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Subsea equipment –
Part 1: 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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INTRODUCTION

Within the oil and gas industry there is an increasing use of electrical power equipment on the seabed. Subsea processing activities like compression and pumping require increasingly higher amount of electrical power. Power generation, whether onshore or offshore, requires development of equipment both for subsea transmission and distribution.

Current standards for topside equipment do not include requirements related to equipment installed below the sea surface. Project and client specific specifications are used for both design and testing. The fact that equipment is qualified on a project basis, rather than to common standards, has several drawbacks:

- similar equipment is qualified to different type and routine test specifications;
- equipment has to be re-qualified for new projects that have slightly different requirements, for instance increased water depth;
- project specific ratings leading to higher number of equipment versions than strictly required.

All these issues lead to increased costs and schedule (for type testing), and also increased risk for failure (several type test programs are performed on a high number of various designs). By standardizing tests and implement continuous improvement on fewer products, this risk will be reduced in the long term.

The SEPS JIP (Subsea Electrical Power Standardization Joint Industry Project) was established in 2010 by seven oil and gas companies, with the aim to develop common operator standards for subsea electrical power equipment and systems and support further development of these into internationally recognized standards. This document is developed upon base material by SEPS. The aim for the SEPS JIP is to contribute to the development of IEC/IEEE dual logo standards; hence both IEC and relevant ANSI/IEEE standards are referenced where applicable. Relevant equipment manufacturers have contributed with review and comments to the document.

The lack of accessibility (for repair or replacement) defines strict requirements to reliability, beyond what is normally seen in topside applications.

As subsea equipment in many cases is interconnected to topside equipment, specifications for subsea equipment are considered to be within the scope of IEC TC 18 – Electrical installations of ships and of mobile and fixed offshore units.

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1 Scope

This document is applicable to single and three-phase wet-mateable and dry-mateable AC connectors, penetrators and jumper assemblies with rated voltages from 3 kV (U_{max} = 3,6 kV) to 30 kV (U_{max} = 36 kV). This document relates to the requirements and tests for products in the "as manufactured and supplied" condition. This document is not applicable to requirements and tests for products that have been subsequently installed, deployed or retrieved.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60156, *Insulating liquids – Determination of the breakdown voltage at power frequency – Test method*

IEC 60243-1:2013, *Electric strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC 60721-3-2:2018, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Transportation and handling*

IEC 60885-3, *Electrical test methods for electric cables – Part 3: Test methods for partial discharge measurements on lengths of extruded power cables*

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 61238-1-3:2018, *Compression and mechanical connectors for power cables – Part 1-3: Test methods and requirements for compression and mechanical connectors for power cables for rated voltages above 1 kV (U_m = 1,2 kV) up to 30 kV (U_m = 36 kV) tested on non-insulated conductors*

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)*

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ISO 7326:2016, *Rubber and plastics hoses – Assessment of ozone resistance under static conditions*

ISO 12103-1, *Road vehicles – Test contaminants for filter evaluation – Part 1: Arizona test dust*

ISO 23936-2:2011, *Petroleum, petrochemical and natural gas industries – Non-metallic materials in contact with media related to oil and gas production – Part 2: Elastomers*

ISO 30013:2011, *Rubber and plastics hoses – Methods of exposure to laboratory light sources – Determination of changes in colour, appearance and other physical properties*

ANSI/ICEA T-27-581/NEMA WC 53, *Standard Test Methods for Extruded Dielectric Power, Control, Instrumentation, and Portable Cables for Test*

ANSI/API Spec 6A:2018, *Specification for Wellhead and Christmas Tree Equipment*

ANSI/NEMA WC 74 ICEA S-93-639, *5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy*

ANSI/NEMA WC 71 ICEA S-96-659, *Standard for Non-shielded Cables Rated 2001-5000 Volts for Use in the Distribution of Electric Energy*

ASTM D877, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes*

ASTM D1141-98, *Standard Practice for the Preparation of Substitute Ocean Water*

ASTM D1169, *Standard test method for Specific Resistance (Resistivity) of Electrical Insulating Liquids*

ASTM D1816, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids using VDE Electrodes*

EN 10204, *Metallic products – Types of inspection documents*

IEEE Std 386™, *IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Rated 2.5 kV through 35 kV*

IEEE Std 4™, *IEEE Standard for High Voltage Testing Techniques*

NORSOK M-710:2014, *Qualification of Non-Metallic Sealing Materials and Manufacturers*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO, IEC and IEEE maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp
- IEEE Standards Dictionary Online: available at http://dictionary.ieee.org

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3.1 Terms and definitions

3.1.1
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

3.1.2
connector assembly
assembly of wet and/or dry mate connectors, penetrators, cable terminations, cable pigtails or jumper cables between subsea components – or any combination of these

3.1.3
connector
fully insulated termination permitting the connection and the disconnection of a cable to other equipment

3.1.4
de-mate
dis-connection of separable connectors so that all electrical, mechanical and environmental sealing functions are fully dis-engaged

3.1.5
differential pressure
difference between the two values of absolute pressure that are acting on either side of a wall or partition

3.1.6
dry mateable connector
connector designed to be submerged in sea water but connected/disconnected in a dry (topside/onshore) environment only – with no voltage or current applied

3.1.7
dummy connector
device allowing connection to a connector half for long term protection when submerged and unmated

Note 1 to entry: Normally, no cable is attached to the dummy connector; internal connection between phases may however be established to allow continuity testing.

3.1.8
inner water seal
water seal closest to the conductor

3.1.9
jumper assembly
cable connection terminated at each end to either a connector or a penetrator

Note 1 to entry: The term includes the connector assembly at both ends, the cable, the protective fluid filled hose and the hose terminations, as applicable.

Note 2 to entry: Other common designations are electrical flying lead and electrical jumper lead

3.1.10
mate
connection of separable connectors so that all electrical, mechanical and environmental sealing functions are fully engaged

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3.1.11
misalignment
misalignment between two connector halves in a connector pair which is expressed by means of the following definitions:

- axial misalignment;
- radial misalignment;
- angular misalignment;
- rotational misalignment

3.1.11.1
axial misalignment
amount of offset from a nominal central datum in a direction parallel to the axes of two connector halves

Note 1 to entry: The axial misalignment is normally expressed in millimetre.

3.1.11.2
radial misalignment
amount of offset between the two axes of two cylindrical connector halves in a direction perpendicular to the axes

Note 1 to entry: The radial misalignment is normally expressed in millimetre.

3.1.11.3
angular misalignment
angle formed at the intersection of two axes of two cylindrical connectors halves

Note 1 to entry: The angular misalignment is expressed in degrees.

3.1.11.4
rotational misalignment
amount of circumferential offset about the axes of two connector halves

Note 1 to entry: The rotational misalignment is expressed in degrees.

3.1.11.5
maximum misalignment capability
maximum degree of misalignment that a connector can tolerate without malfunction, expressed by the maximum values of combined axial, radial, angular and rotational misalignment

Note 1 to entry: The values of axial, radial, angular and rotational misalignment when combined to produce maximum misalignment capability may be less than each misalignment taken singularly. It is therefore not sufficient to determine the maximum misalignment capability by measuring each singular component in turn.

3.1.12
onshore protection cap
device connected to a connector half during handling, transportation and storage

Note 1 to entry: The cap is to protect against ingress of particles and the sealing surfaces against mechanical damage.

3.1.13
outer water seal
water seal closest to the conductive media

3.1.14
penetrator
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

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Note 1 to entry: The means of attachment, flange or fixing device to the partition forms part of the penetrator. Penetrators include bulkhead mounted connector assembly components.

Note 2 to entry: "Bushing" is an alternative commonly used term.

3.1.15
pressure integrity seal
sealing element of a penetrator assembly that prevents leakage between the two sides of the wall/partition to which the penetrator is mounted

3.1.16
primary pressure integrity seal
pressure integrity seal closest to the side with the highest rated absolute pressure (RAP)

Note 1 to entry: If only one value for RAP is specified (pressure balanced conditions), the primary pressure integrity seal is the seal closest to the side with the most aggressive/conductive medium.

Note 2 to entry: This definition applies to penetrators only.

3.1.17
rapid gas decompression
extreme depressurisation event from high pressure (hundreds of bar) to low pressure (tens of bars down to atmospheric) in order of seconds

Note 1 to entry: Rapid gas decompression can occur in a production system when in presence of gas. The phenomenon is also known as "explosive decompression".

3.1.18
rated absolute pressure
maximum absolute pressure that a connector assembly has been designed to operate at under the specified conditions of use

Note 1 to entry: For connector assemblies that are designed to operate under pressure balanced conditions, only one value of rated absolute pressure shall be specified. For penetrators that are designed to operate with different pressures on either side of a wall or partition, two values of rated absolute pressure shall be specified. RAP-1 shall be used to refer to the maximum rated absolute pressure on the external or outboard side of the partition and RAP-2 shall be used to refer to the maximum rated absolute pressure on the internal or inboard side of the partition.

Note 2 to entry: The rated absolute pressure shall not be confused with the maximum test pressure to which the assembly shall be subjected in order to qualify it for service.

3.1.19
rated differential pressure
maximum differential pressure that a connector assembly has been designed to operate at under the specified conditions of use

Note 1 to entry: For connectors and penetrators that are designed to operate under pressure balanced conditions, only one value of rated differential pressure shall be specified and shall be the same in both directions. For penetrators that are designed to operate with different pressures on either side of a wall or partition, the two values RAP-1 and RAP-2 shall be the rated differential pressure in each direction

Note 2 to entry: The rated differential pressure value shall be used to describe the differential pressure rating of the connector assembly and it should not be confused with the maximum differential test pressure to which the assembly shall be subjected in order to qualify it for service.

3.1.20
rated current
I_r
maximum RMS value of current which the connector assembly can carry continuously at rated frequency and at maximum ambient temperature, as given by the temperature class

Note 1 to entry: For connector assemblies operating at other environmental 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.

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3.1.21
rated thermal short-time current
I_{th}
RMS 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, as given by the temperature class

3.1.22
rated dynamic current
I_d
peak value of a current that the connector assembly withstands mechanically

3.1.23
routine test
tests performed by the manufacturer on each connector assembly to verify that the specified requirements are met

3.1.24
sample test
tests performed by the manufacturer on samples of connector assemblies or components taken from a connector assembly, at a specified sampling frequency, so as to verify that the finished product meets the specified requirements

3.1.25
secondary pressure integrity seal
pressure integrity seal closest to the side with the lowest rated absolute pressure (RAP)

Note 1 to entry: If only one value for RAP is specified (pressure balanced conditions), the secondary pressure integrity seal is the seal closest to the side with the less aggressive/conductive medium.

Note 2 to entry: This definition applies to penetrators only.

3.1.26
shell continuity
electrical connection between two metallic connector housings when connected together

3.1.27
special test
test other than a routine, sample or type test, agreed between manufacturer and purchaser

3.1.28
subsea protection cap
device connected to a connector half for protection when unmated subsea

Note 1 to entry: The subsea protection cap provides mechanical protection and prevents marine growth on critical/sealing surfaces.

3.1.29
temperature rise
difference between the temperature of the part under consideration and a reference temperature

[SOURCE: IEC 60050-151:2001, 151-16-26, modified – The note to entry has been deleted.]

3.1.30
test connector
connector used during topside testing, in order to test equipment and systems – without using the full delivery connector set

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3.1.31
type test
conformity test made on one or more items representative of the production, in order to demonstrate satisfactory performance characteristics to meet the intended application

Note 1 to entry: Type tests are performed on connector assemblies representative of other connector assemblies, to demonstrate that these connector assemblies comply with the specified requirements.

Note 2 to entry: A connector assembly is considered to be representative of others if it is built to the same drawings using the same techniques in the same factory.

3.1.32
verification test
test conducted during the type test sequence to verify that the product is performing correctly and within the product performance specification

3.1.33
water seal
sealing element of a connector assembly that prevents intrusion of conductive media into the connector assembly internal volume

3.1.34
wet mateable connector
connector designed to be submerged in sea water, which can be connected/disconnected in a submerged condition – with no voltage or current applied

3.2 Abbreviated terms

CP cathodic protection

CR contact resistance

FAT factory acceptance test

FEA finite element analysis

IR insulation resistance

MBR minimum bend radius

PD partial discharge

PMI positive material identification

PSL product specification level

RAP rated absolute pressure

RDP rated differential pressure

RGD rapid gas decompression

ROT remotely operated tool

ROV remotely operated vehicle

U_0 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

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4 Documentation and marking

4.1 Design documentation

Design documentation shall be provided and shall at least contain information as shown in Table 1. Some parts of the reports may contain confidential and proprietary information – such information shall as a minimum be made available for review, if not provided as part of the final documentation to the purchaser.

Table 1 – Design documentation

Preferred document	Document content
Design specification	Including design specification data sheet, operations interface specification, environmental, mechanical, electrical and thermal design specifications and cathodic protection requirements. Intended installation and intervention procedures.
Design drawings	Detailed, scaled mechanical drawings including weights, dimensions, cross sections and material/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.
Assembly procedures	List of assembly procedures (including revision) used during type testing.
Cleaning and spillage requirements	Procedure with regards to cleaning and spillage requirements.
Handling, transport and storage	Document containing intended handling, transport and storage procedures. List of all fluids used in the product, including safety data sheets.

4.2 Type test documentation

A detailed test specification for each type test sequence is required. This specification shall include procedures, instruments, connection diagrams and all relevant environmental, mechanical and electrical parameters used and shall form the basis of communicating agreement between the client and the manufacturer in instances where deviations to this procedure are permitted. In addition, a type test report shall be provided demonstrating the outcome of each test within each sequence.

4.3 Routine test documentation

Routine test documentation shall be supplied as listed in Table 2.

Table 2 – Routine test documentation

Document	Document content
Routine test procedure	A detailed test specification for each routine test, embracing complete test procedures with all relevant environmental, mechanical and electrical parameters, instruments and connection diagrams used.
Routine 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 4.2.

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4.4 As built documentation

Further to successful type testing, each connector assembly shall be supplied with detailed as built documentation. Documents as listed in Table 3 shall be supplied, as a minimum, and shall contain information as shown in Table 3. Some parts of the reports may contain confidential and proprietary information – such information shall as a minimum be made available for review, if not provided as part of the final documentation to the purchaser.

Table 3 – As built documentation

Preferred document	Document content
Design report	Including design data sheet, design specification, operations interface specification, mechanical, electrical and thermal design analyses, routine test procedures, routine test results 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 on the critical areas of the design to verify that the design is capable of withstanding the stresses to which it may be subjected at all stages of its life. The design analysis shall as a minimum contain the following.

- The connector assembly design shall be subject to a design failure mode effect and criticality analysis (DFMECA) and the results documented. The output from the analysis shall be used to identify areas of interest for further analysis, testing and quality controls. It may be necessary to augment the testing programme given in this document in order to evaluate features of the design that have been identified by the DFMECA.
- Electrostatic, magnetic, thermal and mechanical finite element analysis, covering type tests and intended operational conditions shall be undertaken to evaluate the performance of the design where the performance cannot be inferred from other analysis. Consideration shall be given to worst-case design loads (e.g. test, storage, handling, installation/retrieval and operation) including fault scenarios (e.g. broken seal, short circuit) such that the design loads do not exceed electrical, thermal or mechanical limitations for any material. The analysis shall include the heat generated by the losses in the connector assembly itself. The analysis should also include possible nonlinear material properties.
- Calculations to verify suitability of the pressure compensating system shall be undertaken. The analysis shall include test, storage, transportation, installation/retrieval and operational conditions. Any hysteresis (lag) in the performance of the compensation system 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.

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 Annex A.

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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_0/U (U_m);
- rated current, I_r;
- temperature class;
- rated frequency;
- rated absolute pressure, RAP (RAP-1 and RAP-2 for penetrators);
- rated differential pressure (penetrators only);
- water depth.

If space constraints limit the information that can be included on the product, the name/logo of manufacturer and model/serial number shall as a minimum be included.

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:

a) name, logo or registered mark of the manufacturer or supplier;
b) model/serial number;
c) rated voltage, U_0/U (U_m);
d) rated current I_r;
e) rated frequency
f) type of cable insulation;
g) number and size of conductor;
h) absolute design pressure;
i) water depth;
j) temperature class;

If space constraints limit the information that can be included on the product, the name/logo of manufacturer and model/serial number shall as a minimum be included.

5 Design

5.1 General design requirements

The following design requirements shall apply to all types of connector assemblies:

a) service life time of 30 years;
b) maintenance free throughout service life;
c) minimum 50 surface recoveries;
d) minimum of two years storage onshore as part of the design service life.

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5.2 Temperature class

This document establishes four main temperature classes of connector assemblies, as shown in Table 4. The temperature classes differentiate on the temperature in the media surrounding the connector assembly, not taking into account the heat generated by the connector assembly itself.

The specific values stated in Table 4 for each connector class shall be used in the type testing process to qualify the connector assembly according to the special application requirements. For some of the test sequences, different steps are defined for the classes.

Table 4 – Temperature classes

	Class I	Class II	Class III	Class IV
Parameter				
Minimum ambient temperature [a]	−5 °C	−5 °C	−5 °C	−5 °C
Maximum ambient temperature [a]	20 °C	60 °C	121 °C	> 121 °C [b]
Handling and storage temperature	−25 °C to 60 °C	−25 °C to 60 °C	−25 °C to 60 °C	−25 °C to 60 °C

[a] The specified ambient temperatures do not take into account the heat generated by the connector assembly itself.

[b] Maximum ambient temperature shall be specified in the data sheet.

5.3 Electrical design requirements

5.3.1 Ratings

5.3.1.1 Voltage ratings

The values of rated voltage for connector assemblies shall be according to Table 5.

Table 5 – 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 1 The values in Table 5 are taken from IEC 60038:2009.

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 Table 5 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 as the basis for establishing the test voltages referenced in the testing section (Clause 7 to Clause 14) 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.

NOTE Refer to IEC 60183:2015.

5.3.1.2 Current ratings

The rated current I_r of connector assemblies shall be in accordance with Table 6.

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NOTE 1 The values of Table 6 are taken from IEC 60059.

Table 6 – Current ratings

Rated current A												
100	200	250	315	400	500	630	800	1 000	1 250	1 600	2 000	2 500

Rated current shall normally be specified for rated frequency in sea water at 20 °C for class I and in the relevant medium at the maximum ambient temperature as specified in Table 4 for classes II to IV. For connector assemblies operating in other conditions, the rated current and corresponding operational ambient conditions shall be clearly specified in the data sheet.

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

For systems involving harmonic currents, the system designer should select a current rating that considers the additional heat generated by the harmonic currents (both in the main conductor and cable screens as applicable). If considered required, and agreed between manufacturer and purchaser, additional temperature rise tests can be performed.

5.3.1.3 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.

5.3.2 Earthing

5.3.2.1 Earthing of cable screens

Connector assemblies shall have means for the earthing of housings and cable screens. The earthing connection shall be copper or a copper alloy, with a cross section area and current rating capacity similar to that of the cable screen; however, the cross-section area shall be a minimum of 6 mm^2.

For single phase jumpers (cables), screen currents could be considerable if the screens are earthed in both ends. If single-ended earthing of the screen is selected, the screen termination shall be designed to handle the induced voltage on the screen.

5.3.2.2 Shell continuity

Unless specified differently in the project requirements specification or data sheet, connectors shall be designed to provide a shell continuity corresponding to 100 mV voltage drop or less at room temperature (20 °C) with a current of 10 A DC.

5.3.3 Dummy connectors

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

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5.4 Mechanical design requirements

5.4.1 Pressure classes

Pressure retaining components (penetrators, bushings, bulkhead mounted connectors, etc.) shall be categorized and qualified to standardised rated absolute pressure classes (RAP, RAP-1, RAP-2), in accordance with API Spec 6A as shown in Table 7.

Table 7 – Pressure classes

Pressure classes according to API Spec 6A							
Pressure (bar)	138	207	345	690	1 035	1 380	1 861

5.4.2 Rapid gas decompression

Connector assemblies or parts of connector assemblies that will be in contact with production fluids shall be tested for rapid gas decompression. Allowable 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.

5.4.3 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.

5.5 Material requirements

5.5.1 General material requirements

The connector assemblies shall meet the following requirements.

a) 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 throughout design service life with the relevant interfacing medium and materials as defined in the operational requirements specification.

b) Seal materials shall be compatible with all applicable interfacing materials and media, even if one seal should fail.

c) All polymeric materials shall be compatible with the service environment.

d) 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.

e) A materials selection report including type test reports shall be prepared and presented to the purchaser, before construction of connector assemblies for type testing.

Consequence of potential migration or ingress of conductive media into the connector assembly shall be considered during the design phase, also considering densities of internal fluid compared with the external conductive media (and where conductive media may accumulate).

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5.5.2 Material certification requirements

All connector and penetrator assemblies shall have traceable manufacturing records to allow identification and subsequent rectification of defects after delivery. Manufacturing records and test results shall be traceable to each assembly by a unique identifier (e.g. product serial number). Traceability of components from a common batch is permitted.

For well pressure retaining equipment, the traceability requirements for individual components used in the assembly shall be according to the latest edition of API Spec 6A for the required PSL level of the component in question. Where the component PSL level requires traceability to a specific heat treatment lot, a unique means of identification of the component to the heat run shall be provided.

The composition of all metallic components used for process (well) containment shall be verified by PMI according to the manufacturer's procedure. The PMI shall be performed as late as possible in the assembly process and the result documented.

Certificates of conformity for metallic components shall be supplied with the product according to Type 3.1 of EN 10204. Records shall be retained by the manufacturer for a minimum of 10 years.

5.6 Connector specific requirements

5.6.1 General requirements

The following requirements shall apply to all types of connectors.

a) Efforts shall be made to maximize the duration which a connector half can remain unmated in the operational environment. Minimum product requirement is 28 days over the lifetime, with a minimum of 7 consecutive days.

b) 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:

c) to be capable of vertical, tilted and horizontal operation inclusive of mating and de-mating, or as specified in the datasheet,

d) with a robust locking mechanism, to prevent accidental or vibration-induced de-mating or malfunction, and

e) to have a housing and latch mechanism tolerant to silt and fine sand deposits.

5.6.2 Wet mateable connectors

The following are additional requirements for wet mateable connectors.

a) Wet mateable connectors shall be designed for a minimum of 100 maintenance free mate/de-mate cycles, after delivery.

b) Wet mateable connectors shall be designed to withstand calcium deposits, marine growth and debris without jamming, and without interfering with mating, de-mating and operation.

c) Wet mateable connectors shall be 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.

d) 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 in the operation and maintenance manual.

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e) 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 clearly defined and documented in the operation and maintenance manual, for example maximum concentrations and durations when using citric acid.

f) The connector assembly shall be designed 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. This requirement does not exclude the use of stab type connectors mounted into a separate mating/locking mechanism.

5.6.3 Dry mateable connectors

The following are additional requirements for dry mateable connectors.

a) Dry mateable connectors shall be designed for a minimum of 30 maintenance free mate/de-mate cycles, after delivery.

b) Dry mateable connectors shall be suitable for mating/de-mating in harsh offshore conditions, for example in a humid and salt atmosphere.

c) Means for testing seals between the connector halves after mating should be considered.

5.7 Penetrator specific requirements

5.7.1 Penetrators for pressure compensated equipment

Penetrators used as equipment penetrations for pressure compensated housings shall be designed for normal loading conditions under testing, deployment and usage. If a system requires fault tolerance under abnormal loading conditions including fault scenarios (e.g. internal fault or failure of the compensation system) or if the compensation system has a nominal over-pressure of greater than 10 bar, the system designer should specify the use of a penetrator for pressure retaining equipment (5.7.2). Penetrators for pressure compensated equipment shall be designed with a nominal rated differential pressure of 10 bar (in both directions) at the specified temperature range to allow for pressure differences that may occur between the two compensated volumes due to compensator response lag, temperature differences, etc.

NOTE The rated differential pressure of 10 bar is applicable to the penetrator as a component, and not necessarily to the tank/housing it is attached to.

5.7.2 Penetrators for pressure retaining equipment

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

Pressure retaining penetrators shall be designed to operate at the rated absolute pressure applied as differential pressure across the penetrator (RAP-1 and RAP-2).

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, API Spec 6A should be used as a reference, where PSL 3 and PR2 shall be the level of technical qualification and documentation.

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

For pressure integrity seals, see 5.8.3.

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Whilst this document deals with the requirements for the product only, it is important to recognise that the failure of a penetrator in a pressure retaining application could result in consequences for the system on which it is used. These consequences should be identified at the system design stage so that mitigating actions can be taken.

5.8 Seals

5.8.1 General seal requirements

The use of test ports for testing of seals shall 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. Where two seals are installed, these shall be installed on different seal surfaces. Each seal shall be tested during type testing; at least one seal shall be tested during factory acceptance test.

Each seal shall be designed and qualified for continuous exposure to the relevant media (sea water, oil, water/glycol etc.) at the rated absolute pressure and temperature. Failure of one of the seals shall not jeopardise the function or integrity of the remaining seal. The connector assembly shall operate within its specified electrical requirements with only one seal in operation.

Manufacturer shall identify all seals and classify whether they are water seals, pressure integrity seals or provide both functions (combined).

5.8.2 Water seals

In general, all connector assemblies shall incorporate a minimum of two water seals between the conductive media and the electrical conductors/live parts.

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 seals is also applicable to dummy connectors (main connector disconnected).

5.8.3 Additional requirements for pressure integrity seals

5.8.3.1 Exposed to production fluids

Seals that are exposed or may be exposed to production fluids shall be qualified to PSL 3 or PSL 3G and PR2 as per API Spec 6A. The connector assembly shall have at least two independent pressure integrity seals, unless an API 6A BX seal (or proven industry equivalent) is utilized. Each of the seals shall be installed on different seal surfaces.

Subclause 5.8.3.1 also applies to seals for penetrators for pressure compensated equipment.

5.8.3.2 Not exposed to production fluids

For connector assemblies for pressure compensated equipment that are not and may not be exposed to production fluids, one or two pressure integrity seals may be used.

5.9 Electric field control

Electric field control shall be applied as part of the cable termination when the cable has an outer semi-conductive insulation layer.

Documents
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Full document details: IEC/IEEE 61886-1-2021