

GENERAL SPECIFICATION

SUBSEA SYSTEMS

GS EP SPS 032

Power Connectors, Penetrators and Jumper assemblies with rated voltage from 3 kV to 30 kV

01	05/2015	Organisation change – January 2015
00	09/2013	First issue
Rev.	Date	Purpose of the revision

Owning entity: DSO/TEC

Managing entity: DSO/TEC/SBS

Contents

1. Scope	4
2. Reference documents	4
3. Definitions and abbreviations	6
3.1 Definitions	6
3.2 Abbreviations	8
4. Development, documentation & marking requirements	9
4.1 Design documentation	9
4.2 Qualification process documentation	9
4.3 FAT documentation	10
4.4 As built documentation	10
4.5 Design analysis	10
4.6 Data sheet	11
4.7 Equipment marking	11
4.8 Jumper assemblies	11
5. Performance criteria	12
5.1 General requirements	12
5.2 Environmental conditions	12
5.3 Electrical characteristics	13
5.4 Mechanical characteristics	13
6. Design requirements	13
6.1 General functional requirements	13
6.2 Electrical properties	13
6.3 Mechanical properties	15
6.4 Material properties	15
6.5 Connector specific requirements	16
6.6 Penetrator specific requirements	17
6.7 Seals	17
6.8 Electric field control	18
6.9 Jumper assemblies	18

6.10	Reconditioning	18
6.11	Storage and transportation.....	19
7.	Testing	19
7.1	Test Requirements.....	19
7.2	Technical qualification testing - Connectors and penetrators.....	20
7.3	Factory acceptance testing	33
7.4	Test procedures	36
8.	Hose and hose termination qualification testing	50
8.1	Introduction	50
8.2	Absorption/Compensation test	50
8.3	Ozone resistance	51
8.4	Ultraviolet resistance.....	52
8.5	Thermal shock test.....	53
8.6	Destructive testing	54
9.	Jumper assembly qualification testing	56
9.1	Introduction	56
9.2	Electrical and thermal qualification test - Jumper assemblies.....	57
9.3	Oscillating jumper test.....	58
9.4	Jumper pull test.....	58
9.5	Drop test	59
9.6	Jumper handling simulation test.....	60
9.7	Jumper simulated deployment testing	61
Appendix 1		63

1. Scope

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

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

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

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

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document.

Reference	Title
ANSI/API Spec 6A	Specification for Wellhead and Christmas Tree Equipment
ICEA T-27-581	Standard Test Methods For Extruded Dielectric Power, Control, Instrumentation, And Portable Cables For Test
API RP 17Q	Subsea Equipment Qualification-Standardized Process for Documentation
ASTM D1141-98	Standard Practice for the Preparation of Substitute Ocean Water
EN 10204	Metallic products - Types of inspection documents
ICEA S-93-63	5 to 46 kV Shielded Power Cable For Use In The Transmission And Distribution Of Electric Energy
ICEA S-96-659	Non-shielded power cables rated 2001 - 5000 V
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 60183	Guide to the selection of high-voltage cables

Power Connectors, Penetrators and Jumper assemblies with rated voltage from 3 kV to 30 kV

Rev.: 01

Effective date: 05/2015

Page: 5 of 64

Reference	Title
IEC 60243-1	Electric strength of insulating materials - Test methods - Part 1: Tests at power frequencies
IEC 60270	High-Voltage Test Techniques - Partial Discharge Measurements
IEC 60502 (Parts 2; 4)	Power cables with extruded insulation and their Accessories For Rated Voltages From 1 kV ($U_m = 1.2$ kV) up to 30 kV ($U_m = 36$ kV) - Parts 2; 4
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 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 10423	Wellhead And Christmas Tree Equipment
ISO 12103-1 A4	Coarse Test Dust
ISO 6945	Rubber Hoses - Determination of Abrasion Resistance of the Outer Cover
NORSOK M-001	Materials Selection
NORSOK M-710	Qualification Of Non-Metallic Sealing Materials And Manufactures

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published in the applicable yearly collection.

Reference	Title
Not applicable	

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 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.
Hydrostatic pressure	Hydrostatic pressure corresponding to the design water depth.

Power Connectors, Penetrators and Jumper assemblies with rated voltage from 3 kV to 30 kV

Rev.: 01

Effective date: 05/2015

Page: 7 of 64

Term	Definition
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. <i>Bushing</i> 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 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.
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 seawater into the connector assembly internals.
Wet mateable connector	Connector designed to be submerged in sea water, and can also be connected/disconnected in 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, U_o/U (U_m)
- Rated current, I_r
- Environmental class
- Design pressure
- Water depth.

4.8 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, U_o/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 tested 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°C	-5°C	-5°C
Maximum ambient sea water temperature Note 1	20°C	20°C	20°C
Maximum ambient internal temperature Note 2	+60°C	+80°C	+110°C
Handling and storage temperature	-25 to 60°C	-25 to 60°C	-25 to 60°C
Rapid gas decompression rate Note 3	20-40 bar/min (290 psi/min)	20-40 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.

General Specification		GS EP SPS 032
Power Connectors, Penetrators and Jumper assemblies with rated voltage from 3 kV to 30 kV		
Rev.: 01	Effective date: 05/2015	Page: 13 of 64

5.3 Electrical characteristics

Parameter	Performance Criteria
Rated voltage U_m	$3.6 \text{ kV} \leq U_m \leq 36 \text{ kV}$
Steady state frequency range	15 - 200 Hz
Un-terminated connectors/penetrators	$> 100 \text{ G}\Omega$
Terminated connector assemblies	$> 20 \text{ G}\Omega$

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 minimum two years storage onshore as part of the design service life
- Designed for minimum one year storage subsea with subsea protection cap and minimum 30 days storage subsea without protection as part of the design service life
- Designed for an average number of turn-on/turn-off cycles of minimum 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 is 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 seawater 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 an 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 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 minimum 6 mm².

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 spec 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 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 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 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 minimum two water sealing barriers between seawater 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 seawater (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 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 applicable also 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.
- 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.
- Jumper assemblies shall be oil filled and pressure balanced to reflect the operational conditions.
- Flying leads cables 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 [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 cap 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.

General Specification		GS EP SPS 032
Power Connectors, Penetrators and Jumper assemblies with rated voltage from 3 kV to 30 kV		
Rev.: 01	Effective date: 05/2015	Page: 20 of 64

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 ($U_m = 7.2$ kV) up to 30 kV ($U_m = 36$ 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 ($U_m = 36$ 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 12103-1 A4](#), Coarse test dust.
- The composition and temperature of the seawater 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 purchaser and recorded.