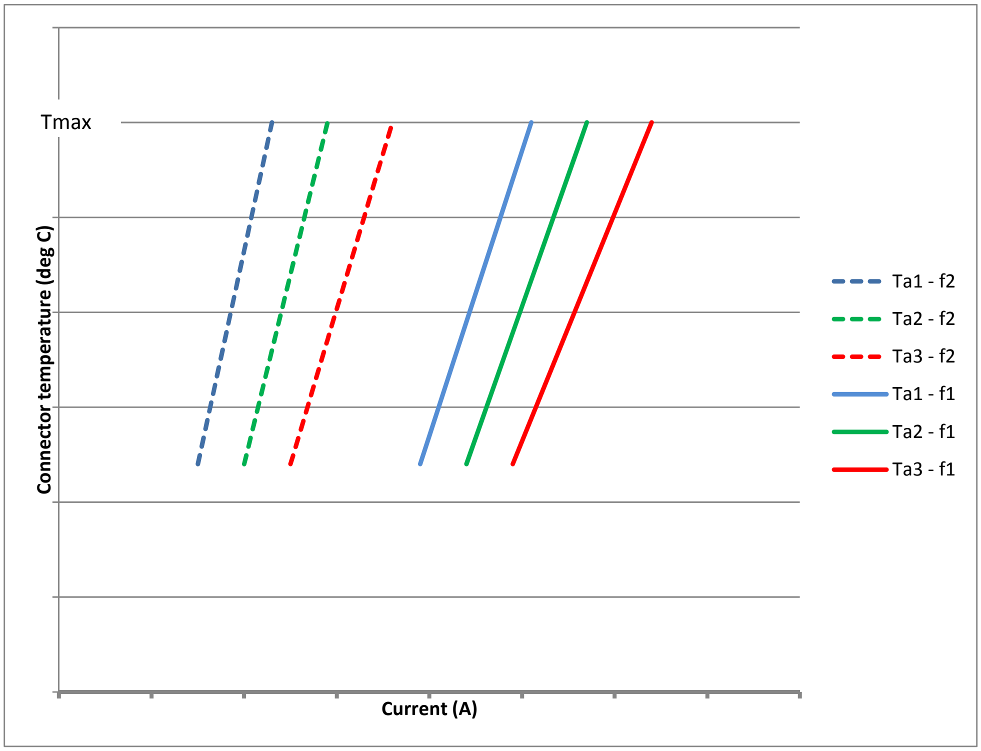
Method 1:
Current carrying capability as a function of ambient temperature – given connector assembly operates at maximum allowed operating temperature. Results/graphs to be established for agreed frequencies. This is illustrated in figure 1, where f_1 and f_2 are two different frequencies, I_r is the rated current.

Figure 1 – typical extended temperature test results, method 1



Method 2 (more comprehensive):
Connector assembly operating temperature as a function of operating current. Results/graphs to be established for agreed ambient temperatures and frequencies. This is illustrated in Figure 2, where T_{a1}, T_{a2} and T_{a3} are three different ambient temperatures, f_1 and f_2 are two different frequencies, and T_{max} is the maximum allowable operating temperature in the connector (as specified by the manufacturer).

Figure 2 – typical extended temperature test results, method 2



7.4.14 Thermal cycling

7.4.14.1 Objective

The objective of the test is to verify the ability of the connector assembly to handle load changes.

7.4.14.2 Method

The assembly shall be installed in conditions corresponding to the actual ambient media and the worst case operational thermal conditions.

The connector assembly shall be heated by passing the current (as determined by the temperature rise test in operational conditions, ref 7.4.12) through the conductor. A voltage of 2.5 x Uo shall be applied during the test. When the conductor temperature has reached a stable value, 5-10 °C above the temperature the connector assembly will have when running at maximum rated operational current; it shall be kept at this temperature for at least 2 hours. The connector assembly shall then be cooled down to maximum 10 °C above ambient temperature. The total duration of each thermal cycle shall be a minimum of 8 hours. Reference is made to IEC 60502-4 and IEC 61442 (heating cycle curve).

7.4.14.3 Acceptance Criteria

The connector assembly electrical performance shall remain within specification and without reduction throughout testing. Acceptance criteria given in subsequent sections shall be met.

7.4.15 Bending moment and free fall tests

7.4.15.1 Scope

The objective of the impact shock test is to verify that the connector assembly can withstand an accidental mechanical load, without degradation or damage.

7.4.15.2 Method

- A bending moment of at least 5 kNm shall be applied to the connector assembly in mated condition. The full bending moment shall be applied within one second. The test shall be repeated in six directions along three mutually perpendicular axis, minimum three times in each direction.
- A free fall test shall be performed in accordance with IEC 60721-3-2 Table 5 Class 2M2. The floor shall be hard, typically as for a transport compartment. For connectors, the test shall be performed with unmated connector halves. The test shall be performed in worst case conditions – details to be agreed between manufacturer and purchaser.

7.4.15.3 Acceptance criteria

The connector assembly electrical performance shall remain unchanged without reduction throughout testing; Acceptance criteria for the subsequent electrical verification tests shall be met.

7.4.16 Static pressure test - penetrators

7.4.16.1 Objective

The objective of this test is to ensure that penetrator assemblies function correctly at operational conditions.

7.4.16.2 Method

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	Submerse in relevant environmental media	Soak for 1 hour	N/A
4	Insulation resistance	See test method	7.4.8
5	Pressurise	From ambient to 1.5 x DP Hold time 3 minutes	N/A

Step	Test	Test level	Reference
6	Depressurise	To ambient.	N/A
7	Pressurise	From ambient to 1.5 x DP Hold time 15 minutes	N/A
8	Insulation resistance	See test method Undertake test after 1 minute pressurised hold time	7.4.8
9	Depressurise	To ambient.	N/A
10	Insulation resistance	See test method Undertake test 1 minute after depressurising Repeat test 1 hour after depressurising	7.4.8
11	Helium leak test	See test method	7.4.1

The test shall be performed for differential pressure in both directions (internal –ambient, ambient-internal). Pressurisation and de-pressurisation rate should be a minimum of 35 bar/min.

7.4.16.3 Acceptance Criteria

No leakage/no pressure drop (any drop in pressure shall be explainable). Acceptance criteria given in referenced sections shall be fulfilled.

7.4.17 Extended static pressure test – penetrators

This test shall be performed if agreed between purchaser and manufacturer. When to perform the test in the test sequence is also subject to agreement between purchaser and manufacturer.

The test procedure shall be as specified in 7.4.16, at the following pressure and temperature combinations:

- 1.5 x DP at maximum ambient temperature
- 2.5 x DP at room temperature

7.4.18 Combined pressure and temperature cycling test procedure - penetrators

The test shall be performed in accordance with ANSI/API Spec 6A - Specification for Wellhead and Christmas Tree Equipment, Annex F, section F.1.11.3. Test pressure to be applied shall be 1.1 x DP.

7.4.19 Vibration test

7.4.19.1 Objective

The objective of the test is to verify that the connector assembly is able to withstand vibrations, without degradation or damage.

7.4.19.2 Method

As a minimum, vibration tests shall be based on all vibration sources acting on the connector assembly, including relevant interfaces which may cause amplification or dampening, and where a safety margin ≥ 5 shall be catered for. The tests shall be performed such that amplifications built-up over time are registered, where gravity and mounting position shall also be catered for.

The outline test specification is as follows:

1. Sweep test of 25 mm/s (rms) in the frequency range 5 – 190 Hz, in all directions (X-Y-Z). The 25 mm/s is based on worst case level vibrations (normally 5 mm/s) and that a safety margin of 5 normally is used for accelerated vibration testing.
2. Sweep test of 3 g acceleration in the frequency range 190 – 1000 Hz.
3. Endurance testing to prove calculated fatigue properties, where the test procedure shall reflect design service life. The endurance test shall be performed at the worst case mechanical frequency identified during the sweep tests in point 1 and 2 above. Number of cycles shall be minimum 10^7. A fatigue level safety margin of 2.5 shall be verified.

For the sweep tests, the sweep rate shall be a maximum of one octave per minute. The sweep rate shall be low enough to allow any resonance to build up any amplitude.

7.4.19.3 Acceptance criteria

1. No resonances with amplification > 10 in the frequency range 5 - 1000 Hz.
2. No fractures or visible signs of fatigue induced cracks.
3. No signs of fretting, deterioration of seals or seal leakages.
4. No reduction in pretension of mechanical parts.

7.4.20 Cleaning and spillage test

7.4.20.1 Objective

The objective of the test is to verify that cleaning of marine growth, calcium or accidental spillage of chemicals can be performed topsides or subsea, without degradation or damage. The ability to withstand short time exposure to the applicable fluids shall be demonstrated, and maximum exposure limitations shall be specified.

7.4.20.2 Method

The test shall be performed in dry conditions. Submerge the mated connector assembly in a 50% citric acid solution for one hour. Wash the connector assembly with a metal brush with vigour as expected for a purpose built subsea ROV washing and brushing tool.

Typical fluids the mated or unmated connector assembly may be exposed to are; hydraulic fluids (Brayco, Oceanic or Transaqua), glycol, methanol or diesel. It shall be documented if there is any need to clean these fluids from the connector assembly, and/or specify exposure limitations and cleaning methods/tools (both topsides and subsea cleaning methods).

7.4.21 Cable Pull test

7.4.21.1 Objective

The purpose of the pull test is to ensure acceptable mechanical strength for the connector assembly including connections to the conductors of power cables.

7.4.21.2 Method

Testing shall be carried out as outlined in IEC 61238-1, section 7, for through connectors. The tensile force applied (in Newton) shall be a minimum of 60 times the conductor cross section area (mm^2 Cu).

7.4.21.3 Acceptance criteria

No slipping shall occur during the last minute of the test.

7.4.22 Mate/de-mate operation test

7.4.22.1 Objective

The objective is to simulate operational functionality without hindrance, misalignment or damage. Correct operation shall be demonstrated in the worst case conditions, (axial, radial, rotational and angular misalignment).

7.4.22.2 Method

The mate and de-mate procedure shall be undertaken as advised by the manufacturer within the operations and maintenance manual. This test may be performed as part of one of the tests specifying a number of mate/de-mate operations, or as a separate test. A minimum of 3 mate/de-mate operations at each extreme misalignment condition shall be performed.

- Correct operation of the connector assembly at specified worst case angles/speed/misalignment during mating and de-mating shall be demonstrated, where the maximum misalignment tolerances, speed and mating forces are used. All reasonable attempts to mate and lock the connector assembly with various worst case angles/speed/misalignment shall be performed.
- Correct operation of the locking mechanism shall be demonstrated. The locking mechanism shall be checked for correct operation/position both in locked and unlocked positions.
- This test shall verify that applicable forces needed to mate/de-mate and lock/unlock the connector assembly in all applicable conditions are within the defined envelope for each applicable force. The needed forces shall be thoroughly tested and reported. This applies to rotational and axial alignment tolerances and indications for both mating and locking.

7.4.22.3 Acceptance criteria

Operational functionality shall be maintained without hindrance, misaligned connection or damage.

7.4.23 Dismantling and examination

7.4.23.1 Objective

The objective of dismantling and examining the connector assembly is to assess whether or not any damage or degradation has occurred as a result of the qualification process, and if so why.

7.4.23.2 Method

The assembly shall be assessed as a whole initially. Checks shall be made for any signs of damage, wear, accumulation of deposits, solids and such.

The assembly shall then be systematically dismantled. Components shall be assessed for damage, wear, contamination and any deposits. Dielectric fluids shall be sampled and checked for contamination. Materials shall be assessed for property changes, and pictures taken for documentation.

7.4.23.3 Acceptance criteria

- No damage or carbon deposits shall be observed. Wear shall be evaluated for acceptability.
- Accumulation of solids shall not interfere with the mating or locking operation of the connector assembly.
- Water, salt and silt content of fluid filled enclosures should be quantified and the supplier shall assess the impact of this upon the operation of the connector assembly over its lifetime.
- Insulation resistance and dielectric strength of dielectric fluid samples should be quantified. Any change in material properties shall not interfere with the operation of the connector assembly throughout its design service life.

7.4.24 High voltage breakdown test

7.4.24.1 Objective

This test is to verify the connector assembly voltage limits.

7.4.24.2 Method

Each half of the connector assembly shall be connected to a specimen of the design cable. The connector assembly shall be mated in air at AP.

The test shall be performed on each circuit with the voltage applied between the cable conductor (pin) and the earthed metallic screen and housing, with all other circuits earthed. This procedure shall be repeated on each test circuit.

The test shall be performed as a 60 sec step-by-step test in accordance with IEC 60243-1 section 10.4. Start voltage shall be 4 U_0. Voltage shall be increased until 8 U_0 or flash over occurs.

7.4.24.3 Acceptance criteria

No flash over shall occur at voltages ≤ 5 U_0.

7.4.25 Rapid gas decompression (RGD) test - General

7.4.25.1 Objective

Connector assemblies or parts of connector assemblies that will be in contact with production fluids shall be tested for rapid gas decompression. The objective is to verify that the connector assembly can withstand the specified decompression rate.

7.4.25.2 Method

The vessel should be pressurised with 145 psi (10 bar) using the test gas mixture at ambient temperature.

Temperature shall then be brought to the max temperature, as given by the connector assembly Class, and kept constant throughout the test. After the test temperature has been reached and stabilised, the pressure of the vessel shall be slowly increased to 1000 psi and held for 15 minutes.

The pressure shall then be slowly raised to 5000 psi and held for 72 hours. Once 72 hours has been completed a rapid de-compression shall be done. Pressure shall be decreased at a rate of 1000 psi per minute from 5000 psi until 500 psi is achieved. The pressure shall then be held at 500 psi for 2 hours. After the 2 hours the pressure shall slowly be increased to 1000 psi and held for 15 minutes.

The pressure shall then be slowly be increased to 5000 psi and held for 23 hours, at which point the connector should go through a rapid decompression again. The total amount of RGD cycles shall be 10.

Note: To perform this test the gas must be in contact with the back end of the connector.

7.4.25.3 Acceptance criteria

No leakage or unexplainable pressure drop shall be witnessed. There shall be no damage to the connector assembly.

7.4.26 Rapid gas decompression (RGD) test - Elastomeric Materials

7.4.26.1 Objective

Connector assemblies or parts of connector assemblies that will be in contact with production fluids shall be tested for rapid gas decompression. The objective is to verify that the elastomeric materials in the connector assembly can withstand the effect of rapid depressurisation after periods at elevated temperature and high pressure in a gaseous environment.

7.4.26.2 Method

Testing shall be carried out as outlined in the NORSOK Standard M-710, Annex B.

For compliance with this standard the test pressure shall reflect the rated pressure of the connector assembly.

7.4.26.3 Acceptance criteria

Acceptance criteria shall be in accordance with NORSOK Standard M710, B4.

7.4.27 Material testing

7.4.27.1 General test requirements

Qualification testing of new materials, new combination of materials or bonding between materials shall be performed. New is defined as a new material grade or materials not used in similar equipment, application and/or environment. The qualification programme and acceptance criteria shall be presented for acceptance prior to testing. This qualification testing also covers polymeric materials. A change in polymer material or in seal design shall require a new qualification test.

NORSOK standard M-001 should be used as a reference standard for materials selection and qualification.

7.4.27.2 Polymeric materials test requirements

The following requirements are applicable to polymeric materials:

- Compatibility shall be documented according to those requirements and the test methodology given in NORSOK standard M-710, Qualification of non-metallic sealing materials and manufacturers.
- Testing of polymeric materials shall also include sealability testing in relevant fluids or gas. Testing of this kind should be done in the actual seal/gland geometry and size, to ensure that sealing is adequate for the required functionality.
- Aging tests of elastomeric and thermoplastic materials shall be performed in accordance with NORSOK Standard M-710 (Annex A and C).
- For insulation materials, electrical properties shall be verified also after ageing tests.
- New non-metallic sealing and barrier materials, new combination of materials or bonding between materials shall be tested and qualified to prove the ability to withstand the thermal, electrical and mechanical stresses it may be exposed to. The test programme should typically include, but not be limited to, the following:
    - Compatibility tests
    - Sealing test
    - Disc bursting tests (for insert moulding materials, e.g. epoxy)
    - Mandrel test for boot seals. The mandrel test shall be performed at the same test conditions as the general ageing test (temperature, fluid, duration etc.)
    - Bonding tests

    - RGD (as relevant)
- For non-metallic materials, the compatibility test programme and acceptance criteria shall, in general, be based on NORSOK standard M-710. All acceptance criteria shall be defined prior to the commencement of testing, be based on operational knowledge of the equipment, and shall be agreed between all parties prior to testing taking place.

Testing performed to other standards than mentioned above may be acceptable, based on comparative qualification between the applicable standards. Due to material selection it may be appropriate to perform testing to other standards.

8 HOSE AND HOSE TERMINATION QUALIFICATION TESTING

8.1 Introduction

The purpose of this section is to define qualification testing on a hose and its associated termination as a stand-alone item independent of the connector/penetrator qualification programs. Unless otherwise specified, the cable is not included in these tests.

Table 8 – Hose qualification test sequence

Summary of hose and hose termination qualification tests		
Test Type	**Qualification Test**	**Section**
Material tests	Material qualification tests	7.4.27
Environmental Stress Tests	Hose Absorption/Compensation	8.2
	Ozone Resistance	8.3
	Ultraviolet Resistance	8.4
	Thermal Shock	8.5
Destructive Testing	Tensile Failure	8.6.1
	Burst Pressure	8.6.2
	Crush Resistance	8.6.3
	Outer Sheath Abrasion	8.6.4
	Hose Kink Testing	8.6.5

8.2 Absorption/Compensation test

8.2.1 Applicability

Qualification

8.2.2 Objective

The objective of this test is to determine the compensation and ageing characteristics of a conduit hose filled with insulating oil and immersed in sea water at hydrostatic operating pressure. Ageing is accelerated using high temperature.

8.2.3 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 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. For sea water applications, the test parameters shall be:

Vessel fluid:	Sea water
Vessel fluid temperature:	55 °C
Test pressure:	1.0 x HP

For applications in other fluids or at other temperatures, the assembly shall be tested in the relevant fluid at the worst case conditions; in this case the test parameters shall be agreed between the manufacturer and purchaser.

At the end of the test period allow the hose to return to ambient room temperature, release the vessel 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 dielectric strength of the oil shall be recorded prior to and after the test.

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

- Vessel pressure
- Internal hose pressure
- Vessel temperature

Electronic data storage or a chart recorder with a suitable number of channels is 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.

8.2.4 Acceptance criteria

- The hose shall be free from damage or defects. All observations shall be documented within the qualification report.
- The dielectric strength of the compensating fluid within the hose shall remain unchanged to denote no water egress.
- A net positive pressure is maintained within the hose throughout the test duration.

8.3 Ozone resistance

8.3.1 Applicability

Qualification

8.3.2 Objective

The objective of this test is to verify hose resistance to damage from the ozone.

8.3.3 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 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 test shall be performed in two steps:

1. The assembly shall be placed within an ozone test chamber and the temperature increased to 40 ^{o}C to monitor the hose pressure and chamber temperature. Maintain the assembly at stable conditions for a minimum of 2 hours.
2. Expose the assembly to 50 pphm (parts per hundred million) ozone concentration for a minimum duration of 72 hours at 40 ^{o}C ambient temperature. The hose pressure shall be monitored at the start and finish of the test and the chamber temperature shall be monitored during the test.

8.3.4 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 of the 72 hours test in step 2 above. All deviations shall be explained within the qualification report.

8.4 Ultraviolet resistance

8.4.1 Applicability

Qualification

8.4.2 Objective

The objective of this test is to verify hose resistance to damage from ultraviolet light.

8.4.3 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 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 test shall be performed in two steps:

1. The assembly shall be placed within an UV test chamber and the temperature increased to 70 ^{o}C. Monitor the hose pressure and chamber temperature. Maintain the assembly at stable conditions for a minimum of 2 hours.
2. Exposed the assembly 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 temperature. The hose pressure shall be monitored at the start and finish of the test and chamber temperature shall be monitored during the test.

8.4.4 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.

8.5 Thermal shock test

8.5.1 Applicability

Qualification

8.5.2 Objective

The objective of this test is to verify that thermal shock produces have no detrimental effects on the hose assembly.

8.5.3 Method

A hose assembly consisting of at least a 2 m 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 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 shall be performed at atmospheric pressure.

8.5.3.1 High temperature

The temperature shall be raised to 60 °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 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.

8.5.3.2 Low temperature

The hose assembly temperature shall be lowered to -25 °C and maintained for a 4 hour period.

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

8.5.4 Acceptance criteria

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

8.6 Destructive testing

8.6.1 Tensile failure

8.6.1.1 Applicability

This test shall be performed both as a qualification test and a batch test on random samples.

8.6.1.2 Objective

The objective of this test is to establish/verify the failure load of the hose and or associated hose fittings.

8.6.1.3 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 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.

8.6.1.4 Acceptance criteria

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

8.6.2 Burst pressure

8.6.2.1 Applicability

This test shall be performed both as a qualification test and as a batch test on random samples.

8.6.2.2 Objective

The objective of this test is to establish/verify the pressure containment performance of hose and associated hose fittings.

8.6.2.3 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.

8.6.2.4 Acceptance criteria

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

8.6.3 Crush resistance

8.6.3.1 Applicability

Qualification

8.6.3.2 Objective

The objective of this test is 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.

8.6.3.3 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 the hose.

8.6.3.4 Acceptance criteria

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

8.6.4 Outer sheath abrasion resistance

8.6.4.1 Applicability

Qualification.

8.6.4.2 Objective

The objective of this test is to establish the abrasion resistance of the hose assembly to ensure that it is sufficiently durable for site handling. The test shall be performed in accordance with ISO 6945.

8.6.5 Hose kink test

8.6.5.1 Applicability

Qualification.

8.6.5.2 Objective

The objective of this test is to establish the bend radius at which the oil filled hose collapses and to ascertain if the hose recovers after such an incident.

8.6.5.3 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 specified internal pressure. The hose termination fittings shall be as per the type used in jumper assemblies. The hose shall then be 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.

8.6.5.4 Acceptance criteria

- The hose assembly will be considered acceptable if no visible damage is apparent and the hose returns to its original form.
- The radius at which the hose collapses shall be equal to or less than 6 x the hose outside diameter with an acceptance criteria that it is less than the stated Minimum Bend Radius of the hose.

9 JUMPER ASSEMBLY QUALIFICATION TESTING

9.1 Introduction

The objective of these tests is to verify that the completed jumper assembly comprising of connectors, hose, hose termination fittings and electrical cables perform as intended when integrated together.

All jumper testing shall be performed with a 20m jumper assembly terminated at both ends with connectors and oil filled to the 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. In this case, the manufacturer and purchaser shall agree upon additional testing that may be required.

An overview of the test sequence is shown in Table 9.

Table 9 – Jumper assembly qualification test sequence

Jumper assembly qualification testing		
Test Type	**Qualification Test**	**Section**
Material test	Material qualification tests	7.4.27
	Electrical and thermal qualification - jumpers	9.2
	Oscillating Jumper Test	9.3
	Jumper Pull Test	9.4
	Drop Test	9.5
	Jumper Handling Simulation Test	9.6
	Simulated Deployment Test	9.7

9.2 Electrical and thermal qualification test – jumper assemblies

The scope of this test is to ensure that the complete assembly can effectively deal with load changes, both at and without hyperbaric pressure. Information about capability for operation in air will also be determined. This test may be combined with thermal qualification tests for connectors and/or penetrators (sections 7.2.4 and 7.2.5), subject to agreement between the manufacturer and purchaser.

9.2.1.1 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Temperature rise test	See test method	7.4.12
5	Thermal cycles	15 cycles at AP	7.4.14
6a	Thermal cycles – Class I and II	50 cycles at 1.1 x HP	7.4.14
6b	Thermal cycles – Class III	300 cycles at 1.1 x HP	7.4.14
7	Contact resistance	See test method	7.4.2
8	Insulation resistance	See test method	7.4.8
9	PD test	1.73 x U_0 (10 pC)	7.4.5
10	High voltage AC test	2.5 x U_0 (1 hour)	7.4.6
11	PD test	1.73 x U_0 (10 pC)	7.4.5

9.2.1.2 Acceptance criteria

The electrical performance of the assembly shall remain within specified design limits throughout the test sequence. Acceptance criteria defined in the referenced test procedure shall also be fulfilled.

9.3 Oscillating jumper test

9.3.1 Objective

The objective of this test is to verify that the complete jumper assembly is sufficiently durable.

9.3.2 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Oscillating jumper test	See below	
6	Contact resistance	See test method	7.4.2
7	PD test	1.73 x U_0 (10 pC)	7.4.5

Step	Test	Test level	Reference
8	High Voltage AC test	2.5 x U_0 (1 hour)	7.4.6
9	PD test	1.73 x U_0 (10 pC)	7.4.5

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 resistance and contact resistance should be monitored regularly.

9.3.3 Acceptance criteria

- No cable damage shall be observed.
- Acceptance criteria for the specified electrical verification tests shall be fulfilled.

9.4 Jumper pull test

9.4.1 Objective

The objective of this test is 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 stated working maximum.

9.4.2 Sequence

Step	Test	Test level	Reference
1	Measure jumper length		
2	Contact resistance	See test method	7.4.2
3	Insulation resistance	See test method	7.4.8
4	PD test	1.73 x U_0 (10 pC)	7.4.5
5	Jumper pull test	See below	
6	Contact resistance	See test method	7.4.2
7	PD test	1.73 x U_0 (10 pC)	7.4.5
8	High Voltage AC test	2.5 x U_0 (1 hour)	7.4.6
9	PD test	1.73 x U_0 (10 pC)	7.4.5

Step	Test	Test level	Reference
10	Measure jumper length		

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

9.4.3 Acceptance criteria

- No damage shall be observed.
- Acceptance criteria for the specified electrical verification tests shall be fulfilled.
- The jumper shall return to the original length (pre pull test) after a sufficient relaxation period.

9.5 Drop test

9.5.1 Objective

The objective of this test is to verify that the jumper assembly is sufficiently rugged to withstand rough handling and the loads which may be generated in an accidental drop.

9.5.2 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Drop test	See below	
5	Contact resistance	See test method	7.4.2
6	PD test	1.73 x U_0 (10 pC)	7.4.5
7	High Voltage AC test	2.5 x U_0 (1 hour)	7.4.6
8	PD test	1.73 x U_0 (10 pC)	7.4.5

Each end of the jumper assembly shall be subject to a free fall test in accordance with IEC 60721-3-2 Table 5 Class 2M2. The floor shall be hard, typically as for a transport compartment. Protection caps shall be assembled, as required.

9.5.3 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.
- Acceptance criteria for the specified electrical verification tests shall be fulfilled.

9.6 Jumper handling simulation test

9.6.1 Objective

The objective of this test is to verify that the assembled connector and associated jumper assembly is sufficiently designed to withstand normal handling loads during workshop handling and installation.

9.6.2 Sequence

Step	Test	Test level	Reference
1	Contact resistance	See test method	7.4.2
2	Insulation resistance	See test method	7.4.8
3	PD test	1.73 x U_0 (10 pC)	7.4.5
4	Jumper handling test	See below	
5	Contact resistance	See test method	7.4.2
6	PD test	1.73 x U_0 (10 pC)	7.4.5
7	High Voltage AC test	2.5 x U_0 (1 hour)	7.4.6
8	PD test	1.73 x U_0 (10 pC)	7.4.5

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.

9.6.3 Acceptance criteria

- No damage shall be observed on either half of the connectors.
- Acceptance criteria for the specified electrical verification tests shall be fulfilled.

9.7 Jumper simulated deployment testing

9.7.1 Objective

The objective of this test is to simulate deployment of the jumper assembly and verify that cable management allows sufficient free movement of cables to accommodate changes due to expansion and contraction of the jumper during pressure changes.

9.7.2 Sequence

Prior to performing the hyperbaric testing of the jumper, the 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

Step	**Test**	**Test level**	**Reference**
1	Contact resistance, AP	See test method	7.4.2
2	Insulation resistance, AP	See test method	7.4.8
3	PD test, AP	1.73 x U_0 (10 pC)	7.4.5
4	Measure hose pre-charge pressure		
5	Submerse in environmental media, AP	Soak for one hour	
6	Increase pressure from AP to 1.0 x HP	Rate: app. 35 bar/min	
7	Allow to soak for 1 hour at 1.0 x HP		
8	Contact resistance	See test method	7.4.2
9	Insulation resistance	See test method	7.4.8
10	Decrease pressure from 1.0 x HP to AP	Rate: app. 35 bar/min	
11	Allow to soak for 1 hour at AP		
12	Contact resistance	See test method	7.4.2
13	Insulation resistance	See test method	7.4.8
14	Repeat steps 6-13 a further 4 times		
15	PD test	1.73 x U_0 (10 pC)	7.4.5
16	High Voltage AC test	2.5 x U_0 (1 hour)	7.4.6
17	PD test	1.73 x U_0 (10 pC)	7.4.5
18	Measure hose pre-charge pressure		

9.7.3 Acceptance criteria

- Acceptance criteria for the specified electrical verification tests shall be fulfilled.
- Both pre and post hose pre-charge pressure measurements shall be the same.

APPENDIX 1

CONNECTOR ASSEMBLY DATA SHEET

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General	
Type of connector assembly	Wet mate ( ), Dry mate ( ), Penetrator ( )
Manufacturer	
Product series	
Serial Number(s) Male/Female	
Technical Qualification Approved (according to this standard)	Yes ( ), No ( )
Design life	30 years
Rated no. of de-mate/mate operations (Connectors)	100
Environmental data	
Temperature Class	
Maximum operational water depth	3000m
External operating temperatures (min/max)	_ / _ ˚C
Internal operating temperature (min/max)	_ / _ ˚C
Storage and handling temperature (min/max)	_ / _ ˚C
Maximum storage time topside	
Suitable for exposure to process fluids	Yes ( ), No ( )
Gas seal	Yes ( ), No ( )
Flushing fluid / Fluid type	Yes ( ), No ( ) /Type: _
Dielectric filled / Dielectric type	Yes ( ), No ( ) /Type: _
Electrical parameters	
Rated voltage, U_0/U (U_m)	_ / _ (_) kV
Rated current, I_R (ambient temperature and frequency)	I_R _ A At ambient temperature _ ˚C At frequency _ Hz
Rated frequency range	Hz Min________to _______Hz Max
Short circuit current rating (kA rms symmetrical and duration)	_kA, _ms
Number of ways	

Mechanical parameters	
Weight	_kg
Overall length (mated)	_cm
Outside diameter	_ cm
Max/min mating and de-mating forces	_ kN
Impact protection class	IK 10
Tension tolerance (cable termination)	_ kN
Torque tolerance (connection interface)	_Nm
Misalignment tolerances	Angular (linear) misalignment: _ ° Axial misalignment: _ mm Rotational misalignment: _ °
Pressure parameters	
Maximum operational pressure	_ bar
Maximum decompression ratio	69 bar/min (penetrators in contact with process fluids)
Penetrator differential pressure rating	Internal to external: _bar External to internal: _bar