Document No: SEAFOM Technical Standard Document – 02 (SEAFOM TSD-02)

Functional Design and Test Specification for Subsea Electrical and Optical Connectors and Jumpers

Issue Date: November 2016

(Document title changed – April 2017)

Table of content

© 2010 All rights reserved

© 2010 All rights reserved

© 2010 All rights reserved

1.1 Scope

This specification covers the requirements for design, fabrication, performance, materials, operation and installation, intervention, testing and qualification for seawater exposed dry-mate and wet-mate subsea connectors and jumper assemblies as defined herein for subsea production equipment. Covered designs include; electrical, electrical/optical (hybrid), and optical connectors.

The Ethernet testing described in Section 12 is relevant for communication links utilizing the Ethernet subsea, even if parts of the link are not seawater exposed i.e. internal to instruments or subsea control modules.

The target groups for this specification are personnel involved in technology development, fabrication and delivery of referenced connectors, project planners and project executioners utilizing these connectors in their projects.

© 2010 All rights reserved

2 References

2.1 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 amendments) applies.

API 6A, Specification for Wellhead and Christmas Tree Equipment

API 17D, Design and Operation of Subsea Production Systems-Subsea Wellhead and Tree Equipment

API 17F, Subsea Production Control Systems

ASTM D903-98, Standard Test Methods for Peel or Stripping Strength of Adhesive Bonds

ASTM D3164-02(2011), Standard Test Method for Strength Properties of Adhesively Bonded Plastic Lap-Shear Sandwich Joints in Shear by Tension Loading

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

EN 10204, Metallic Products. Types of inspection documents

IEC 60721-3-2, Classification of groups of environmental parameters and their severities – Section 2: Transportation

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

IEC 60502-1, Power cables with extruded insulation and their accessories for rated voltages from 1kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 1: Cables for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)

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

IEC 61300-3-4, Fiber optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-4: Examinations and measurements – Attenuation

IEC 60885-2, Electrical test methods for electric cables Part 2: Partial discharge tests

NORSOK M-630, Material data sheets and element data sheets for piping

NORSOK M-710, Qualification of non-metallic sealing materials and manufactures

ITU-T L.12, Optical fibre splices

© 2010 All rights reserved

2.2 Informative references

These are references identified in the text but not in a mandatory way.

[1] API 17H, Recommended Practice for ROV Interfaces with Subsea Production Equipment

[2] API 17N, Recommended Practice for Subsea Production System Reliability and Technical Risk Management

[3] ANSI/TIA/EIA 568 B.2, Commercial Building Telecommunications Standard Part 2: 100 Ohm Balanced Twisted-Pair Cabling Standard

[4] ASTM D395-03, Standard Test Methods for Rubber Property – Compression Set

[5] ASTM D471-06, Standard Test Method for Rubber Property - Effect of Liquids

[6] ASTM D877, Dielectric Breakdown Testing of Dielectric Fluids

[7] ASTM D1414-94, Standard Test Methods for Rubber O-Rings

[8] ASTM D2240, Standard Test Method for Rubber Property - Durometer Hardness

[9] ASTM D3164-03, Standard Test Method for Determining Strength of Adhesive Bonded Plastic Lap-shear Sandwich Joints in Shear by Tension Loading

[10] BS903 Part A2, Physical Testing of Rubber, Method for Determination of Tensile Stress-strain Properties

[11] BS903 Part A3, Physical Testing of Rubber, Determination of Tear Strength

[12] BS903 Part C2, Physical Testing of Rubber, Determination of Volume Resistivity

[13] BS903 Part A26, Physical Testing of Rubber, Method for Determination of Hardness (between 10 IRHD and 100 IRHD)

[14] BS6899, Specification for Rubber Insulation and Sheath of Electric Cables

[15] IEC 60228, Conductors of Insulated Cables

[16] IEC 60287, Electric Cables. Calculation of the Current Rating

[17] IEC 60811, Common Test Methods for Insulating and Sheathing Materials of Electrical Cables

[18] IEEE SA 802.3-2012 IEEE Standard for Ethernet, Section Two-Clause 25, Physical Medium Dependent (PMD) Sublayer and Baseband Medium, Type 100BASE-TX

[19] ISO 1431-1, Rubber, Vulcanized or Thermoplastic – Resistance to Ozone Cracking - Part 1: Static strain test

[20] ISO 8580, Rubber and Plastics Hoses – Determination of Ultra-violet Resistance Under Static Conditions

[21] ISO 6945, Rubber Hoses - Determination of Abrasion Resistance of the Outer Cover

[22] ITU-T G.650, Definition and Test Methods for the Relevant Parameters of Single-mode

© 2010 All rights reserved

[23] ITU-T G.651, Characteristics of a 50/125 µm Multimode Graded Index Optical Fiber Cable for the Optical Access Network
[24] ITU-T G.652, Characteristics of a Single-mode Optical Fiber and Cable
[25] ITU-T G.653, Characteristics of a Dispersion Shifted Single-mode Optical Fiber and Cable
[26] ITU-T G.654, Characteristics of a Cut-off Shifted Single-mode Optical Fiber and Cable
[27] ITU-T G.655, Characteristics of a Non-zero Dispersion Shifted Single-mode Optical Fiber and Cable
[28] ITU-T G.911, Parameters and Calculation Methodologies for Reliability and Availability of Fiber Optic Systems
[29] ITU-T G.972, Definition of Terms Relevant to Optical Fiber Submarine Cable Systems
[30] NORSOK M-001, Materials Selection

© 2010 All rights reserved

3 Terms and Definitions

For the purpose of this document the following definitions apply.

Alien crosstalk
A measure of the unwanted signal coupling between adjacent link segments at the near-end

Delay skew
The difference in propagation delay between any two pairs in a cable assembly

Dry-mate connectors
Subsea connector not designed to be mated under water

Far-end crosstalk loss
A measure of the unwanted signal coupling from a transmitter at the near-end into another pair measured at the far-end, and relative to the transmitted signal level

Insertion loss
The signal loss resulting from the insertion of a component, or link, or channel, between a transmitter and receiver (often referred to as attenuation)

Jumper assembly
Pressure compensated hose containing electrical wires and/or fibers, terminated by one or more connectors

Flashover
Unintended electrical discharge over an insulator

Near-end crosstalk loss
A computation of the unwanted signal coupling from transmitters at the near-end into a pair measured at the near-end.

Subsea connectors
Connector designed for operation under water

Hybrid connectors
Connector with both electrical and optical contacts

Power sum equal level far-end crosstalk
A computation of the unwanted signal coupling from multiple transmitters at the near-end into a pair measured at the far-end, and normalized to the received signal level

© 2010 All rights reserved

Power sum near-end crosstalk loss
A computation of the unwanted signal coupling from multiple transmitters at the near-end into a pair measured at the near-end

Propagation delay
The amount of time it takes the signal to travel from the sender to the receiver

Qualification (design validation)
Process of proving a design by testing to demonstrate conformity of the product to the design requirements (API Q1)

Qualified person
Individual or individuals with characteristics or abilities gained through training or experience or both, as measured against established requirements, such as standards or tests that enable the individual to perform a required function

Return loss
A ratio expressed in dB of the power of the outgoing signal to the power of the reflected signal

Structural return loss
Return loss associated with variations in the cable impedance

Wet-mate connectors
Connector designed to be mated under water

Wire map
Map showing the configuration of the wire runs

© 2010 All rights reserved

4 Acronyms, Abbreviations and Symbols

For the purpose of this document, the following acronyms, abbreviations, and symbols apply.

ACRF	Attenuated Crosstalk Ratio at Far-end
ANSI	American National Standards Institute
APC	Angled Physical Contact
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
AXT	Alien Crosstalk
BS	British Standard
dB	Decibel
DUT	Device Under Test
EIA	Electronics Industries Association
FEXT	Far-end Crosstalk
FAT	Factory Acceptance Test
g	Acceleration Due to Gravity
IEC	International Electrotechnical Commission
ISO	International Organisation for Standardisation
ITU-T	International Telecommunication Union
MHz	Mega Hertz
mm	Multi-Mode
NEXT	Near-end crosstalk
pk-pk	peak to peak
pphm	parts per hundred million
ppm	parts per million
PSELFEXT	Power Sum Equal Level Far-end Crosstalk
PSNEXT	Power Sum Near-end Crosstalk
RMS	Root Mean Square
ROT	Remote Operated Tool
ROV	Remote Operated Vehicle
SCM	Subsea Control Module
SIIS	Subsea Instrumentation Interface Standardization
SM	Single Mode
SRL	Structural Return Loss
TIA	Telecommunication Industries Association
UPC	Ultra Physical Contact

© 2010 All rights reserved

UTP	Unshielded Twisted-pair
VAC	Volts Alternating Current
VDC	Volts Direct Current

© 2010 All rights reserved

5 General Requirements

Subsea mateable electrical, electrical/optical and optical connectors and cable assemblies shall:

a) Be designed for long term subsea use without cathodic protection.
b) Support electrical insulation from a cathodically protected structure.
c) Be suitable for deepwater applications.
d) Utilize electrical connections of a conductive type and optical connections of a low-loss design.
e) Have successfully completed a full qualification test program.
f) Have a minimum of dual sealing barriers between seawater and electrical conductors in the mated condition. Both barriers shall be designed for continuous operation in seawater and the selected dielectric fluid. Oil, gel or compounds used for water blocking or insulation that do not prevent water absorption and provide a testable mechanical isolation are not considered a barrier.
g) Be designed and qualified for its final use, e.g. installation/operation/retrieval at subsea depth by diver, ROV/ROT or hydraulic cradle with configuration changes to suit the method of installation.
h) Ensure that electrical and optical contact between the two wet-mate connector halves takes place in an insulating fluid filled environment.
i) Be maintenance-free over the connector's design life when used within its rated number of mate/de-mate cycles.
j) Support bulkhead mounting towards a pressure vessel, an oil-filled, pressure-compensated enclosure, stab plate mounting, individual diver and ROV/ROT installation/retrieval formats, and it shall be possible to configure either the plug or the receptacle as the fixed half.
k) Be available for termination towards an oil-filled hose (containing electrical conductors/fibers).
l) Be robust to withstand the stresses and strains normally experienced during subsea handling and installation by ROV.
m) Withstand environmental extremes normally experienced during shipping, storage and deployment.
n) Have a housing and latch mechanism that shall be tolerant of silt and fine sand deposits.
o) Have a latch mechanism and visual indicator clearly visible from an ROV camera.
p) Be constructed from materials suitable for marine duty to the lifetime specified or suitable for marine duty to the lifetime specified with cathodic protection if connector is in a stab configuration.
q) If configured with an Ethernet cable inside an oil-filled jumper, include a fixing device to ensure no forces are transferred from the cable to soldering/crimping points at the connector back-end.
r) Fusion splices shall be mechanically proof tested at minimum 1,9N, e.g. automatically by fusion splicer. Splicing of fibers shall be performed according to ITU-T L.12 but with acceptance criteria as stated in Table 1.
s) All optical splices shall be protected by either recoating of the optical fiber or use of a heatshrink splice protector.
t) The number of splices in a jumper or assembly shall be minimized.
u) Orientation marks shall be clearly visible when required before mating.

© 2010 All rights reserved

v) Where requirements are described as "should" in this document, alternative solutions shall have a documented quality level equivalent to the recommended solution.

w) Optical connectors based on UPC and APC shall handle optical power up to 200mW. If higher optical power is to be applied, it is recommended to verify insertion loss and back reflection in situ after connection subsea to avoid premature failure.

5.1 Design Approval Documentation

The following information shall be available for review for each qualified product design:

- Materials and material specifications for all materials of construction
- Method of corrosion protection
- Evidence of compatibility with relevant chemicals
- Qualification testing program, procedures, data, results and certificates
- Factory acceptance testing program, procedures, data, results and certificates
- ROV operational characteristics including angular, rotational, lateral and axial misalignment allowance, as applicable
- Statement covering the consequence of accidental mate/de-mate with power applied and water-jetting of unmated connectors
- Reliability data and maintenance procedures as defined by the supplier/manufacturer
- Handling, packing, storage and shipping procedures/guidelines

© 2010 All rights reserved

6 Performance Parameters

Products covered under this specification shall conform to the requirements defined in Table 1, as applicable:

Table 1: Performance Parameters Summary

Parameter	Performance
Design life	30 years
Water depth (ref API17D AnnexM5.3	3050m
Minimum External Design Pressure	314 bar
Minimum test pressure for components according to API17F	346 bar
Minimum test pressure for well pressure barrier components according to API17D and API6A	471 bar
The rated voltage between conductors for which the equipment is designed. For AC voltage, the definition is corresponding to U in IEC 60502-1 (AC voltage), hence no considerations were taken for: 1) the ability to operate with one earth fault , 2) the possibility of voltages 180° out of phase and 3) that subsea located equipment should be designed with higher margins than topside located equipment	1500VDC, 1000VAC RMS
The rated voltage between conductor and earth or metallic screen for which the equipment is designed. For AC voltage the definition is corresponding to U_0 in IEC60502-1	1500VDC, 600VAC RMS
The maximum value of the "highest system voltage" for which the equipment may be used (corresponding to U_m in IEC60502-1) This value covers the situation where 2 adjacent pairs are 180° out of phase	1200VAC RMS
Maximum continuous operational voltage for connectors with reduced proof voltage testing	50VDC
Make/break of wet-mate under power	Not a required feature, but consequence to be described by supplier/manufacturer
Maximum continuous operational current	According to manufacturer's specifications, based on tests. Amperage on single/multiple/all pins to be specified
Maximum in-rush current 1)	10 x maximum continuous operational current for ½ sec. duration
Insulation Resistance - Connector Connector body to conductor/pin Conductor/pin to conductor/pin	 >20GΩ >20GΩ
Insulation Resistance - Jumper assembly Connector body to conductor/pin Conductor/pin to conductor/pin	 >10GΩ >10GΩ
Optical communication wavelength (single-mode)	1550nm & 1625nm

© 2010 All rights reserved

Parameter	Performance
Optical communication wavelengths (multi-mode)	850nm & 1300nm
Maximum optical insertion loss (per mated connector pair) as defined within G.671	0.5dB single-mode 1dB multi-mode
Maximum insertion loss per fusion splice (as measured or estimated by fusion splicer)	0.05dB
Maximum optical cross talk between lines	-60dB
Optical power handling capability	200mW
Maximum optical return loss for single-mode	UPC ≥30dB, 75%≥45dB APC ≥45dB, 75%≥55dB Other technology≥20dB
Minimum number of mate/de-mate cycles for wet-mate connectors	250 Electric / 100 Optic
Connector/jumper assembly maximum handling load - jumper to connector interface	2500N
Jumper assembly minimum breaking strength - jumper to connector interface	5000 N
Maximum ROV mate de-mate force required	750 N
Maximum applied ROV force (damage)	5000 N
Jumper Minimum Bend Radius (MBR)	To be defined by manufacturer
Connector/jumper assembly design test temperature 2)	-25^{0}C to 50^{0}C
Temperature ratings	According to API17F extended ratings
Minimum requirement to maximum mating speed under operating conditions	0.5m/s
Minimum requirement to maximum de-mating speed under operating conditions	1m/s
Maximum mating and de-mating speed in dry condition at temperatures below operating conditions, reference is made to test temperatures in API 17F table 2 Temperature rating - subsea installed equipment	To be defined by manufacturer

1) Maximum in-rush current values listed are applicable for typical subsea control system electronics. Where other loads are connected, in-rush current requirements shall be evaluated on a case by case basis.

2) This is considered suitable test temperature including margins to comply with the applicable API temperature ratings.

© 2010 All rights reserved

7 Design Requirements

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

The principle of the wet-mate connector (see Figure 1) and jumper assembly design shall be as follows:

1. Double water blocking barriers shall be provided between seawater and electrical conductors. The integrity of both barriers shall be capable of being tested during qualification testing and a minimum of one shall be testable during Factory Acceptance Testing (FAT).
2. The connector shall utilize double barrier sealing of the electrical elements for at least one of the 2 connector halves when in the unmated condition.
3. The inner barrier is the barrier formed closest to the electrical conductor.
4. Water blocking from the back-end, cable termination area of the connector, to the front-end of the connector shall be provided.
5. Water blocking from the front-end of the connector to the rear cable termination area of the connector shall be provided.
6. The pressure integrity and water blocking methodology shall be demonstrated via qualification.
7. The connector shall provide means for termination of hose assembly with adequate strain relief and provide support for each individual wire/fiber terminated within the connector.
8. The electrical contacts shall be robustly constructed irrespective of the current/power requirements. The contacts shall preferably be gold plated.
9. The connector pins shall not be capable of physical contact with the opposing connector pins during primary engagement to ensure that the connector pins do not experience any primary connector alignment forces.
10. The design shall cater to applications requiring that more than one independent AC electrical circuit be provided through the same connector allowing for the potential of 180^{o} phase difference between adjacent electrical circuits.
11. The connector shall be qualified and supplied both in straight and angled termination form.
12. A design review shall be performed by the appropriately qualified personnel and shall include:
    - A review of the detailed design
    - Methods of water barriers and insulation towards connections and cabling
    - Evaluation of defined stroke lengths for electrical engagement, optical engagement and full engagement
    - Design review topics, attending personnel and review results shall be documented
13. All materials shall be identified and verified fit for use in the connector's application.

© 2010 All rights reserved

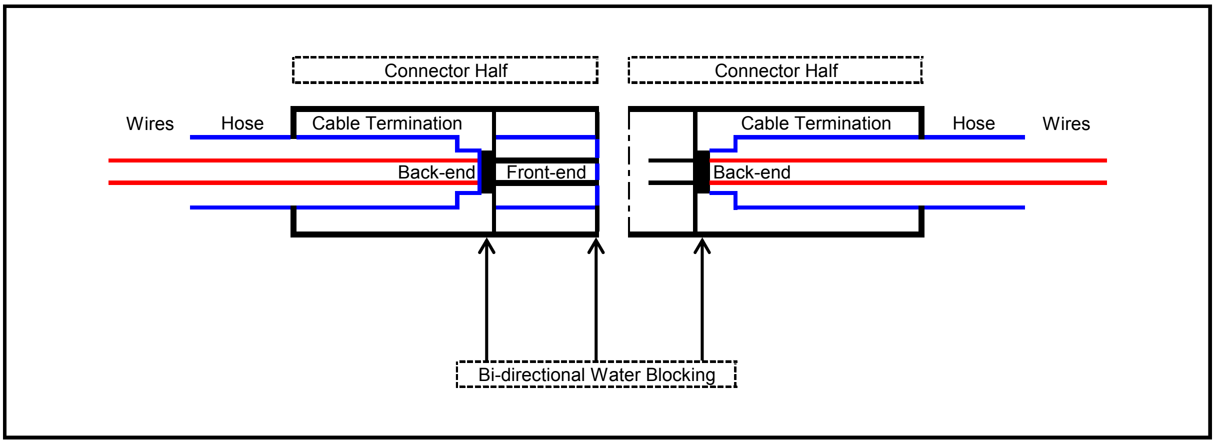

Figure 1: Principle Components of a Connector Assembly

7.1 Design Requirements for Intervention

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

- Diver
- ROV/ROT
- Hydraulically operated cradle
- Stab plate

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

- Misalignment
- Mating/de-mating speeds
- Stroke
- Mating force
- Break-out force
- Tolerances

All ROV/ROT interface handles shall be coloured orange.

7.2 Subsea Jumper Assembly Requirements

a) The subsea jumpers shall be comprised of dielectric fluid filled hoses containing electric wire and/or optical fibers terminated at each end with the appropriate connector half.

b) Sufficient overlength of electrical wires and optical fibers shall be provided within the jumper assembly to accommodate for maximum elongation of the hose assembly.

c) All subsea jumpers and hose assemblies shall be pre-charged in order to maintain a positive internal overpressure of minimum 0.3 bar under all conditions of surface and subsea temperature and pressure (including during deployment). The pre-charge pressure shall not cause a strain in the hose material which adversely affects ozone or ultraviolet resistance.

d) Consideration shall also be given to jumper hose materials during storage under the action of ozone and ultraviolet light both whilst under internal pre-charge and lashed to structure

© 2010 All rights reserved

e) Electrical insulation of wires in jumpers shall not be in direct contact with any conducting material with earth potential.

7.3 Optical Fiber Requirements

Compatibility of selected fiber type with pressure compensation fluid shall be verified.

Compatibility between fibers used in jumper/umbilical and connector pigtails shall be verified to ensure the pass criteria for a fusion splice can be achieved.

Full details of this interface shall be agreed between interfacing contractors. This data will be project specific and shall include the optical fiber type, coating and protective outer jacket.

© 2010 All rights reserved

8 Material Testing Requirements

8.1 General

The connector assembly shall be designed and tested to consist of proven materials, which are qualified and suitable for relevant equipment, applications and environments for the lifetime specified. NORSOK M-001 should be used as the reference standard for the selection of materials and material testing.

A materials selection report shall be made available for review when requested by the user/purchaser and all material data sheets shall be according to NORSOK M-630. All of the materials in the design and construction of the subsea connectors shall have a documented material specification and all of the components supplied shall conform to the material specifications.

Each connector assembly and its individual parts shall be documented as 100% traceable, enabling comparison and rectification on similar connector assemblies. Therefore, the materials, manufacturing records and the test results shall ensure full traceability for each connector assembly.

The compatibility of all materials, with the service environment and with each other, shall be documented according to requirements and its testing methodology given in the applicable parts of NORSOK M-710.

The polymeric and elastomeric materials used for sealing and/ or insulation shall be compatible with the service environment. Fluid compatibility shall also be documented for the following cases:

a) Connector mated (or with dummy cap): Mineral oil/diesel, synthetic base hydraulic fluid, water based hydraulic fluid, Glycol.
b) Connector unmated, exposed for one hour: 50% citric acid/50% water and 50% acetic acid/50% water.
c) Connector mated and unmated, effects on material and connector integrity to be described with considerations for various concentrations of Xylene, Methanol, and MEG.

Testing performed to standards other than those defined herein may be acceptable, based on comparative qualification between the applicable standards. Qualification testing of new materials, new combinations of materials or bonding between materials shall be performed to documented acceptance criteria. New is defined as new material grade or materials not used in similar equipment, applications and/or environments.

Dielectric oils shall be carefully selected, considering density relative to water, such that potential migration and/or ingress of water do not gather in critical areas within the connector assembly – potentially leading to reduction of service life.

New non-metallic sealing and barrier materials, new combinations of materials or bonding between materials shall be tested and qualified to prove its ability to withstand the thermal, electrical and mechanical stresses it may be exposed to. The test program should typically include, but not be limited to:

© 2010 All rights reserved

a) Compatibility tests
b) Disc bursting tests (for insert moulding materials, e.g. epoxy)
c) Bonding tests

The test program and acceptance criteria shall be based on applicable parts of NORSOK M-710. Connectors qualified and tested according to this specification are not to be used in applications requiring resistance to rapid gas decompression.

8.2 Metallic Material Requirements

The metallic materials shall be delivered with certificate type 3.1 according to EN 10204.

The composition of all seawater wetted metallic components shall be verified by Positive Material Identification (PMI). The PMI shall be performed as late as possible in the assembly process and the result documented if the client so requires. All testing and traceability documentation shall be available for review upon request.

8.3 Polymeric and Elastomeric Material Requirements

Non-metallic material shall have batch traceability. The polymeric and elastomeric materials used in connector construction shall be assessed by documentation or by performing a number of qualification tests. This shall establish the material compatibility in the respective environments and also, where applicable, the electrical performance characteristics. The use of elastomers in the connector construction serves two functions: environmental protection and electrical insulation. The environmental protection is designed to provide oil resistance and mechanical sealing performance.

The materials shall be delivered with an ISO 10204, type 3.1 certificate. Batch testing shall be performed according to methods described in ISO 10204 section 6.1. For special cases where burst disc or bonding performance is a part of the design, the batch testing shall be performed according to 6.3 and 6.3, respectively.

The properties for thermoplastic and elastomeric materials shall be documented as required in NORSOK M-710. In addition, each batch of material used to produce sealing and/or insulation materials shall be tested to document satisfactory properties according to NORSOK M-710. All results shall be recorded on material data sheets that indicate the specific testing it was derived from.

The supplier/manufacturer shall establish acceptance criteria based on documented material properties and the following guidelines; where a maximum value is given, the result shall be +0% -20%. Where a minimum value is given, the result shall be -0% +20%.

8.4 Other Material Requirements

The supplier/manufacturer shall have documented material specifications applicable to all materials which are included within the connector assembly. These material specifications shall include the parameters necessary to ensure repeatable performance of the design.

8.4.1 Burst Disc Testing

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

© 2010 All rights reserved

For each batch of inserts produced, a disc shall be cast from the same material and cured under the same conditions as the inserts. The disc is then machined to a nominal thickness of 3.5mm. The exact thickness is recorded and the disc subjected to hydrostatic pressure until failure. Calculations relating thickness and diameter to bursting pressure will determine the material strength and ascertain if expected results are being attained.

The calculation used is:

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

Where p = bursting pressure [psi] t = thickness of disc [inches]

The test procedure may alternatively be performed on samples representing the final product. The tested strength shall be related to the design strength which shall not be lower than 1087.5 psi.

8.4.2 Bonding Tests

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

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

- Peel Strength per ASTM D903-98
    - The intentions of the standard shall be adhered to within the bounds of economy. A simple spring balance and lead screw drive at 6 ins/min will suffice. The peel strength shall be reported in kg/mm
- Lap Shear Strength per ASTM D3164-03
    - The shear strength shall be reported in MPa
- Seawater Immersion
    - The specimens are prepared similarly to test D3164 and then immersed in salt water 60°C for 72 hours. The lap shear test is performed and any reduction in strength is observed and documented

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

© 2010 All rights reserved

9 Operational and Installation Requirements

The listed requirements shall be applied to all connector designs, as applicable:

a) The connector qualification requirements do not include mate/de-mated with power applied. The consequence of accidental mate/de-mate shall be defined.
b) As a minimum, one half of the wet-mate connector pair shall be designed for subsea operation at full rated voltage in the unmated condition.
c) The connector, if standing alone, shall be fitted with a robust locking mechanism to prevent accidental or vibration-induced disengagement or malfunction.
d) The connector shall have a self-evident means to indicate that it has reached the fully mated condition. For wet-mate connectors the indication shall be visible from an ROV camera.
e) The wet-mate connector shall be designed for operation in the presence of sand and silt as a defined qualification. The design shall not be inclined to seizure due to the entrapment of sand particles during mating or de-mating.
f) The wet-mate connector shall be capable of both vertical and horizontal operation.
g) If parts of the connector are connected to a cathodic protection system, prevention of calcite deposits (on exposed working or other relevant surfaces) and electro-chemical action in seawater shall be catered for (e.g. protective coating).
h) The connector design shall accept some calcite deposits, marine growth and debris without jamming or interfering with mating/de-mating action.
i) The connectors are required to be maintenance free during subsea operation and lifetime but shall be able to be refurbished/maintained during suitable opportunities following retrieval. The recommended maintenance procedures shall be provided. If relevant, provisions shall be made for renewing the dielectric fluid each time the connector is taken to the surface.
j) The connector shall be capable of being water-jetted clean of marine growth in the mated condition only. The potential risks of performing this water-jetting upon an unmated connector shall be clearly defined.
k) The operation and maintenance manual shall cover cleaning and maintenance for all conditions including sand and dust at all stages from connector FAT to operation and retrieval.
l) The connector shall be capable of being acid cleaned subsea, with both 50% citric and acetic acid solution and brushed with a purpose made ROV brushing tool to remove calcite growth.
m) Prevention of jamming shall be catered for, special attention required where connector orientation is obtained via keyways within the connector body.
n) The connector body shall contain a clearly visible means of indicating correct rotational alignment to the keyway prior to engagement.
o) The wet-mate connector shall be capable of tolerating worst case, applied mating forces (in the connector's axial direction) of greater than 5000N.
p) Transport protection shall be provided for the connector parts and used during transportation.
q) All precautions required for air freight of pre-pressurised equipment shall be highlighted within the Handling, Packing, Storage and Shipping procedures/guidelines.
r) The connector shall be capable of being deployed, retrieved or simulated in a hyperbaric chamber of a minimum rate of change of 35bar/min.

© 2010 All rights reserved

10 Qualification Testing Requirements

10.1 General

The objective of the design qualification testing is to validate that each new connector/ jumper assembly type (design) is fit for its intended purpose, is capable of achieving its defined ratings and therefore, these can be considered type tests.

The validity of the qualification testing should periodically be reassessed and documented according to supplier/manufacturer documented procedures.

The qualification testing should periodically be reassessed and documented. Relevant parts of qualification testing should, as a minimum, be repeated every 5 years even if the connector or jumper design is considered unchanged.

The supplier/manufacturer shall establish and implement requirements which are approved by a qualified person(s) for calibration of measuring/testing equipment. Inspection, measuring and testing equipment used for acceptance shall be used within its calibrated range. Measurement equipment shall be identified, controlled, calibrated and adjusted at specific intervals in accordance with the supplier/manufacturer requirements which conform to a national or international standard.

Documented testing procedures shall identify the required measurement parameters and acceptance criteria. The acceptance criteria shall include the test instrument tolerances. Visual examinations shall be recorded within the test documentation. All measured parameters shall be documented in the test report. Acceptance criteria shall be focused to detect inherent weaknesses in components and connections, and not limited to “fit for use” evaluations. The acceptance criteria shall be defined as the minimum requirements for testing.

The simulated worst case seawater shall be used in all tests requiring seawater and shall meet the following requirements:

a) Salinity according to ASTM D1141-98.
b) The distribution of particle size shall be approximately flat between 2-500 microns. Typically 1% river silt (2-50 microns) and 0.5% builders’ soft and sharp sand (50-500 microns) may be used.
c) The composition and temperature of the seawater shall be established, recorded and verified prior to testing, and circulation shall be provided and maintained during the testing.

10.2 Qualification Testing Summary

All connector and jumper assembly designs to be delivered shall first pass a qualification test program. There is no required sequence of the testing, therefore, the supplier/manufacturer can choose to perform tests in parallel or in a sequence different from that described in this specification. Refurbishment of the connector is allowed between tests. Each connector and jumper assembly undergoing qualification testing shall be identified with a serial number prior to the commencement of the tests.

The qualification testing shall, as a minimum, be based on the specifications and acceptance criteria defined in this specification’s and the supplier/manufacturer’s design requirements.

© 2010 All rights reserved

Qualification testing shall be performed on a minimum of 3 units in each test. The actual number of units required shall be assessed for each test. Design changes made during the testing process shall be documented as per the design changes portion of this specification.

All detailed drawings used to manufacture the qualification tested connector shall be listed and stored to enable comparison between the tested items and identical (or close to identical) items which are manufactured later.

Supplier/manufacturer shall include in the qualification documentation:

- Operational temperature versus the temperature utilized during the testing, and the correlation of the test results to the performance at the rated temperature.
- The sequence of the qualification testing and location at which the qualification testing was performed.
- All deviations from specified requirements within one test and between tests shall be highlighted, justified and explained.
- An assessment of the supplier/manufacturer's Quality Assurance System.

The proposed qualification testing program can be divided into the following sections:

Table 2: Summary of Connector Qualification Testing

Summary of Connector Qualification Tests		
Test Type	**Qualification Test**	**Section**
Electrical	Contact Resistance-light and rated current	10.3.1.1
	Shell Continuity	10.3.1.2
	Insulation Resistance	10.3.1.3
	Proof Voltage	10.3.1.4
	Partial Discharge	10.3.1.5
	Temperature Rise	10.3.1.6
	High Voltage Breakdown	10.3.1.7
	Long-Term DC Voltage	10.3.1.8
	Ethernet -Table 29 (if applicable)	12.7.10
Optical	Optical Insertion loss	10.3.2.1
	Optical Crosstalk	10.3.2.2
	Optical Return Loss	10.3.2.3
Mechanical	Gas Leak	10.3.3.1
	Maximum Misalignment	10.3.3.2
	Locking Device	10.3.3.3
	Mating Forces	10.3.3.4
	Dry-mating over temperature range	10.3.3.5
Turbid Tank	WetMating	10.3.4.1
	Partial Mating	10.3.4.2
	Post Turbid Tank Test Inspection	10.3.4.3
Flooded Connector Test	Flooded Connector Back-End	10.3.5.1
	Long Term Flooded Connector	10.3.5.2
	Flooded Connector Front-End	10.3.5.3
	Mating Durability Test	10.3.5.4

© 2010 All rights reserved

Environmental Stress Tests	Thermal Shock	10.3.6.1
	Mechanical Shock	10.3.6.2
	Vibration	10.3.6.3
	Drop test of Connector	10.3.6.4

Table 3: Summary of Hose and Hose Termination Qualification Testing

Summary of Hose and Hose Termination Qualification Tests		
Test Type	**Qualification Test**	**Section**
Environmental Stress Tests	Absorption/Compensation	10.4.1.1
	Ozone Resistance	10.4.1.2
	Ultraviolet Resistance	10.4.1.3
	Thermal Shock	10.4.1.4
Destructive Testing	Tensile Failure	10.4.2.1
	Burst Pressure	10.4.2.2
	Crush Resistance	10.4.2.3
	Outer Sheath Abrasion	10.4.2.4
	Hose Kink Testing	10.4.2.5

Table 4: Summary of Jumper Assembly Qualification Testing

Summary of Jumper Assembly Qualification Testing		
Test Type	**Qualification Test**	**Section**
Environmental Stress Tests	Oscillating Jumper Test	10.5.1.1
	Jumper Pull Test	10.5.1.2
	Drop Test	10.5.1.3
	Jumper Handling Simulation	10.5.1.4
	Simulated Jumper Assembly Deployment	10.5.1.5
	Jumper Snag	10.5.1.6
Electrical / Optical Tests	Flooded Jumper Assembly Ethernet	10.5.2.1
	Partial Discharge	10.5.2.2
	Jumper Assembly Impedance	10.5.2.3
	Ethernet -Table 29 (if applicable)	12.7.10

Table 5: Summary of Connector Qualification Testing (Dry-mate)

Summary of Connector Qualification Tests (dry-mate)		
Test Type	**Qualification Test**	**Section**
Electrical	Contact Resistance - light and rated current	10.3.1.1
	Shell Continuity	10.3.1.2
	Insulation Resistance	10.3.1.3
	Proof Voltage	10.3.1.4
	Partial Discharge	10.3.1.5
	Temperature Rise	10.3.1.6
	High Voltage Breakdown	10.3.1.7

© 2010 All rights reserved

	Long-Term DC Voltage	10.3.1.8
	Ethernet -Table 29 (if applicable)	12.7.10
Optical	Optical Insertion Loss	10.3.2.1
	Optical Crosstalk	10.3.2.2
	Optical Return Loss	10.3.2.3
Mechanical	Gas Leak	10.3.3.1
	Locking Device	10.3.3.3
	Mating over Temperature Range	10.3.3.5
Flooded Connector Test	Flooded Connector Back-End	10.3.5.1
	Long Term Flooded Connector	10.3.5.2
Environmental Stress Tests	Thermal Shock	10.3.6.1
	Mechanical Shock	10.3.6.2
	Vibration	10.3.6.3
	Drop test of Connector	10.3.6.4

Table 6: Summary of Jumper Assembly Qualification Testing (Dry-Mate)

Summary of Jumper Assembly Qualification Testing (dry-mate)		
Test Type	**Qualification Test**	**Section**
Environmental Stress Tests	Oscillating Jumper	10.5.1.1
	Drop	10.5.1.3
	Jumper Handling Simulation	10.5.1.4
	Simulated Jumper Assembly Deployment	10.5.1.5
Electrical / Optical Tests	Flooded Jumper Assembly Ethernet	10.5.2.1
	Partial Discharge	10.5.2.2
	Jumper Assembly Impedance	10.5.2.3
	Ethernet -Table 29 (if applicable)	12.7.10

Table 7: General Material Qualification and Batch Testing

General Material Qualification and Batch Testing		
Test Type	**Qualification Test**	**Section**
Material Testing	Material Batch Testing	8.3
	Burst Disc Test	8.4.1
	Material Bonding Test	8.4.2

© 2010 All rights reserved

10.3 Connector Qualification Testing

10.3.1 Electrical Testing Requirements

10.3.1.1 Contact Resistance

The objective of this testing is to measure contact resistance between two wet or dry-mated contacts in two mating connectors.

10.3.1.1.a Method

Light current test: The contact resistance of individual contacts shall be measured with direct current not exceeding 50mA. During the measurements the open circuit source voltage shall not exceed 20mVDC.

The contact resistance shall either be derived from the voltage drop measured between the points (i.e. solder pots/crimping points) intended for connection of the wiring to the contacts (at rated current only) or by using an ohm-meter (4-wire Kelvin type measurement) giving the same measuring accuracy. When measured as line resistance, i.e. with external leads, the wire resistance have to be measured and verified before the connector to cable termination is completed. In no case shall the resistance of the wires cause reduced accuracy in the measurement significant for the test result. Actual measurements shall be recorded.

Rated current test: The contact resistance of individual contacts shall be measured at the DC current rated value of the connector. During the measurements the open circuit source voltage shall not exceed 2.5V DC.

10.3.1.1.b Acceptance Criteria

The acceptance criteria shall be less than 30mΩ with no more than ± 10 mΩ difference between pins.

10.3.1.2 Shell Continuity

Shell continuity shall be for connectors with cathodic protection. The objective of this testing is to determine the resistance between connectors having metallic housings intended to provide electrical continuity when mated.

10.3.1.2.a Method

Measurements shall be made on mated connectors using equipment as prescribed for test conditions in section 8. Connections for this test shall be made to the braid or shell connecting wire for free connectors and to the mounting flange for fixed connectors. Actual measurements shall be recorded.

10.3.1.2.b Acceptance Criteria

The acceptance criteria shall be less than 0.1Ω

10.3.1.3 Insulation Resistance

The objective of this testing is to quantify the insulation resistance between:

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

© 2010 All rights reserved

10.3.1.3.a Method

The insulation resistance of individual contacts shall be measured with an instrument with a minimum measurement scale of 100GΩ. Temperature and humidity shall be recorded.

The test voltage shall be 1000V DC with following exceptions:

- Testing of Ethernet cables in jumpers shall be performed in accordance with the voltage rating of actual cable.
- Testing of jumpers with terminated equipment shall be performed in accordance with the voltage rating of actual terminated equipment.

The connector shall be mated and the test voltage shall be applied for at least 1 min or the time required to get a stabilized reading. Measurements shall be made between all adjacent contact pairs and also outer contact/shell pairs. Actual measurements shall be recorded.

10.3.1.3.b Acceptance Criteria

The acceptance criteria shall be greater than 20GΩ for the connector and greater than 10GΩ for the jumper assembly.

10.3.1.4 Proof Voltage Testing

The objective of this testing is to verify that the insulation and contact spacing is sufficient to prevent flashover, current leakage or insulation breakdown at the connector proof voltage.

10.3.1.4.a Method

A number of proof voltage tests may be performed during assembly, but a final proof voltage test in accordance with this section shall be performed as late as possible in the qualification to ensure that the connector insulation integrity has not been degraded.

Proof voltage testing shall be performed in accordance with IEC 60502-1 and IEC 60060-1.

The selected proof voltage between conductors shall be 6kV AC. This caters for the connector to be used for two different power pairs that may be in opposite phase. Remaining conductors not subject to test shall be connected to earth.

The selected proof voltage between each conductor and the shell (earth) with remaining conductors connected to earth shall be 4.5kV AC.

Proof voltage testing of Ethernet cables in jumpers shall be performed in accordance with the test voltage rating of actual cable. Proof voltage testing of jumpers shall be performed in accordance with the test voltage rating of actual terminated equipment.

The proof voltage shall be applied for 4 hours. All results shall be recorded as absolute values.

© 2010 All rights reserved

10.3.1.4.b Acceptance Criteria

The acceptance criteria shall include the following:

a) No evidence of insulation breakdown
b) No evidence of flashover
c) Current leakage shall be measured and logged

10.3.1.5 Partial Discharge Testing

The objective of this testing is to verify that the connector's electrical insulation properties with regards to design and build quality are within acceptable limits.

The test setup and associated wiring arrangement shall reflect that the aim is to find the PD levels for the connector and termination including boot seals. The earth potential shall be brought as close as possible to the isolation material corresponding to a flooded back-end test and connected to connector housing.

10.3.1.5.a Method

This test shall be performed both before and after the HV proof test (i.e. test to be performed as part of the HV proof test).

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

10.3.1.5.b Acceptance Criteria

The acceptance criteria shall be – one connector with a suitable pigtail:

- PD level < 10pC @ 2.5kV
- PD level < 50pC @ 4.5kV

Actual measurements shall be recorded. Any unexpected behaviour shall be described and evaluated.

10.3.1.6 Temperature Rise Testing

This test is to verify that the connector will operate as designed (optically/electrically) at the rated current capacity without producing an objectionable over temperature condition. The test temperature ambient shall be according to highest operating temperature, i.e. 40°C according to API17F table 2.

10.3.1.6.a Method

The connector assembly shall be mated and mounted in a framework to allow air circulation around the external shell. Temperature sensors shall be attached to various locations on the connector to enable monitoring of the temperature variations. The location of sensors should be:

a) Ambient temperature.
b) As close as possible to the hottest spot in the connector.
c) At cable terminations.

© 2010 All rights reserved

d) At the hottest spot on external surfaces at each accessible material type.
e) As close as possible to the contact surface between male and female.

The measurements shall commence after the temperature has been established and stable for ½ hour and the test shall continue for 24 hours with measurement intervals of ½ hour. Electronic data storage or a chart recorder with a suitable number of channels is preferred to record the temperature rise. Actual current values and voltage drop shall be recorded in parallel with each temperature measurement. After completion of the test, the connector shall be stripped down to its piece parts and examined for effects and evidence of excessive temperatures. All findings shall be recorded within the final qualification report.

10.3.1.6.b Acceptance Criteria

The acceptance criteria shall include the following:

a) Prior to disassembly electrical performance shall be recorded contact resistance & insulation resistance.
b) No physical damage or burns shall be observed on any of the connector piece parts
c) < 30°C temperature rise

10.3.1.7 High Voltage Breakdown Testing (Destructive)

This test is to verify the connector voltage limits.

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

10.3.1.7a Method

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

With the connectors mated increase, the AC voltage at a rate of max 500VAC/min until breakdown occurs. The breakdown voltage shall be recorded and the point of failure identified by means of photographs.

10.3.1.7b Acceptance Criteria

The acceptance criteria shall be a breakdown at greater than or equal to 8kV AC

Component high voltage breakdown tests consisting of single pin breakdown test are preferred, but are not mandatory.

10.3.1.8 Long Term DC Voltage Testing

The objective of this test is to verify the connector DC voltage performance.

© 2010 All rights reserved

10.3.1.8a Method

Apply 4.1kVDC to mated connector immersed in seawater. One conductor shall be connected to shell (earth) with the remaining conductors connected to the voltage source. The voltage shall be applied for a continuous period of time with three months as the minimum requirement. The temperature of the seawater shall be maintained above 18oC throughout the test. IR shall be monitored (by e.g. leakage current) throughout the test and recorded once a day as a minimum.

The applied formula:

$(t_{system}/t_{test}) = (V_{test}/V_{system})^{n}$

n = empirical coefficient = 4,75

t_{system} = design life

t_{test} = test time

V_{test} = test voltage

V_{system} = rated voltage pin-pin = rated voltage pin-earth

10.3.1.8.b Acceptance Criteria

The acceptance criteria shall be that there is no breakdown of the connector performance over the duration of the test period.

10.3.2 Optical Testing Requirements

10.3.2.1 Optical Insertion Loss (IL) Testing

The objective of this testing is to determine the optical insertion loss of two mated connectors.

10.3.2.1.a Method

The test shall be performed according to IEC 61300-3-4: Fiber optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-4: Examinations and measurements – Attenuation for the following wavelengths:

- 1550nm and 1625nm for single mode
- 850nm and 1300nm for multimode

The purpose of this test is to establish loss figures attributable directly to the DUT without the test-setup in circuit

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

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

© 2010 All rights reserved

10.3.2.1.b Acceptance Criteria

The acceptance criteria shall be calculated according to the criteria in Table 1 for the DUT.

10.3.2.2 Optical Crosstalk Testing

The objective of this testing is to determine the optical crosstalk between each optical line within the connector and all other optical lines within the connector. The optical cross talk attributable to the test equipment shall be established prior to commencing the test.

This test is not applicable if it can be proven, with reference to the mechanical properties of the connector, that crosstalk between individual optical fibers is impossible.

10.3.2.2.a Method

This test may be combined with the optical insertion loss testing test as both utilise the same test equipment.

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

10.3.2.2.b Acceptance Criteria

The acceptance criteria shall be less than or equal to -60dB crosstalk of source signal at all defined wavelengths.

10.3.2.3. Optical Return Loss (RL) Testing

To determine the optical return loss of two mated connectors.

The test shall be performed according to IEC 61300-3-6: Fiber optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss for the following wavelengths:

- 1550nm and 1625nm for single mode
- 850nm and 1300nm for multimode

The purpose of this test is to establish loss figures attributable directly to the DUT without the test setup in circuit.

10.3.2.3.a Method

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

10.3.2.3.b Acceptance Criteria

The acceptance criteria shall be in accordance with the criteria in Table 1.

© 2010 All rights reserved

10.3.3 Mechanical Testing Requirements

10.3.3.1 Gas Leak Testing

This mechanical test is used to verify that seals are correctly fitted and do not leak.

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

The vacuum technique as outlined in this section shall be used for tightness control. If the vacuum technique cannot be used due to the design solution, the sniffer technique as outlined in this section may be considered acceptable for tightness control. However, the sniffer technique has a much lower sensitivity - such that reliable and quantitative results may be challenging to obtain.

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 used 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.

10.3.3.1.1 Vacuum Technique

10.3.3.1.1.a 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 an accuracy better than 1·10-9 mbar·l/s. Temperature and pressure shall be continuously recorded during the testing.
An outline procedure/sequence should be as follows:

1. 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.
2. 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.
3. The mass spectrometer helium rate before and after each purging shall be recorded.

© 2010 All rights reserved

10.3.3.1.1.b Acceptance Criteria

The acceptance criteria is that the reading shall not increase with more than $5 \cdot 10^{-8}$ mbar·l/s during purging with helium.

10.3.3.1.2 Sniffer Technique

10.3.3.1.2.a Method

If the sniffer technique shall be used for tightness control in a serial production, measures to prevent a changing helium to air ratio in the test room/area should be performed.

1. The sealing barriers/termination chamber to be tested should be entirely wrapped (to gather leakages). The sniffer probe should be positioned inside the wrapping at relevant locations (as and where required).
2. There shall be a verified calibration procedure for each sniffer test, i.e. for each sealing barrier/termination chamber to be tested. When developing each calibration procedure, an acceptable sniffer signal shall be documented. Due to the uncertainty related to this sniffer test method, a safety factor of minimum 10 should be applied on the sniffer signal - to account for inaccuracies.

10.3.3.1.2.b Acceptance Criteria

The acceptance criteria shall be based on a documented analysis for each case/design solution that is tested.

10.3.3.2 Maximum Misalignment Testing

The objective of this testing is to demonstrate the correct operation and mounting integrity of the connector at specified worst case misalignment during mating.

10.3.3.2.a Method

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

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

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

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

© 2010 All rights reserved

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

10.3.3.2.b Acceptance Criteria

The acceptance criteria shall include:

a) Mating and de-mating force: According to specifications
b) No damage shall be observed.
c) The connector shall be verified to function as per specification (electrically and optically) after misalignment testing.

10.3.3.3 Locking Device Testing

The objective of this test is to verify correct operation of the locking mechanism and that no mechanical damage occurs to the connector due to the locking mechanism.

10.3.3.3.a Method

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

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

The connector pair shall be engaged by hand or by a simulated ROV, i.e. not in a straight guided manner as by a hydraulic cylinder. The testing in turbid seawater is preferred, but not mandatory for qualification.

10.3.3.3.b Acceptance Criteria

The acceptance criteria shall be an evaluation assessing the ease with which the locking device is activated shall be part of the final qualification report, and no damage observed to either half of the connector pair due to the incorrect orientation of connectors.

10.3.3.4 Mating Forces Testing

The objective of this testing is to measure the forces required for subsea (ROV) mating and evaluate the influence of sand / silt. Testing shall be performed in a turbid seawater tank. Testing at design pressure is preferred, but not mandatory.

10.3.3.4.a Method

This test shall be performed with a bulkhead mount and free connector configuration.
The following measurements of force shall be performed:

- Engagement force - dry and wet
- Disengagement force – dry and wet
- Force at maximum mating speed - dry
- Maximum misalignment forces – dry

© 2010 All rights reserved

10.3.3.4.b Acceptance Criteria

The acceptance criteria shall be that the mating and de-mating forces recorded are within the specified operational characteristics and no damage observed to either halves of the connector pair.

10.3.3.5 Dry Mating Over Temperature Test Range

The objective of this testing is to measure the forces required for connector (ROV) mating over the defined temperature test range of the connector system.

10.3.3.5.a Method

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

The following measurements of force shall be performed:

- Engagement force – both at the low and the high temperature
- Disengagement force – both at the low and the high temperature
- Force at maximum mating speed - both at the low and the high temperature.
- Maximum misalignment forces – both at the low and the high temperature

10.3.3.5.b Acceptance Criteria

The acceptance criteria shall be that the connector is capable of being mated over its full temperature range and no damage observed to either half of the connector pair

10.3.4 Turbid Tank Testing

A pressure vessel filled with chilled seawater is required. An externally controlled mating frame for the mating of the two connector halves shall be installed inside the pressure vessel. The mating frame shall allow for connector orientation and movement in vertical and horizontal axis and fully engage/disengage both connectors. Mounting angle and orientation for final use shall be tested.

When the connectors are fully disengaged a minimum separation distance of 100mm between connectors shall be achieved.

The rate of change of pressure during pressurisation shall be minimum 35 bar/min. The rate of change of pressure during depressurisation shall be minimum 70 bar/min.

While the turbid tests are being performed the seawater shall be continuously agitated to ensure that the solids remain in suspension and are evenly distributed. Agitation may be achieved by a thruster.

The temperature of the seawater shall be maintained between 0^{o}C and 4.5^{o}C throughout the test.

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

Seawater Characteristics to be recorded:

- Seawater conductivity (Ω-1)

© 2010 All rights reserved

- Salinity (ppm)
- Silt (%)
- Sand (%)
- Temperature (^{o}C)

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

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

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

10.3.4.1 Turbid Tank Wet Mating Testing

The objective of this testing is to verify the connector performance as specified for the minimum of mate/de-mate cycles in Table 1 within a turbid environment.

10.3.4.1.a Method

The connector shall be mounted in a special test rig for performing mating operations in a manner that simulates normal mounting. Both a vertical mounting and a horizontal mounting are considered base cases, but consideration shall be done with respect to the application for the connector and "worst case" angles. Alternative angles or tilting of connector in testing can be relevant dependent on the actual application.

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

The first mating shall be performed at ambient pressure, the next 2 matings at approx. 0.5 times design pressure, and the next 2 matings at connectors test pressure. Sequence shall be repeated 3 times (4 in total). The remaining matings shall be performed at connectors test pressure. The pressure shall then be released (to ambient) and the connector shall be examined externally for damage/defects.

Initially the following test shall be conducted:

Pre and Post Turbid Tank Testing
- Contact resistance
- Shell continuity
- Insulation resistance
- Optical insertion loss and return loss

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

© 2010 All rights reserved

Intermediate testing
- Contact resistance
- Shell continuity
- Insulation resistance
- Optical insertion loss and return loss

During each de-mate operation the connectors shall remain fully separated (minimum 100mm) for a period of no less than 1 min.

Measurements shall be performed and recorded during each of the 1st 20 matings. Thereafter measurements shall be performed and recorded at each 5th mating until the specified total number of matings has been achieved.

Table 8: Turbid Tank Testing Sequence

Turbid Tank Test Sequence		
Mating Cycle	**Pressure**	**Test Type**
0	Ambient – dry	Pre/Post
1	Ambient – wet	Intermediate
2 and 3	0,5 x test pressure	Intermediate
4 and 5	Test pressure	Intermediate
Hold for 60 min and reduce to ambient		
6	Ambient – wet	Intermediate
7 and 8	0,5 x test pressure	Intermediate
9 and 10	Test pressure	Intermediate
Hold for 60 min and reduce to ambient		
11	Ambient – wet	Intermediate
12 and 13	0,5 x test pressure	Intermediate
14 and 15	Test pressure	Intermediate
Hold for 60 min and reduce to ambient		
16	Ambient – wet	Intermediate
17 and 18	0,5 x test pressure	Intermediate
19 and 20	Test pressure	Intermediate
Hold for 60 min		
21 to 120	Test pressure	Intermediate
Hold for 60 min		
121 to 220	Test pressure	Intermediate
Hold for 60 min		
221-250	Test pressure	Intermediate
Reduce to ambient pressure		
251	Ambient – dry	Pre/Post

© 2010 All rights reserved

10.3.4.1.b Acceptance Criteria

The acceptance criteria shall be that the connector's electrical and optical performance shall remain within specification and no damage observed to connector during post-test visual examination. Upon completion of the test sequence the connectors shall be examined externally for damage/defects.

10.3.4.2 Turbid Tank Partial Mating Testing

The objective of this testing is to verify the connector performance as specified for a minimum of 20 mate/de-mate cycles that are interrupted at various stages within a turbid environment.

10.3.4.2.a Method

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

Pre and Post Partial Mating Turbid Tank Testing
- Contact resistance
- Shell continuity
- Insulation resistance
- Optical insertion loss and return loss

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

Intermediate Testing
- Contact resistance
- Shell continuity
- Insulation resistance
- Optical insertion loss and return loss

The total number of matings shall be no less than 20, which shall include:

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

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

10.3.4.2.b Acceptance Criteria

The acceptance criteria shall be that the connector's electrical and optical performance shall remain within specifications. No damage observed to connector during post-test visual examination.

10.3.4.3. Connector Inspection Post Turbid Tank Testing

The objective of this testing is to establish the level of wear and contamination external and internal to the connector after completion of the Turbid Tank Testing.

© 2010 All rights reserved

10.3.4.3.a Method

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

- Visual inspection for damage and wear
- Assessment of accumulation of solids on critical interface surfaces
- Analysis of contamination of dielectric fluid within primary and secondary fluid filled chambers (water, salt, silt and sand content)
- Water, salt and silt content of fluid filled enclosures to be quantified and the supplier shall assess the impact of this upon the operation of the connector over its lifetime
- Insulation resistance of dielectric fluid

10.3.4.3.b Acceptance Criteria

The acceptance criteria shall include the following:

- No damage observed to connector (excluding wear upon interfacing surfaces)
- The accumulation of solids on the external body of the connector shall not interfere with the correct operation of the connector
- Insulation resistance of dielectric fluid samples to quantified

10.3.5 Flooded Connector Testing

10.3.5.1 Flooded Connector Back-End Testing

The objective of this testing is to verify that the connector will continue to operate even if salt water breeches the oil filled hose. During this test the conductor insulation and the connector to conductor sealing mechanism shall be the only barriers between the seawater and the live conductor.

10.3.5.1.a Method

The free half of the connector pair shall be terminated to individual wires in the approved manner. The specified method of water blocking between the wire insulation jacket and the connector shall be fitted, duplicating the actual termination itself. A gas leak check shall then be performed in accordance with section 11.2.3.1 before the modification of the unit subject to test.

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

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

- Contact resistance
- Shell continuity (if applicable)
- Insulation resistance
- Optical insertion loss and return loss

The complete assembled unit will be loaded into a pressure vessel that will be filled with seawater.

© 2010 All rights reserved

Pressure shall be cycled between ambient and overpressure corresponding to performance requirements in section 6. Gradient during pressurisation shall be minimum 35 bar/min. Gradient during depressurisation shall be minimum 70 bar/min. Pressure and temperature within the pressure vessel shall be continuously recorded throughout the test.

At the end of the test while pressure is still at highest test pressure, insulation resistance, optical insertion loss and return loss shall be measured and recorded.

The following hydrostatic pressure sequence shall be performed as shown in Table 9.

Table 9: Flooded Connector Back-end Testing

Flooded Connector Back-End Test Sequence		
Step	**Pressure**	**Test Type**
0	Ambient - dry	Pre/Post
1	Ambient - wet allow connector to soak for 15 min	None
2	Increase pressure from ambient to test pressure at minimum 35 bar/min rate of change	None
3	Hold at test pressure for 20 min	None
4	Decrease pressure from test pressure to ambient at minimum 70 bar/min rate of change	None
5	Hold at ambient pressure period for 15 min	None
6	Repeat steps 2 to 5 for a total of 25 cycles. Test on final hold at test pressure	Pre/Post
7	Ambient – dry	Pre/Post

10.3.5.1.b Acceptance Criteria

The acceptance criteria shall be that the connector’s electrical and optical performance shall remain within the documented specifications.

10.3.5.2 Long Term Flooded Connector Testing

The objective of this testing is to verify the long-term performance of the electrical system with both the rear and the front of the connector flooded in seawater. The primary seal shall be removed before testing both for back-end and front-end seal.

10.3.5.2.a Method

The test shall be performed with the same test-set-up for the flooded connector back-end testing but in addition the primary seal at the front-end shall be removed. The test shall be maintained at a constant pressure according to test pressure in Table 1 and only the electrical insulation performance shall be monitored.

Insulation measurements shall be performed daily until completion of the 1,000 hours with all results documented and included within the final qualification report.

© 2010 All rights reserved

10.3.5.2.b Acceptance Criteria

The acceptance criteria shall be that the connector's electrical insulation resistance remains greater than 10GΩ.

10.3.5.3 Flooded Connector Front-End Testing

The objective of this testing is to verify that the connector will continue to operate even if salt water breeches the front primary seal. During this test the conductor insulation and the connector to conductor sealing mechanism shall be the only barriers between the seawater and the live conductor. The process to achieve the correct flooded status of the connector in the test setup shall be described on a per connector basis.

10.3.5.3.a Method

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

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

- Contact resistance
- Shell continuity (if applicable)
- Insulation resistance
- Optical insertion loss and return loss

The complete assembled unit will be loaded into a pressure vessel that will be filled with seawater.

Pressure shall be cycled between ambient and overpressure corresponding to performance requirements in Table 1. Pressure gradient during pressurisation shall be minimum 35 bar/min. Pressure gradient during depressurisation shall be minimum 70 bar/min. Pressure and temperature within the pressure vessel shall be continuously recorded throughout the test.

At the end of the test while pressure is still at highest test pressure, insulation resistance, optical insertion loss and return loss shall be measured and recorded.

The hydrostatic pressure sequence shall be performed as shown in Table 10:

Table 10: Flooded Connector Front-end Testing

Flooded Connector Front-End Test Sequence		
Step	**Pressure**	**Test Type**
0	Ambient - dry	Pre/Post
1	Ambient - wet allow connector to soak for 15 min	None
2	Increase pressure from ambient to test design pressure at minimum 35 bar/min rate of change	None
3	Hold at test pressure for 20 min	None
4	Decrease pressure from test design pressure to	None

© 2010 All rights reserved

	ambient at minimum 70 bar/min rate of change	
5	Hold at ambient pressure period 15 min	None
6	Repeat steps 2 to 5 for a total of 25 cycles. Test on final hold at test pressure	Pre/Post
7	Ambient – dry	Pre/Post

10.3.5.3.b Acceptance Criteria

The acceptance criteria shall be that the connector's electrical and optical performance shall remain within documented specifications.

10.3.5.4 Mating Durability Testing

The objective of this testing is to verify the connector's electrical and optical performance remains within acceptable limits after 1000 mate/de-mate cycles have been performed. This high requirement is due to the proven difficulties in keeping track of test connector usage, and the test connector's potential impact on the connectors to be installed subsea. This test is not required if the test connectors have an automatic built-in feature limiting the allowed number of matings e.g. by alarm or disabling of functionality.

10.3.5.4.a Method

Both connector halves shall be arranged for mating in a pressure vessel. The initial 750 of the mate/de-mate cycles shall be performed dry and the remaining 250 cycles to be performed in seawater conditions at design pressure.

Prior to commencing the durability testing and upon completion of the initial dry part, and at completion of the durability testing (pre and post) the following tests shall be performed:

- Contact resistance
- Shell continuity (if applicable)
- Insulation resistance
- Optical insertion loss and return loss

The complete assembled unit will be arranged for 750 mate/de-mate operation in dry condition.

Connector performance shall then be verified, the connector shall be loaded into a pressure vessel and the pressure vessel shall then be filled with seawater.

Pressure shall be set to an overpressure corresponding to the design hydrostatic pressure. Gradient during pressurisation shall be minimum 35 bar/min. Gradient during depressurisation shall be minimum 70 bar/min. Pressure and temperature within the pressure vessel shall be continuously recorded throughout the test.

At the set condition shall the connector finalize the 250 mate/de-mate cycles.

At the end of the test while pressure is still at design hydrostatic pressure, insulation resistance, optical insertion loss and return loss shall be measured and recorded.

The above described test is summarized in the test sequence of Table 11.

© 2010 All rights reserved

Table 11: Connector Duration Testing

Connector Duration Test Sequence		
Step	**Pressure**	**Test Type**
0	Ambient – Dry	Pre /Post
1	750 mate/de-mate cycles in dry.	None
2	Verify connector performance	Pre /Post
2	Fill chamber and allow connectors to soak for 15 min	None
3	Increase pressure from ambient to test pressure at minimum 35 bar/min rate of change	None
4	Hold at test pressure for 20 min	None
5	250 mate/de-mate cycles in seawater at design pressure	None
6	Perform verification test	Pre/Post
6	Decrease pressure from design pressure to ambient at minimum. 70 bar/min rate of change	None
7	Ambient – dry	Pre/Post

10.3.5.4.b. Acceptance Criteria

The acceptance criteria shall be that the connector's electrical and optical performance shall remain within the documented specifications.

10.3.6 Environmental Stress Testing

10.3.6.1 Thermal Shock Testing

The objective of this testing is to verify that thermal shock produces no detrimental effects on the connector.

10.3.6.1.a Method

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

The tests are to be performed at atmospheric pressure:

a) The temperature shall be raised to 70°C and maintained for a period of minimum 4 hours. The connectors shall then be rapidly cooled by immersion in a water bath, the temperature of which shall be between 0°C and 4.5°C.
b) Repeat the above sequence twice more.
c) Allow the connector to return to ambient room temperature.
d) Inspect the assembly for physical damage together with electrical insulation measurements (unmated and mated) and optical insertion loss and return loss measurements (mated).
e) The temperature of each assembly shall be lowered to -40°C and maintained for a period of minimum 4 hours.

© 2010 All rights reserved

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

g) Repeat the above sequence a further 2 times and allow the connector to return to ambient room temperature. Inspect and test as above.

10.3.6.1.b Acceptance criteria

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

10.3.6.2 Mechanical Shock Testing

The objective of this testing is to verify that the connectors (with electrical cables and optical fibers) are sufficiently rugged to withstand rough handling and the loads which may be generated when integrated within a system.

10.3.6.2.a Method

Each half of the connector pair shall be subjected to 3 shocks in 6 orthogonal directions (+/- of normal Cartesian). The profile of the shocks shall be of a half sine period of 11ms at 30g.

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

- Contact resistance
- Shell continuity (as applicable)
- Insulation resistance
- Optical Insertion loss and return loss
- Proof voltage

10.3.6.2.b Acceptance Criteria

The acceptance criteria shall be that no damage shall be observed on either half of the connectors. The connector halves shall mate together and the results of the electrical and optical testing are within the connectors design specifications.

10.3.6.3 Vibration Testing

The objective of this testing is to verify that the connectors (with electrical cables and optical fibers) are sufficiently rugged to withstand handling loads which may be generated in transit.

10.3.6.3.a Method

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

The electrical cables and optical fibers may be anchored to the test fixture if required.
The following excitation shall be applied to 3 mutually perpendicular axes. The axes shall be selected to maximise the probability of detecting faults in the design. The excitation level shall be:

- 5 Hz to 25 Hz +/- 2mm displacement
- 25 Hz to 150 Hz 5g acceleration

© 2010 All rights reserved

- Sweep rate maximum one octave/min
- A double sweep from 5 Hz to 150 Hz and back to 5 Hz shall be performed

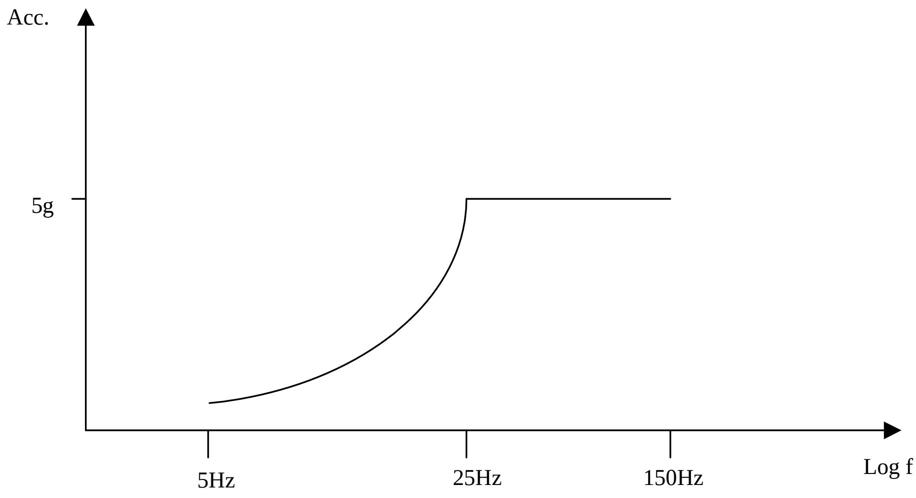

Figure 2: Acceleration (g) Over Mechanical Vibration Frequency

NOTE: Some vibration test equipment rigs have problems with large displacement amplitudes. Therefore, the excitation is specified with constant amplitude (+/- 2mm) in the region below 25 Hz as otherwise the displacement amplitude would be prohibitively large for 5g acceleration at these low frequencies. The maximum sweep rate is specified as 1 min/ octave; i.e. 1 min minimum between each doubling of the frequency. The sweep rate shall be low enough to allow any resonances to build-up amplitude.

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

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

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

- Contact Resistance
- Shell Continuity (if applicable)
- Insulation Resistance
- Optical Insertion loss and Return Loss

10.3.6.3.b Acceptance Criteria

The acceptance criteria shall include:

a) No damage shall be observed on either half of the connectors.
b) No intermittent contacts or increased insertion loss (electrical or optical) detected during vibration. This shall be verified with suitable test equipment with trig function e.g. oscilloscope for electrical continuity.

© 2010 All rights reserved

c) Results of the electrical and optical testing during and after vibration are within the connectors documented design specifications.

10.3.6.4 Drop Test of Connector

The objective of the test is to verify that the connector assembly is able to withstand an accidental force or impact, without degradation or damage, typically from an ROV or during transport/assembly.

10.3.6.4.a Method

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. The test shall be performed both with a mated connector assembly and with unmated connector halves. Damage to the protective cover, if used, is permissible.

10.3.6.4.b Acceptance Criteria

As per IEC 60721-3-2 Table 5 Class 2M2:

- Contact resistance
- Shell continuity (if applicable)
- Insulation resistance
- Optical insertion loss and return loss

10.4 Hose and Hose Termination Qualification Testing

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

10.4.1 Environmental Stress Testing

10.4.1.1 Absorption/Compensation Testing

To determine the compensation and ageing characteristics including dead volume compensation characteristics of a conduit hose filled with insulating oil and immersed in seawater at hydrostatic operating pressure. Dead volume refers to a volume of non-compensating housing, but compensated by the hose. Ageing is accelerated using high temperature.

10.4.1.1.a Method

A hose assembly consisting of at least a 2 meter 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. The seawater temperature within the vessel shall be set to a minimum of 50°C.

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

© 2010 All rights reserved

The oil insulation resistance shall be recorded prior to and after the test. Dielectric test cells for resistivity measurement of compensation fluid shall have electrode gap spacing from 1-2.5mm.

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

a) The vessel pressure
b) The internal hose pressure
c) The 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.

10.4.1.1.b Acceptance Criteria

The hose shall be free from damage or defects. All observations shall be documented within the qualification report. The insulation resistance of the compensating fluid within the hose shall not change more than 5% from original value. A net positive pressure is maintained within the hose throughout the test duration. How much dead volume per length the hose can compensate throughout the pressure and temperature range shall be calculated.

10.4.1.2 Jumper Ozone Resistance Evaluations

The objective of jumper ozone resistance evaluations is to verify hose resistance to damage from ozone.

10.4.1.2.a Method

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

10.4.1.2.b Acceptance Criteria

The acceptance criteria shall be that the hose be free from damage or defects. All observations shall be documented within the qualification report. A net positive pressure is maintained within the hose throughout the test duration.

10.4.1.3 Jumper Ultraviolet Resistance Evaluations

The objective of jumper ultraviolet resistance evaluations is to verify hose resistance to damage from ultraviolet light.

© 2010 All rights reserved

10.4.1.3.a Method

A hose assembly consisting of at least a 2m 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 assembly shall be placed within a test chamber and exposed to an ultraviolet light source with a wavelength of approximately 350nm at an irradiance level of approximately 50W/m^2 for a minimum duration of 500 hours.

Throughout the test the temperature shall be maintained at a constant 70^{o}C (-0/+2^{o}C).

The hose pressure shall be monitored at the start and finish of the test and chamber temperature shall be monitored during the test.

10.4.1.3.b Acceptance Criteria

The hose shall be free from damage or defects. All observations shall be documented within the qualification report. A net positive pressure is maintained within the hose throughout the test duration.

10.4.1.4 Jumper Thermal Shock Testing

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

10.4.1.4.a Method

A hose assembly consisting of at least a two meter 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 are to be performed at atmospheric pressure.

The temperature shall be raised to 70°C (-0/+2^{o}C) and maintained for a period of minimum 4 hours. The hose assembly shall then be rapidly cooled by immersion in a water bath, the temperature of which shall be between 0°C and 4.5°C. Repeat this sequence twice more. Allow the hose assembly to return to ambient temperature. Inspect the assembly for physical damage and record all observations.

The temperature of the hose assembly shall be lowered to -40°C (-2/+0^{o}C) and maintained for a period of minimum 4 hours. The hose assembly shall then be rapidly brought to ambient by immersion in a water bath, the temperature of which shall be between 0°C to 4.5°C. Repeat this sequence twice more. Allow the hose assembly to return to ambient temperature. Inspect the assembly for physical damage. Record all observations

10.4.1.4.b Acceptance Criteria

The acceptance criteria shall be that hose assembly will be considered acceptable if no physical damage is observed. The pre-charge after completed test shall be >50% of original pre-charge.

© 2010 All rights reserved

10.4.2 Jumper Destructive Testing

10.4.2.1 Tensile Failure (Qualification and Batch)

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

10.4.2.1.a Method

A hose assembly consisting of sufficient length, hose fittings and end caps, shall be filled with the relevant compensation fluid and pressurized 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 nominally 0^o 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 hose elongation and applied tensile load at point of failure shall be recorded.

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

10.4.2.1.b Acceptance Criteria

The acceptance criteria shall be that 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 5000N).

10.4.2.2 Burst Pressure (Qualification and Batch)

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

10.4.2.2.a Method

A hose assembly consisting of at least a 2m length of hose, hose fittings and end caps shall be internally pressurised with water until failure of hose or hose fittings occurs. The pressure at which failure occurs shall be recorded.

10.4.2.2.b Acceptance Criteria

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

10.4.2.3 Crush Resistance

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

10.4.2.3.a Method

A minimum 1m long sample of hose shall be selected and the outer hose diameter recorded. The area that has been measured shall then be compressed with a weight sufficient to allow the hose to collapse flat until its inner surfaces are touching. The weight shall remain in place for a minimum of 24 hours after which the weight shall be

© 2010 All rights reserved

removed. The outer diameter of the hose shall be measured 60 seconds after removal of weight and again after 4 hours.

The hose shall be empty and open at ambient pressure. The following parameters shall be recorded:

- Weight required to collapse hose
- 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

10.4.2.3.b Acceptance Criteria

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

10.4.2.4 Jumper Outer Sheath Abrasion Resistance

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

10.4.2.4.a Method

The hose shall be pulled back and forth 100 cycles within a distance of 100mm, across a 100-mm diameter steel tube with a coefficient of roughness of minimum 500 micron.

The hose shall shape an angle of 90 with the tube. Pulling force shall be 250 N.

10.4.2.4.b Acceptance Criteria

The acceptance criteria shall be that the outer sheath shall not be penetrated, i.e. no aramid (Kevlar) or inner liner shall be visible within the abrasion area.

10.4.2.5 Jumper Hose Kink Testing

The objective of this testing is to establish the bend radius at which the oil filled hose kinks and to ascertain that the hose recovers after such an incident.

10.4.2.5.a Method

A hose assembly consisting of at least a 2m 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 be then positioned in a loop such that the bend radius can be adjusted. The loop shall then be tightened to the point at which the hose kinks. The bend radius at which the kink occurs shall be recorded. A documented alternative testing method may be acceptable.

10.4.2.5.b Acceptance Criteria

The acceptance criteria for the qualification tested hose assembly shall be that no visible damage is apparent and the hose returns to its original form. The applied kinking radius shall be < 30% of manufacturer’s specified maximum bend radius.

© 2010 All rights reserved

10.5 Jumper Assembly Qualification Testing

The purpose of the tests described in this section is to verify that the completed jumper assembly comprising of connectors, hose, hose termination fittings, junction boxes, electrical cables and optical fibers perform as intended when integrated together.

Qualification tests that are relevant to verify a complete jumper shall be performed with a minimum 20m jumper assembly terminated at both ends with connectors and oil filled to the specified pre-charge pressure. In addition to the jumper subject to test, 2 bulkhead connector assemblies shall also be required. New combinations of cables and fibers shall be regarded as a new jumper assembly, and an assessment has to be performed to decide upon the required qualification tests that need to be repeated for the new assembly.

NOTE 1: For qualification of jumpers significantly longer than the length defined within this document, alternative test methods may be more applicable or appropriate, hence alternative testing shall be evaluated.

NOTE 2: Jumper assemblies used for qualification have to follow the same assembly procedures and filling procedures as during normal manufacturing. The procedures have to be qualified. Filling procedure qualification shall document that positive pre-charge pressure is maintained during the hyperbaric test sequence and the pressure curve reflects that the jumper is fully fluid filled.

10.5.1 Environmental Stress Testing

10.5.1.1 Oscillating Jumper Testing

The objective of this testing is to verify that the wiring/fiber attachment, wire/fiber assemblies and hoses are sufficiently durable.

10.5.1.1.a Method

The test shall utilise a bulkhead mounted connector mounted securely within a salt water test tank, with one end of the jumper assembly mated. The jumper shall 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 shall be approximately 4 rotations/min lasting for 30 days, (equivalent 170,000 cycles). Insulation resistance, continuity and optical insertion loss and return loss shall be monitored once per day.

10.5.1.1.b Acceptance Criteria

The acceptance criteria shall be that no damage be observed, the results of the electrical and optical testing are within the jumpers design specifications, including the Ethernet communication (if applicable).

10.5.1.2 Jumper Pull Testing

The objective of this testing 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 specified working maximum pull rating.

© 2010 All rights reserved

10.5.1.2.a Method

The test shall be performed as a simple pull test with 2500N force applied at a nominal 0^{o} to the termination. With maximum force applied, the total elongation of the cable/hose shall be recorded.

Insulation resistance, contact resistance, optical insertion loss and return loss shall be verified before and after the testing.

10.5.1.2.b Acceptance Criteria

The acceptance criteria shall be that no damage be observed, the results of the electrical and optical testing are within the jumpers design specifications, including the Ethernet communication (if applicable). The jumper shall return to the original length (pre-pull test) after a sufficient relaxation period.

10.5.1.3 Drop Test

The objective of this testing 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.

10.5.1.3.a Method

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

- Contact Resistance
- Shell Continuity
- Insulation Resistance
- Optical Insertion loss and Return Loss

This test shall be repeated for the 2nd connector on the other end of the jumper.

10.5.1.3.b Acceptance Criteria

The acceptance criteria shall be that no damage shall be observed on either connectors and both connectors mate with the test bulkhead connector. Damage to the protective cover, if used, is permissible and the results of the electrical and optical testing are within the connectors design specifications.

10.5.1.4 Jumper Handling Simulation Test

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

10.5.1.4.a Method

The jumper assembly shall be coiled in at least 5 "figure-of-8" patterns such that the minimum bend radius is achieved. The jumper shall then be uncoiled and laid out straight. This procedure shall then be performed 10 times.

© 2010 All rights reserved

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

- Electrical Continuity
- Insulation Resistance
- Optical Insertion loss and return loss
- Ethernet communication (if applicable)

10.5.1.4.b Acceptance Criteria

The acceptance criteria shall be that no damage shall be observed on either half of the connectors and the results of the electrical and optical testing are within the connectors design specifications.

10.5.1.5 Simulated Jumper Assembly Deployment Testing

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

Prior to performing the hyperbaric testing, the jumper assembly shall have completed all production leakage testing.

10.5.1.5.a Method

During this test, the following parameters shall be recorded at each hold point within the pressure cycling sequence outlined in Table 12:

a) Loop resistance
b) Insulation resistance
c) Optical insertion loss
d) Optical return loss
e) Jumper assembly pre charge pressure
f) Ethernet communication (if applicable)

Table 12: Simulated Deployment Testing

Simulated Deployment Test Sequence	
Step	**Pressure**
1	Ambient – dry test
2	Ambient- wet allow to soak for 15 min and test
3	Increase pressure from ambient to test pressure at minimum 35 bar/min rate of change
4	Test Pressure - hold for 20 min and test
5	Decrease pressure from test pressure to ambient at minimum 70 bar/min rate of change
6	Ambient - allow to soak for 15 min and test
7	Repeat Steps 3 - 6 a further 4 times

© 2010 All rights reserved

10.5.1.5.b Acceptance Criteria

The acceptance criteria shall be that the jumper's electrical and optical performance shall remain within specification throughout the testing. A positive pre-charge pressure shall be maintained during the test sequence and the pressure curve shall reflect that the jumper is fully fluid filled.

10.5.1.6 Jumper Snag Testing

The unit under test is to be a full 20m flying lead with 4m under test and without splice box at the point of force. E.g. if a 20 meter fiber flying lead were tested the splice box would be at 10 meters and not at a point of impact.

10.5.1.6.a Method

Pull test giving instant energy of 500 Joule (N.m) shall be performed. The force shall be applied in line to the article.

The common method for testing is to drop a weighted object connected to the article under test a given distance. That distance is verified using high speed video and used to calculate actual energy applied. The other end is held by the hose using wire mesh grips or a similar method.

Test sample to be 4m and without splice box.

Pull test giving instant energy of 500 Joule shall be performed.

a) Optical and electrical performance to be within specification before and after the test.
b) Ethernet communication (if applicable) shall conform to specification before and after the testing.
c) No leaking or splits of the hose are to be observed.
d) Hose diameter should be within 2% of original on an average basis. (Add high and low reading divide by 2).
e) Hose should return to original length +/- 2% within 24 hours.

10.5.2 Electrical/Optical Testing Requirements

10.5.2.1 Flooded Jumper Assembly Ethernet Testing

The objective of this testing is to verify correct performance, for the Ethernet communication within the Ethernet connection in the seawater filled jumper assembly.

10.5.2.1.a Method

The test shall be performed as in Table 9: Flooded Connector Back-end Testing.The hose shall be seawater filled, hence the tank may contain fresh water.

Ethernet traffic testing shall be used to verify that the Ethernet signal performance is not significantly altered by the existence of other communication or power signals in the same jumper. The qualification test shall be performed with a representative power level feeding on the applicable pair(s) within the jumper assembly.

The qualification test is valid only for the connector pin configuration used during the test.

© 2010 All rights reserved

10.5.2.1.b Acceptance Criteria

Ethernet traffic test verification of signal performance shall comply with requirements in section 12 Ethernet Testing.

10.5.2.2 Partial Discharge Testing

The objective of this testing is to verify that the electrical insulation properties with regards to design and build quality for jumper assemblies with connectors and junction boxes are within acceptable limits.

10.5.2.2.a Method

The partial discharge test shall be performed in accordance with IEC 60270 and IEC 60885-2.

The test setup and associated wiring arrangement shall reflect that the aim is to find the PD levels for the terminated connector and junction boxes including all seals. The earth potential shall be brought as close as possible to the isolation material corresponding to a flooded back-end test and connected to connector housing. This is typically achieved by flooded jumpers and junction boxes.

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

10.5.2.2.b Acceptance Criteria

The acceptance criteria shall be that the PD level is less than 10pC @ 2.5 kV

10.5.2.3 Jumper Assembly Impedance Testing

The objective of this testing is to verify correct impedance level in the jumper assembly that shall be used to hook up SIIS level 2 instruments subsea. Qualification testing of impedance level in the jumper shall verify that the actual impedance is within the requirements as specified by the actual application.

10.5.2.3.a Method

The performance testing shall also be performed with water filled jumper under pressure.

Actual test to be defined by supplier/manufacturer and shall as a minimum comply with requirements defined in SIIS level 2.

10.5.2.3.b Acceptance Criteria

The acceptance criteria shall be defined by the control system supplier/manufacturer.

10.6 Dry-mate Connector and Jumper Assemblies Qualification Testing

10.6.1 General

Dry-mate connector jumper assemblies may be considered qualified by similarity to wet-mate connector jumpers. Data from specific tests already performed on wet-mate connectors shall

© 2010 All rights reserved

be evaluated before being placed into the dry-mate connector qualification report. Qualification by similarity is not accepted for Ethernet jumpers.

Each connector and jumper assembly undergoing a qualification test shall be clearly identified with serial number prior to the commencement of the tests.

10.6.2 Mechanical Testing

10.6.2.1 Locking Device (dry-mate specific)

The objective of this test is to verify correct operation of the dry-mate connector locking mechanism (e.g. threaded, bayonet, snap) and that no mechanical damage occurs to the connector due to the locking mechanism.

10.6.2.1.a Method

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

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

10.6.2.1.b Acceptance Criteria

1. An evaluation assessing the ease with which the locking device is activated shall be part of the final qualification report.
2. No damage observed to either half of the connector pair due to incorrect orientation of connectors.

10.6.2.2 Dry Mating over Temperature Test Range (dry-mate specific)

The objective of this test is to verify mateability over the defined temperature test range of the dry-mate connector.

10.6.2.2.a Method

The connector shall be checked for satisfactory positive location, the locking mechanism undone and the connector separated. This test shall be performed at both the low and the high temperature.

10.6.2.2.b Acceptance Criteria

1. An evaluation assessing the ease with which the locking device is activated shall be part of the final qualification report.
2. No damage observed to either half of the connector pair due to incorrect orientation of connectors.

10.6.2.3 Jumper Handling Simulation Test (dry-mate specific)

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

© 2010 All rights reserved

10.6.2.3.a Method

The jumper assembly shall be coiled in a “figure-of-8” pattern such that the minimum bend radius is achieved. The jumper shall then be uncoiled and laid out straight. This procedure shall be performed 10 times.

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

a) Electrical Continuity
b) Insulation Resistance
c) Optical Insertion loss and return loss

10.6.2.3.b Acceptance Criteria

The acceptance criteria shall be that no damage shall be observed on either half of the connectors and the results of the electrical and optical testing are within the connectors design specifications.

© 2010 All rights reserved

11 Factory Acceptance Testing Requirements

11.1 General

The objective of the factory acceptance testing is to verify the quality of each connector / jumper assembly manufacturer. All dry-mate connectors, wet-mate connectors and jumper assemblies to be delivered shall pass a factory acceptance test in accordance with approved procedure. This test shall, as a minimum, be based on the recommendations and acceptance criteria defined in this section.

The testing requirements identified within this section are segmented as individual, discrete tests to afford a supplier/manufacturer the option of selecting the applicable test for a specific product design.

The supplier/manufacturer shall establish and implement requirements which are approved by a qualified person(s) for calibration of measuring/testing equipment. Inspection, measuring and testing equipment used for acceptance shall be used within its calibrated range. Measurement equipment shall be identified, controlled, calibrated and adjusted at specific intervals in accordance with the supplier/manufacturer requirements which conform to a national or international standard.

Documented testing procedures shall identify the required measurement parameters and acceptance criteria. The acceptance criteria shall include the test instrument tolerances. Visual examinations shall be recorded within the test documentation. All measured parameters shall be documented in the test report. Acceptance criteria shall be focused to detect inherent weaknesses in components and connections, and not limited to “fit for use” evaluations. The acceptance criteria shall be defined as the minimum requirements for testing.

The factory acceptance test for the wet-mate connector can be divided into the following segments and are summarised in the Tables below:

Table 13: Summary of Factory Acceptance Testing Requirements (Wet-Mate)

Summary of minimum FAT requirements – Wet-Mate Connectors		
Function	**Test Type**	**Section**
Electrical	Contact Resistance –light current	11.2.1.1
	Shell Continuity	11.2.1.2
	Insulation Resistance	11.2.1.3
	Proof Voltage	11.2.1.4
	Ethernet (Table30) if applicable	12.7.10
Optical	Optical Insertion loss	11.2.2.1
	Optical Crosstalk	11.2.2.2
	Optical Return Loss	11.2.2.3
Mechanical	Gas Leak	11.2.3.1
	Locking Device	11.2.3.2

© 2010 All rights reserved

	Mate Verification	11.2.3.3
	CT/X-Ray (for connectors installed on critical units)	11.2.3.4
ESS test	Environmental Stress Screening	11.2.4
Hyperbaric	Single Connector Hyperbaric	11.2.5
Visual	Tolerance Check	Supplier/manufacturer Defined
Inspection	Interface Check	Supplier/manufacturer Defined
	Verification of Marking	Supplier/manufacturer Defined

The Factory Acceptance Test for the dry-mate connector can be divided into the following sections:

Table 14: Summary of Factory Acceptance Testing Requirements (Dry-mate)

Summary of minimum FAT requirements – Dry-Mate Connectors		
Function	**Test Type**	**Section**
Electrical	Contact Resistance - light current	11.2.1.1
	Shell Continuity	11.2.1.2
	Insulation Resistance	11.2.1.3
	Proof Voltage	11.2.1.4
	Ethernet (Table30) if applicable	12.7.10
Optical	Optical Insertion loss	11.2.2.1
	Optical Crosstalk	11.2.2.2
	Optical Return Loss	11.2.2.3
Mechanical	Gas Leak	11.2.3.1
	Locking Device	11.3.1
ESS test	Environmental Stress Screening	11.2.4
Hyperbaric	Single Connector Hyperbaric	11.3.2
Visual Inspection	Tolerance Check	Supplier/manufacturer Defined
	Interface Check	Supplier/manufacturer Defined
	Verification of Marking	Supplier/manufacturer Defined

For Jumper Assemblies the sections listed below apply as part of the FAT program.

Connector tests already performed as part of the connector FAT are not required to be repeated if jumper assembly process does not affect the tested property. Testing performed at the jumper level need not have been performed at the connector level.

© 2010 All rights reserved

Table 15: Summary of Factory Acceptance Testing Requirements (Jumper Assemblies)

Summary of minimum FAT requirements – Jumper Assemblies		
Function	**Test Type**	**Section**
Electrical	Contact Resistance –light current	11.2.1.1
	Shell Continuity	11.2.1.2
	Insulation Resistance	11.2.1.3
	Proof Voltage	11.2.1.4
	Jumper Assembly Impedance	11.4.1
	Ethernet (Table30) if applicable	12.7.10
Optical	Optical Insertion Loss	11.2.2.1
	Optical Crosstalk	11.2.2.2
	Optical Return Loss	11.2.2.3
Mechanical	Gas Leak	11.2.3.1
	Locking Device	11.2.3.2
	Mate verification	11.2.3.3
ESS test	Environmental Stress Screening	11.2.4
Hyperbaric	Jumper Assembly Deployment	11.4.2
Visual	Tolerance Check	Supplier/manufacturer Defined
Inspection	Interface Check	Supplier/manufacturer Defined
	Verification of Marking	Supplier/manufacturer Defined

For Dry-Mate Jumper Assemblies the sections listed below apply as part of the FAT program.

Connector tests already performed as part of the connector FAT are not required to be repeated if the jumper assembly process does not affect the tested property. Testing performed at the jumper level need not have been performed at the connector level.

Table 16: Summary of Factory Acceptance Testing Requirements (Dry-Mate Jumper Assemblies)

Summary of minimum FAT requirements – Dry-Mate Jumper Assemblies		
Function	**Test Type**	**Section**
Electrical	Contact Resistance –light current	11.2.1.1
	Shell Continuity (if applicable)	11.2.1.2
	Insulation Resistance	11.2.1.3
	Proof Voltage	11.2.1.4
	Jumper Assembly Impedance Testing	11.4.1

© 2010 All rights reserved

	Ethernet (Table30) if applicable	12.7.10
Optical	Optical Insertion loss	11.2.2.1
	Optical Crosstalk (only if relevant)	11.2.2.2
	Optical Return Loss	11.2.2.3
Mechanical	Gas Leak	11.2.3.1
	Locking Device	11.3.1
ESS test	Environmental Stress Screening	11.2.4
Hyperbaric	Jumper Assembly Deployment	11.5.1
Visual Inspection	Tolerance Check	Supplier/manufacturer Defined
	Interface Check	Supplier/manufacturer Defined
	Verification of Marking	Supplier/manufacturer Defined

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

11.2 Minimum FAT Requirements – Wet-Mate Connectors

11.2.1 Electrical Testing

11.2.1.1 Contact Resistance-Light Current

This electrical test is used to measure contact resistance between 2 wet or dry-mated contact in 2 mating connectors.

11.2.1.2.a Method

The contact resistance shall either be derived from the voltage drop measured between the points (i.e. solder pots/crimping points) intended for connection of the wiring to the contacts (at rated current only) or by using an ohm-meter (4-wire Kelvin type measurement) giving the same measuring accuracy. When measured as line resistance, i.e. with external leads, the wire resistance have to be measured and verified before the connector to cable termination is completed. In no case shall the resistance of the wires cause reduced accuracy in the measurement significant for the test result. Actual measurements shall be recorded.

A light current test requires that the line resistance of individual contacts be measured with direct current not exceeding 50mA. During the measurements the open circuit source voltage shall not exceed 20mVDC.

11.2.1.2.b Acceptance Criteria

The acceptance criteria shall be, less than 30mΩ + wire resistance with no more than ± 10 mΩ difference between pins.

11.2.1.2 Shell Continuity

Shell continuity is utilized for connectors with cathodic protection. This test is used to determine the resistance between connectors having metallic housings intended to provide electrical continuity when mated.

© 2010 All rights reserved

11.2.1.2.a Method

Measurements shall be made on mated connectors. Connections for this test shall be made to the braid or shell connecting wire for free connectors and to the mounting flange for fixed connectors. Actual measurements shall be recorded.

11.2.1.2.b Acceptance Criteria

Acceptance criteria shall be less than 0.1Ω.

11.2.1.3 Insulation Resistance Testing

To quantify the insulation resistance between:

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

11.2.1.3.a Method

The insulation resistance of individual contacts shall be measured with an instrument with a minimum measurement scale of 100GΩ. Temperature and humidity during the testing shall be recorded.

The test voltage shall be 1000V DC with following exceptions:

a) Testing of Ethernet cables in jumpers shall be performed in accordance with the voltage rating of actual cable.
b) Testing of jumpers with terminated equipment shall be performed in accordance with the voltage rating of actual terminated equipment. Reference is made to API17F Annex H.

Actual measurements shall be recorded, including measurements exceeding the instrument measurement scale, e.g. >100GΩ.

11.2.1.3.b Acceptance Criteria

The acceptance criteria shall be readings greater than 20GΩ (connector only), greater than 10 GΩ for jumper assemblies (including jumpers with cables or equipment not rated for 1000V DC testing), and greater than 1GΩ for jumper assemblies with terminated instruments.

11.2.1.4 Proof Voltage Testing

This test is used to verify that the dielectric isolation and contact/circuit spacing is sufficient to prevent flashover, minimize current leakage or insulation breakdown at the connector proof voltage.

11.2.1.4.a Method

Proof voltage testing shall be performed in accordance with IEC 60502-1 and IEC 60060-1.

The selected proof voltage between each conductor and the shell (earth) with remaining conductors connected to earth shall be 3.5kV AC. Connectors where all pins in final use will not be exposed to more than 50V DC, may be tested with 4.5kV DC.

© 2010 All rights reserved

Proof voltage testing of Ethernet cables in jumpers shall be performed in accordance with the test voltage rating of actual cable. Proof voltage testing of jumpers shall be performed in accordance with the test voltage rating of actual terminated equipment.

Each voltage check shall be applied for a 5 min period. All results shall be recorded as absolute values. A number of such tests may be performed during the assembly process.

11.2.1.4.b Acceptance Criteria

The acceptance criteria shall be that there is no evidence of insulation breakdown, no evidence of flashover and the current leakage shall be measured and logged.

11.2.2 Optical Testing Requirements

11.2.2.1 Optical Insertion Loss (IL) Testing

This testing is used to determine the optical insertion loss through an optical system component. This can be defined as a connector pair, a penetrator, a harness or any other relevant optical system component.

11.2.2.2.a Method

The test shall be performed according to IEC 61300-3-4*:* Fiber optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-4: Examinations and measurements – Attenuation for the following wavelengths:

- 1550nm and 1625nm for single mode
- 850nm and 1300nm for multimode

The purpose of this test is to establish loss figures attributable directly to the DUT without the test-setup in circuit.

11.2.2.1.b Acceptance Criteria

The acceptance criteria shall be calculated according to the criteria in performance Table 1 for the DUT.

11.2.2.2 Optical Crosstalk Testing

This test is not applicable if it can be proven with reference to the mechanical properties of the connector that crosstalk between individual optical fibers is impossible.

11.2.2.2.a Method

This testing will determine the optical crosstalk between each optical line within the connector and all other optical lines within the connector. Again the optical cross talk attributable to the test equipment shall be established prior to commencing the test. This test may be combined with the Optical Insertion Loss test as both utilize the same test equipment.

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

© 2010 All rights reserved

11.2.2.2.b Acceptance Criteria

The acceptance criteria shall be less than or equal to -60dB crosstalk of the source signal at all defined wavelengths.

11.2.2.3 Optical Return Loss (RL) Testing

The objective of this testing is to determine the return loss of an optical connection (not a splice).

11.2.2.3.a Method

The test shall be performed according to IEC 61300-3-6: Fiber optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-6: Examinations and measurements – Return loss for the following wavelengths:

- 1550nm and 1625nm for single mode
- 850nm and 1300nm for multimode

This test shall be performed 10 times in total. Between measurements the connector pairs shall be completely separated and reconnected. A statistical analysis result is to be recorded. Performance requirement refers to the total number of measurements per connector. E.g. for UPC connector; 60 measurements out of 80 for an 8-channel connector shall be better than 45dB. The remaining 20 measurements shall be better than 30dB.

Thereafter, RL is to be recorded as needed during FAT. A lower performance limit applies (see performance Table 1)

The purpose of this test is to establish loss figures attributable directly to the DUT without the test-setup in circuit.

11.2.2.3.b Acceptance Criteria

The acceptance criteria shall be according to the criteria in performance Table 1.

11.2.3 Mechanical Testing Requirements

11.2.3.1 Gas Leak Testing

This test is used for verification at final stage of assembly, to ensure that seals are correctly fitted and do not leak.

This section describes alternative test methods using helium or nitrogen as a test medium. The helium test is not intended to be performed on hose assemblies due to the absorption/permeation characteristics of the hose. The required 2 independent barriers between wire/fluid filled hose and the seawater shall be separately tested, while double O-rings cannot in most cases be tested separately. A gas leak test shall be carried out on the connector including jumper assembly end fittings and bulkhead cable termination (if applicable to design) to verify all sealing elements.

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 used 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.

© 2010 All rights reserved

The test procedure should consider the 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.

11.2.3.1.1 Helium Vacuum Technique

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 $1 \cdot 10^{-9}$ mbar·l/s. Temperature and pressure shall be continuously recorded.

11.2.3.1.1.a Method

An outline procedure/sequence should be as follows:

1. 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.
2. 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.
3. The mass spectrometer helium rate before and after each purging shall be recorded.

11.2.3.1.1.b Acceptance Criteria

Acceptance criteria shall be that the reading shall not increase with more than $5 \cdot 10^{-8}$ mbar·l/s during purging with helium.

11.2.3.1.2 Helium Sniffer Technique

If the sniffer technique shall be used for tightness control in a serial production, measures to prevent a change in the helium to air ratio in the test room/area should be performed.

11.2.3.1.2.a Method

1. The sealing barriers/termination chamber to be tested should be entirely wrapped (to gather leakages). The sniffer probe should be positioned inside the wrapping at relevant locations (as and where required).
2. There shall be a verified calibration procedure for each sniffer test, i.e. for each sealing barrier/termination chamber to be tested. When developing each calibration procedure, an acceptable sniffer signal shall be documented. Due to the uncertainty related to this sniffer test method, a safety factor of minimum 10 should be applied on the sniffer signal - to account for potential inaccuracies.

11.2.3.1.2.b Acceptance Criteria

The acceptance criteria shall be based on a documented analysis for each case/design solution that is tested.

© 2010 All rights reserved

11.2.3.1.3 Nitrogen Leak Technique for Jumpers

11.2.3.1.3.a Method
Jumper assembly shall be pressurised with nitrogen to 15 bar and submerged in water for a minimum of 15 min.

11.2.3.1.3.b Acceptance Criteria

The acceptance criteria shall be that no bubbles are observed during the testing period.

11.2.3.1.4 Helium Leak Technique for Jumpers

11.2.3.1.4.a Method

Jumper assembly shall be pressurised with helium to minimum 2 bar, pressure to be stabilized and maintained for a minimum of 30 min. For jumpers longer than 30m, holding time is to be increased with 10 min for each additional 20m.

11.2.3.1.4.b Acceptance Criteria

Acceptance criteria shall be a pressure drop less than 0.03 bar.

11.2.3.2 Locking Device Testing

The objective of this test is to verify correct operation of the locking mechanism and that no mechanical damage occurs to the connector due to the locking mechanism.

11.2.3.2.a Method

The connector pair shall be engaged by hand or suitable mating fixture. This test may be combined with other tests for a more efficient performance of the FAT.

11.2.3.2.b Acceptance Criteria

The acceptance criteria shall be that no damage is observed to either half of the connector pair due to incorrect orientation (if possible) of connectors. The connector shall be checked for satisfactory positive locked location, the locking mechanism undone and the connector separated.

11.2.3.3 Mate Verification Testing

This test is used to determine mechanical verification of the connectors mating mechanism.

11.2.3.3.a Method

This test shall be performed with a mounted and a free connector configuration. The connector pair shall be engaged by hand or suitable mating fixture. The test may be combined with other tests for a more efficient performance of the FAT.

11.2.3.3.b Acceptance Criteria

The acceptance criteria shall be that the mating mechanism functions as intended and no damage observed to either half of the connector pair.

© 2010 All rights reserved

11.2.3.4 CT/X-Ray

The objective of this testing is to verify correct soldering filling levels and soldering quality on connectors to be installed on critical units like subsea umbilical terminations.

11.2.3.4.a Method

Each soldering point shall be X rayed from 2 angles 90° of each other or CT scanned.

Procedure to be signed by the performing operator and countersigned by qualified inspector for the soldering of each electrical connector.

11.2.3.4.b Acceptance Criteria

The description of the acceptance criteria for the soldering shall be developed prior to the control.

11.2.4 ESS Testing – Environmental Stress Screening

This test may be omitted for connectors and junction boxes containing only spliced or routed cables providing the design has shown no findings for at least 100 units previously tested. Junction boxes containing Ethernet cables, fibers, resistors or other components shall always be tested.

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

11.2.4.a Method

Connector: The connector half that is normally permanently attached to subsea equipment shall be fixed to the vibration equipment in a similar manner as intended for normal operation. The retrievable half of the connector shall interface to the fixed half of the connector as intended for normal operation. The electrical cables and optical fibers may be anchored to the test fixture if required.

Junction Box: The junction box shall be fixed to the vibration equipment. The connectors, electrical cables and optical fibers may be anchored to the test fixture if required.

The random vibrations shall be applied for a total of 10 min with the following characteristics:

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

© 2010 All rights reserved

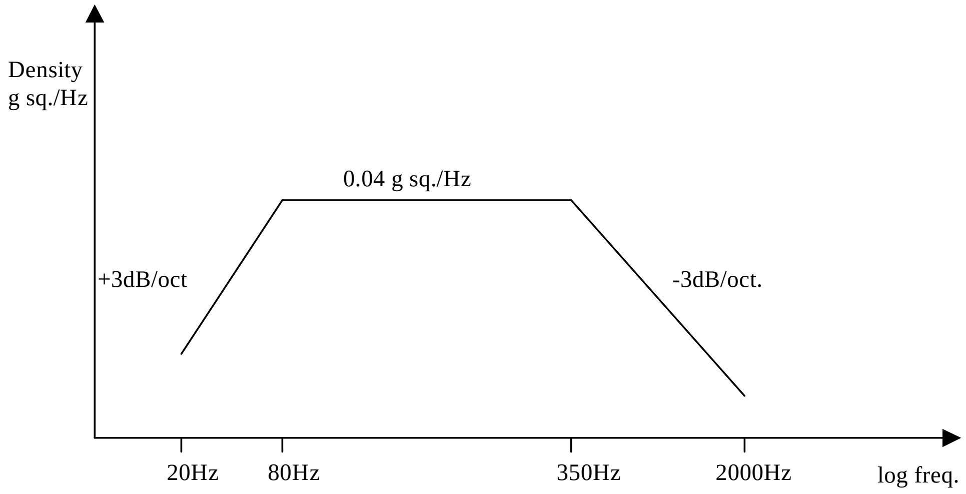

Figure 3: Acceleration Spectral Density Over Frequency Range

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

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

a) Line resistance, continuity
b) Shell continuity (if applicable)
c) Insulation resistance
d) Optical insertion loss and return loss
e) Ethernet communication (if applicable)

11.2.4.b Acceptance Criteria

The acceptance criteria shall include:

a) No damage shall be observed on either half of the connectors as defined in the design specification.
b) No intermittent contacts or increased attenuation (electrical or optical) detected during vibration. This shall be verified by continuous monitoring with suitable test equipment with trig function e.g. oscilloscope for electrical continuity.
c) Results of the electrical and optical testing during and after vibration are within the connectors design specification.
d) Actual measurements shall be recorded.

11.2.5 Hyperbaric Testing - Single Connector Hyperbaric Testing Requirements

The objective of this testing is to verify correct operation of each production connector at the specified test pressure. Prior to performing the hyperbaric testing of the connectors both halves of the connector shall have completed all production leak testing. The rate of pressure change shall be approximately 35 bar/min.

11.2.5.a Method

During this test, the following parameters shall be recorded after each pressure change stage:

© 2010 All rights reserved

a) Shell continuity (if applicable)
b) Insulation resistance
c) Optical insertion loss
d) Optical return loss
e) Line resistance shall be measured before and after test.

Table 17: Single Connector Hyperbaric Testing

Single Connector Hyperbaric Test Sequence	
Step	**Pressure**
1	Ambient conditions - Wet de-mate-mate test
2	Increase pressure to 33% of test pressure.
3	Hold for 5 min and return to ambient conditions.
4	Increase pressure from ambient to test pressure.
5	Hold for 15 min.
6	Wet de-mate-mate test. The test may be replaced by a repeat of test sequence with unmated connectors ensuring that connectors are exposed to pressure in both mated and unmated condition. Electrical measurements will then be done before and after test sequence
7	Return to ambient conditions
8	Ambient conditions - Wet de-mate-mate test

11.2.5.b Acceptance Criteria

The acceptance criteria shall be that the connector's electrical and/or optical performance remain within specification throughout the testing.

11.3 Minimum FAT Requirements – Dry-Mate Connectors

11.3.1 Mechanical Testing – Locking Device Testing Requirements (Dry-mate)

The objective of this test is to verify correct operation of the dry-mate connector locking mechanism (e.g. threaded, bayonet, snap) and that no mechanical damage occurs to the connector due to the locking mechanism.

11.3.1.a Method

The connector shall be checked for satisfactory positive location, the locking mechanism undone and the connector separated. The connector pair shall be engaged by hand.

11.3.1.b Acceptance Criteria

The acceptance criteria shall be that the correct operation of the locking device shall be recorded.

11.3.2 Single Connector Hyperbaric Testing (Dry-mate specific)

The objective of this testing is to verify correct operation of each production connector at the specified test pressure. Testing performed at the connector level does not have to be repeated at the jumper level.

© 2010 All rights reserved

11.3.2.a Method

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

All seals shall be tested in the deployed configuration (pressure balanced or differential).

With the test pressure vessel dry, the production dry-mate connector shall be mated to either a test reference connector or another production dry-mate connector. Bulkhead penetrations shall be provided so that each circuit may be tested, either looped or individually. The connector shall remain in this configuration for the remainder of the test.

Rate of pressure change shall be approximately 35 bar/min.

During this test the following parameters shall be recorded where noted in the table below:

- Shell continuity (if applicable)
- Insulation resistance
- Optical insertion loss
- Optical return loss

Line resistance shall be measured before and after testing.

Table 18: Single Connector Hyperbaric Testing (mated)

Single Connector Hyperbaric Test Sequence (mated)	
Step	**Pressure**
1	Ambient conditions – optical & electrical tests
2	Increase pressure to 33% of test pressure.
3	Hold for 5 min and return to ambient conditions.
4	Increase pressure to 66% of test pressure.
5	Hold for 5 min and return to ambient conditions.
6	Increase pressure from ambient to test pressure.
7	Hold for 15 min
8	Test Pressure – optical & electrical tests
9	Return to ambient conditions
10	Ambient conditions – optical & electrical tests

11.3.2.b. Acceptance Criteria

The connector's electrical and/-or optical performance shall remain within documented specification throughout the testing.

11.4 Minimum FAT Requirements – Jumper Assemblies

11.4.1 Electrical Function Testing – Jumper Assembly Impedance Testing

This form of testing is used to verify that the impedance of the harness complies with required communication performance for SIIS level 2.

© 2010 All rights reserved

11.4.1.a Method

Impedance measurement of complete harness included terminated instruments

11.4.1.b Acceptance Criteria

Acceptance criteria shall be as specified by control system supplier/manufacturer.

11.4.2 Hyperbaric Testing - Jumper Assembly Deployment Testing

The objective of this testing is to verify correct operation of each jumper assembly at the specified test pressure and verify that cable and fiber management allows sufficient free movement of conductors and fibers to accommodate changes due to expansion and contraction of the jumper during pressure changes.

11.4.2.a Method

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

Rate of pressure change shall be approximately 35 bar/min.

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

- Insulation resistance
- Optical insertion loss
- Optical return loss
- Ethernet communication (if applicable)

Pre-charge pressure shall be recorded pre-hyperbaric testing. Line resistance shall be recorded both pre and post hyperbaric testing.

Table 19: Jumper Assembly Hyperbaric Testing

Jumper Assembly Hyperbaric Test Sequence	
Step	**Pressure**
1	Ambient conditions - Wet de-mate-mate test
2	Increase pressure to 33% of test pressure.
3	Hold for 5 min and return to ambient conditions.
4	Increase pressure from ambient to test pressure.
5	Hold for 15 min.
6	Wet de-mate-mate test. The test may be replaced by a repeat of test sequence with unmated connectors ensuring that connectors are exposed to pressure in both mated and unmated condition. Electrical measurements will then be done before and after the test sequence.
7	Return to ambient conditions.
8	Ambient conditions - Wet de-mate-mate test

© 2010 All rights reserved

11.4.2.b Acceptance Criteria

The acceptance criteria shall be that the jumper’s electrical and/or optical performance shall remain within specification throughout the testing.

© 2010 All rights reserved

11.5 Minimum FAT Requirements – Dry-Mate Jumper Assemblies

11.5.1 Hyperbaric Testing - Jumper Assembly Deployment Testing (Dry-mate specific)

The objective of this testing is to verify correct operation of each jumper assembly at the specified test pressure and verify that cable and fiber management allows sufficient free movement of conductors and fibers to accommodate changes due to expansion and contraction of the jumper during pressure changes.

11.5.1.a Method

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

All seals shall be tested in the deployed configuration (pressure balanced or differential).

With the test pressure vessel dry, the production dry-mate jumper shall be mated to either a test reference connector or another production dry-mate connector. Bulkhead penetrations shall be provided so that each circuit may be tested, either looped or individually. The jumper shall remain in this configuration for the remainder of the test.

Rate of pressure change shall be approximately 35 bar/min.

During this test the following parameters shall be recorded where noted in the table below:

- Insulation resistance
- Optical insertion loss
- Optical return loss
- Ethernet communication (if applicable)

Pre-charge pressure shall be recorded pre hyperbaric testing. Line resistance shall be recorded both pre and post hyperbaric testing.

Table 20: Dry-mate Jumper Assembly Hyperbaric Testing (mated) Pressure

Dry-mate Jumper Assembly Hyperbaric Test Sequence (mated)	
Step	**Pressure**
1	Ambient conditions – optical & electrical tests
2	Increase pressure to 33% of test pressure
3	Hold for 5 min and return to ambient conditions
4	Increase pressure to 66% of test pressure
5	Hold for 5 min and return to ambient conditions
6	Increase pressure from ambient to test pressure
7	Hold for 20 min
8	Test Pressure – optical & electrical tests
9	Return to ambient conditions.
10	Ambient conditions – optical & electrical tests

11.5.1.b Acceptance Criteria

The jumper's electrical and/-or optical performance shall remain within specification throughout the testing.

© 2010 All rights reserved

12 Ethernet Testing and Requirements

12.1 General

For purposes of system conformance, the SIIS link segment is standardized at the test points described in Figure 4. The test points enable link segment and component testing and provide the basis for link segment and component acceptance criteria for qualification and FAT. Note that all test points may not be accessible in an implemented system.

The SIIS twisted-pair link segment (TP1 to TP6) shall meet or exceed the 100BASE-TX twisted-pair link segment specifications. By meeting this specification the need for additional BER testing is eliminated and provides a better understanding of operational margins. The SIIS link segment twisted-pair cables shall meet or exceed the component specifications in TIA/EIA- category 5. The SIIS link segment wet-mate connectors should meet or exceed the component specifications in TIA/EIA - category 5.

The SIIS link segment assembly transmission and coupling parameters are specified from TP2 to TP5. The subsea control module transmission and coupling parameters are specified from TP1 to TP3. The sensor module transmission and coupling parameters are specified from TP4 to TP6. The wet-mate connector transmission and coupling parameters are specified from TP2 to TP3 and TP4 to TP5.

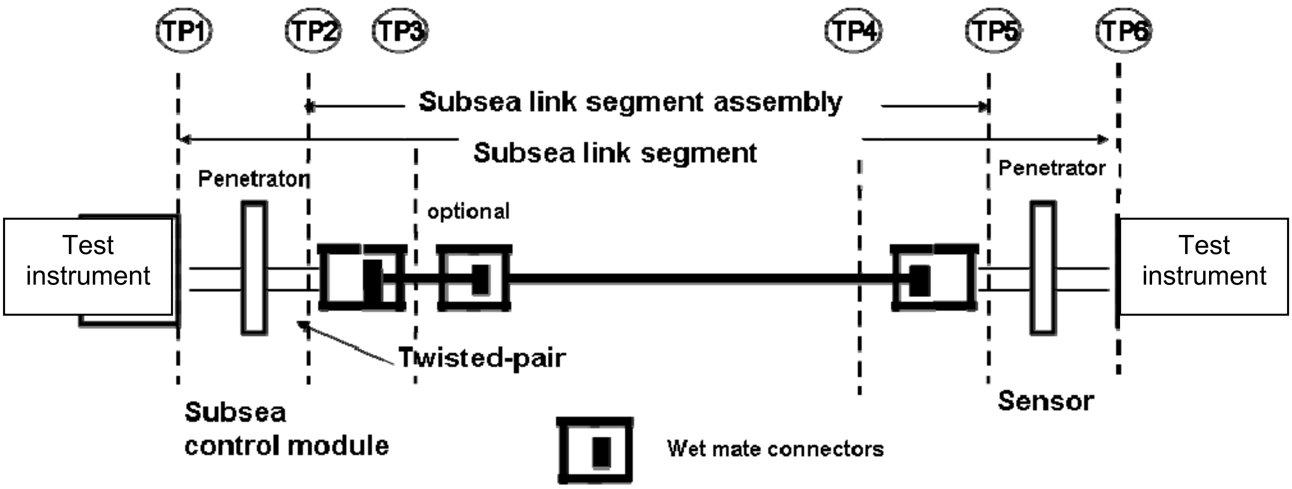

Figure 4: SIIS Twisted-pair Link Segment

Table 21: SIIS Twisted-pair Link Segment Test Points

Test Points	Description
TP1 to TP6	Complete Subsea link segment transmission and coupling parameters between active devices
TP2 to TP5	Link segment assembly transmission and coupling parameters
TP1 to TP3	Subsea control module and wet-mate connector transmission and coupling parameters
TP4 to TP6	Sensor module and wet-mate connector transmission and coupling parameters
TP2 to TP3 TP4 to TP5	Wet-mate connector transmission and coupling parameters

© 2010 All rights reserved

12.2 SIIS Twisted-pair Link Segment Transmission and Coupling Parameters

SIIS Twisted-pair link segment transmission and coupling parameters (TP1 to TP6)

The SIIS twisted-pair link segment (TP1 to TP6) shall meet or exceed the 100BASE-TX twisted-pair link segment specifications. The 100BASE-TX Link transmission and coupling parameters are specified in IEEE 802.3 100BASE-TX sub-clause 25.4.7.1 Cabling system characteristics:

- Insertion loss
- Differential characteristic impedance,
- Return loss
- Near-end crosstalk (NEXT)

The 100BASE-TX Link transmission and coupling parameters align with the structured cabling standards ANSI/TIA/EIA-568-A:1995 (Category 5) and ISO/IEC 11801:1995 (Class D).

12.3 SIIS Twisted-pair Link Segment Transmission and Coupling Parameters (TP1 to TP6)

12.3.1 SIIS Link Segment Insertion Loss

The insertion loss of the link segment pairs shall meet the values determined using equation (1) at all frequencies from 1 MHz to 100 MHz.

$$IL_{linksegment} \geq 2.1 f^{0.529} + 0.4 / f) \text{ (dB)} \qquad (1)$$

where f is frequency in MHz

The insertion loss specification shall be met when the link segment is terminated in 100 Ω.

NOTE: that the above equation approximates the insertion loss specification at 20°C for discrete frequencies of Category 5 100-m links specified in ANSI/TIA/EIA-568-A Annex E and in TIA/EIA TSB-67.

12.3.2 SIIS Link Segment Differential Characteristic Impedance

The nominal differential characteristic impedance of the link segment, which includes cable cords and connecting hardware, is 100 Ω for all frequencies between 1 MHz and 100 MHz. 100 Ω is the reference impedance. Components of the link segments can vary from 100 Ω as long as the return loss requirement is met.

12.3.3 SIIS Link Segment Return Loss

The link segment return loss shall be greater than or equal to the values determined using equation (2) at all frequencies from 1 MHz to 100 MHz. The reference impedance shall be 100 Ω.

Table 22: SIIS Twisted-pair Link Segment Return Loss

Frequency (MHz)	**Return Loss (dB)**
$1 \leq f < 20$ $20 \leq f \leq 100$	15 15 - 10log(f/20)

(2)

© 2010 All rights reserved

where f is the frequency in MHz..

12.3.4 SIIS Link Segment Differential Near-End Crosstalk (NEXT)

In order to limit the crosstalk at the near-end of a link segment, the differential pair-to-pair near-end crosstalk loss between the 2 pairs of the link segment shall meet the values determined using equation (3) at all frequencies from 1 MHz to 100 MHz.

$$NEXT_{linksegment} \geq 27.1 - 16.8\log 10(f/100) \quad \text{(dB)} \qquad (3)$$

where f is the frequency in MHz

NOTE: The above equation approximates the NEXT loss specification at discrete frequencies for Category 5 100-meter links specified in ANSI/TIA/EIA-568-A Annex E and in TIA/EIA TSB-67.

Coupling can occur between adjacent link segments referred to as Alien Cross Talk (AXT). In order to limit the AXT between any 2 link segments the differential pair-to-pair AXT loss shall be 10 dB better than the NEXT requirements (4).

$$AXT_{linksegment} \geq 37.1 - 16.8\log 10(f/100) \quad \text{(dB)} \qquad (4)$$

12.3.5 SIIS Link Segment ACRF (informative)

The SIIS link segment ACRF should meet the values determined using equation (5) at all frequencies from 1 MHz to 100 MHz.

$$ACRF_{linksegment} \geq -20\log(10\wedge(\frac{20.8 - 20\log(f/100)}{20}) + 4x(10\wedge(\frac{32.1 - 20\log(f/100)}{20})) \quad \text{(dB)} \qquad (5)$$

where f is the frequency in MHz

NOTE: ACRF has been referred to as ELFEXT in IEEE 802.3 and TIA/EIA standards.

12.3.5.1 SIIS Link Segment Propagation Delay Skew

The SIIS link segment propagation delay skew shall be less than 50 ns measured at 10 MHz.

12.3.6 SIIS Link Segment Propagation Delay

SIIS link segment propagation delay shall meet or be less than the values determined using the equation (6).

$$\Pr opdelay_{cable,100m} \geq 534 + \frac{36}{\sqrt{f}} + (4x2.5) \qquad (6)$$

where f is the frequency in MHz

12.4 Wet-mate Connector Transmission and Coupling Parameters TP2 to TP3

12.4.1 General

The SIIS link segment components consisting of twisted-pair cables and complete wet-mate connector pair should meet or exceed the component specifications in TIA/EIA- category 5.

© 2010 All rights reserved

For 100BASE-TX, connecting hardware far-end crosstalk (FEXT) loss is provided for information only. The equations used for Return Loss and NEXT are based on the assumptions that the optional connector set is either not used or is located away from additional connectors. Next and Return loss is adversely effected by having multiple connection points close together. In any system with multiple connectors involved, system level checks (TP1-TP2) should be made.

12.4.2 Wet-mate Connecting Hardware Insertion Loss

The worse pair connecting hardware insertion loss should be less than or equal to the values in the table below at the specified frequency in MHz.

Table 23: Connecting Hardware Insertion Loss, Worst Pair

Frequency (MHz)	Category 5 (dB)
1.0	0.1
4.0	0.1
8.0	0.1
10.0	0.1
16.0	0.2
20.0	0.2
25.0	0.2
31.25	0.2
62.5	0.3
100.0	0.4

12.4.3 Wet-mate Connecting Hardware Return Loss

The minimum return loss should be 19 dB or greater for all frequencies between 1 MHz and 20 MHz. For all frequencies from 20 MHz to 100 MHz, the minimum return loss should follow the equation (7) listed in the table below. These return loss values were chosen to limit peak reflected voltages to 7% or less up to 20 MHz and to 20% or less from 20 MHz to 100 MHz.

Table 24: Connecting Hardware Return Loss

Frequency (MHz)	Return Loss (dB)	
$1 \le f < 20$	≥ 19	
$20 \le f \le 100$	$\ge 19 - 10\log(f/20)$	(7)

12.4.4 Wet-mate Connecting Hardware NEXT Loss

The worst case connector NEXT loss for any combination of disturbing and disturbed pairs should meet the values determined using equation (8) at all frequencies from 1 MHz to 100 MHz.

© 2010 All rights reserved

$$NEXT_{conn} \geq 33.5 - 18.4 \log(f/100) \quad \text{(dB)} \qquad (8)$$

where f is the frequency in MHz

AXT loss shall be 10 dB better than the NEXT requirements. See equation (4) as an example.

12.4.5 Wet-mate Connecting Hardware FEXT Loss (informative)

The worst case connector FEXT loss should meet the values determined using equation (9) at all frequencies from 1 MHz to 100 MHz.

$$FEXT_{conn} \geq 23.5 - 18.4 \log(f/100) \quad \text{dB} \qquad (9)$$

where f is the frequency in MHz

12.5 SCM and Sensor Test Points (TP1 to TP3 and TP4 to TP6)

The SCM transmission and coupling parameters shall be verified at TP1 to TP3. The sensor transmission and coupling parameters shall be verified at TP4 to TP6. The equations used for Return Loss and NEXT are based on the assumptions that the optional connector set is either not used or is located away from additional connectors. Next and Return loss is adversely effected by having multiple connection points close together. In any system with multiple connectors involved, system level checks (TP1-TP2) should be made.

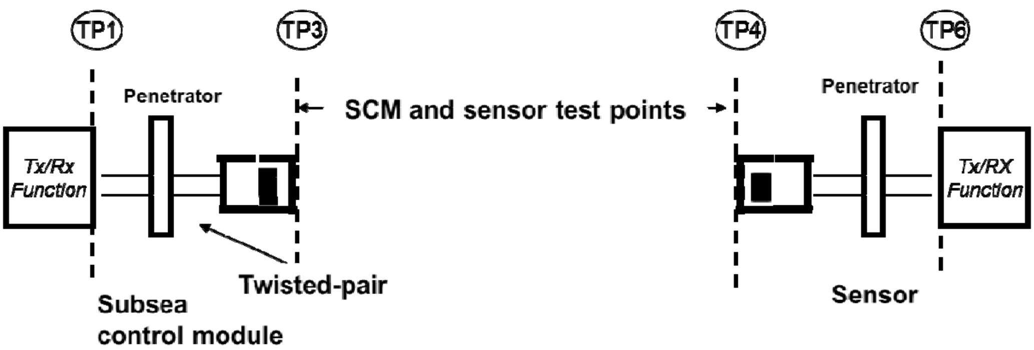

Figure 5: SCM Sensor Test Points

12.5.1 SCM and Sensor Test Points (TP1 to TP3 and TP4 to TP6) Insertion Loss

The insertion loss of TP1-TP3 and TP4-TP6 shall meet the values determined using equation (10) at all frequencies from 1 MHz to 100 MHz.

$$IL_{TP1-TP3-TP5-TP6} \leq 0.10(2.1 f^{0.529} + 0.4/f)) \quad \text{(dB)} \qquad (10)$$

where f is the frequency in MHz

© 2010 All rights reserved

12.5.2 SCM and Sensor Test Points (TP1 to TP3 and TP4 to TP6) Return Loss

The minimum return loss shall be 19 dB or greater for all frequencies between 1 MHz and 20 MHz. For all frequencies from 20 MHz to 100 MHz, the minimum return loss shall follow equation (11).

Table 25: TP1-TP3 and TP4-TP6 return loss

Frequency (MHz)	Return Loss (dB)	
$1 \le f < 20$	≥ 19	
$20 \le f \le 100$	$\ge 19 - 10\log(f/20)$	(11)

12.5.3 SCM and Sensor Test Points (TP1 to TP3 and TP4 to TP6) NEXT

The worst case connector NEXT loss for any combination of disturbing and disturbed pairs shall meet the values determined using equation (12) at all frequencies from 1 MHz to 100 MHz.

$$NEXT_{TP1-TP3-TP5-TP6} \ge 33.5 - 18.4\log(f/100) \text{ (dB)} \qquad (12)$$

where f is the frequency in MHz

AXT loss shall be 10 dB better than the NEXT requirements. See equation (4) as an example.

12.6 Subsea Link Segment Assembly Transmission and Coupling Parameters (TP2to TP5)

The subsea link segment assembly transmission and coupling parameters shall be verified at TP2 to TP5. The equations used for Return Loss and NEXT are based on the assumptions that the optional connector set is either not used or is located away from additional connectors. Next and Return loss is adversely effected by having multiple connection points close together. In any system with multiple connectors involved, system level checks (TP1-TP2) should be made. This length segment is limited to 90m due to length consumption in TP1-TP3 and TP4-TP6. Overall length is limited to 100m TP1 to TP6.

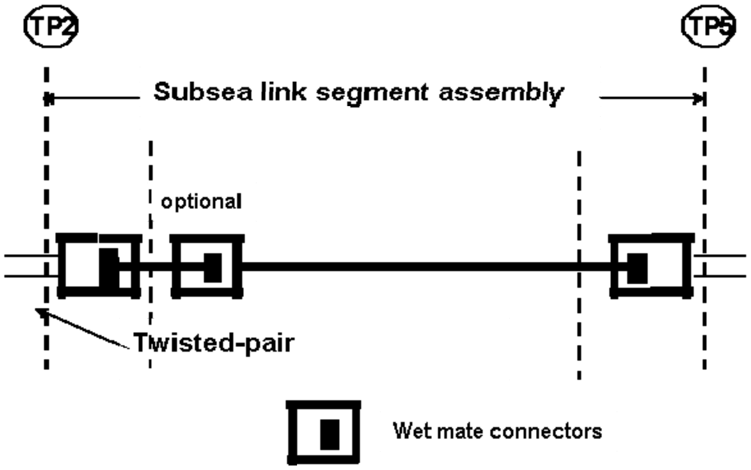

Figure 6: Subsea Link Segment Assembly Test Points

© 2010 All rights reserved

12.6.1 Link Segment Assembly Insertion Loss

The insertion loss of the link segment assembly pairs shall meet the values determined using equation (13) at all frequencies from 1 MHz to 100 MHz.

$$IL_{linksegment} \leq 0.8(2.1f^{0.529} + 0.4/f) \quad \text{(dB)} \qquad (13)$$

where f is frequency in MHz

The insertion loss specification shall be met when the link segment is terminated in 100Ω.

12.6.2 Link Segment Assembly Differential Characteristic Impedance

The nominal differential characteristic impedance of each link segment assembly, which includes cable cords and connecting hardware, is 100Ω for all frequencies between 1 MHz and 100 MHz.

12.6.3 Link Segment Assembly Return Loss

The link segment assembly return loss shall be greater than or equal to the values determined using equation (14) at all frequencies from 1 MHz to 100 MHz. The reference impedance shall be 100Ω.

Table 26: Link Segment Assembly Return Loss

Frequency (MHz)	Return Loss (dB)
1≤ f < 20	15
20 ≤ f ≤100	15 - 10log(f/20)

(14)

where f is the frequency in MHz.

12.6.4 Link Segment Assembly Differential Near-End Crosstalk (NEXT)

In order to limit the crosstalk at the near-end of a link segment assembly, the differential pair-to-pair near-end crosstalk loss between the two pairs of a link segment shall meet the values determined using equation (15) at all frequencies from 1 MHz to 100 MHz.

$$NEXT_{linksegment\_assembly} \geq 27.1 - 16.8\log 10(f/100) \quad \text{(dB)} \qquad (15)$$

where f is the frequency in MHz

AXT loss shall be 10 dB better than the NEXT requirements. See equation (4) as an example.

12.6.5 Link Segment Propagation Delay Skew

Link segment propagation delay skew shall be less than 50 ns measured at 10 MHz.

12.6.6 Link Segment Propagation Delay

The link segment propagation delay shall meet or be less than the values determined using the equation (16).

© 2010 All rights reserved

$$\mathrm{Pr}\,opdelay_{cable,100m} \geq 534 + \frac{36}{\sqrt{f}} + (3x2.5) \qquad (16)$$

where f is the frequency in MHz

12.7 SIIS Link Segment Cable

The SIIS link segment twisted-pair cables shall meet or exceed the component specifications in TIA/EIA- category 5. For 100BASE-TX, cable far-end crosstalk (FEXT) loss is provided for information only. Cable specifications are specified at 20 °C ± 3 °C (68 °F ± 5.5°F).

12.7.1 Cable Mutual Capacitance

The mutual capacitance of any pair at 1 kHz and measured at, or corrected to, a temperature of 20 °C, shall not exceed 5.6 nF/100m (328ft) when measured in accordance with ASTM D 4566.

12.7.2 Cable Structural Return Loss

The SRL for 100 Ω cables shall be greater than or equal to the values determined using equation (17) at all frequencies from 1 MHz to 100 MHz. The reference impedance shall be 100 Ω.

Table 27: Cable Structural Return Loss, Worst Pair

For a length of 100 m (328 ft)

Frequency (f)	**Category 5**	
(MHz)	**(dB)**	
$1 \leq f < 20$	23	
$20 \leq f \leq 100$	16 – 10 log(f / 100)	(17)

where f is the frequency in MHz

12.7.3 Cable Return Loss

The return loss of 100Ω cables shall be greater than or equal to the values determined using equation (18) at all frequencies from 1 MHz to 100 MHz. The reference impedance shall be 100Ω.

Table 28: Cable Return Loss Worst Pair

For a length of 100 m (328 ft)

Frequency (f)	**Category 5**	
(MHz)	**(dB)**	
$1 \leq f < 10$	17 + 3log(f)	
$10 \leq f < 20$	20	
$20 \leq f \leq 100$	20 – 7log(f / 20)	(18)

where f is the frequency in MHz

12.7.4 Cable Insertion Loss

The maximum insertion loss of any cable pair, in dB/100m, measured at, or corrected to, a temperature of 20 °C in accordance with ASTM D4566 shall be less than or equal to the value determined using equation (19) at all frequencies from 1 MHz to 100 MHz.

© 2010 All rights reserved

$$InsertionLoss_{cable,100m} \leq 1.967\sqrt{f} + 0.023 \cdot f + \frac{0.050}{\sqrt{f}} \text{dB} \qquad (19)$$

where f is the frequency in MHz

12.7.5 Cable NEXT Loss

The cable NEXT loss for any pair combination at room temperature shall meet the values determined using equation (20) at all frequencies from 1 MHz to 100 MHz.

$$NEXT_{cable,100m} \geq 32.3 - 15\log(f/100) \text{ dB} \qquad (20)$$

where f is the frequency in MHz

AXT loss shall be 10 dB better than the NEXT requirements. See equation (4) as an example.

12.7.6 Cable 100 Cable FEXT Loss or ACRF (informative)

The cable ACRF should meet the values determined using equation (21) at all frequencies from 1 MHz to 100 MHz.

$$ELFEXT_{cable,100m} \geq 20.8 - 20\log(f/100) \text{ (328 ft)} \qquad (21)$$

where f is the frequency in MHz

12.7.7 Cable Propagation Delay Skew

Horizontal cable propagation delay skew shall be less than 45ns/100m at all frequencies from 1 MHz to 100 MHz. In addition, the propagation delay skew between all pairs shall not vary more than ± 10 ns from the measured value.

12.7.8 Cable Propagation Delay

Horizontal cable propagation delay shall meet or be less than the values determined using the equation (22).

$$\Pr opdelay_{cable,100m} \leq 534 + \frac{36}{\sqrt{f}} \qquad (22)$$

where f is the frequency in MHz

12.7.9 Measurement Precautions for Cable Return Loss and ELFEXT

The transmission measurements of return loss and ELFEXT should be performed on cable samples of 100 m (328 ft) removed from the reel or package. The test sample should be laid out along a non-conducting surface or supported in aerial spans, and all pairs should be terminated with a precision metal film or chip 100 Ω ± 1% resistor.

12.7.10 Test Parameters

The test points described in Figure 4 and corresponding transmission and coupling parameter specifications provide the basis for the acceptance criteria for the SIIS link segment, link segment assembly, and components (wet-mate connectors and cable).

© 2010 All rights reserved

Acceptance criteria test parameters and test points are listed in the tables 29 and 30.

Transmission, coupling and Installation parameters	SIIS Link Segment 100BASE-TX TP1-TP6 Reference requirement Cat5	SIIS SCM/ISD TP1-TP3 TP4-TP6	SIIS Link segment Assembly TP2-TP5 Cable with connectors (male + female)	SIIS Category 5 Connector TP2-TP3 TP4-TP5	SIIS Category 5 SEM/ISD and Penetration TP1-TP2 TP5-TP6
Insertion loss	Reference requirement For limit refer to equ. (1)	Mandatory For limit refer to equ. (10)	Mandatory For limit refer to equ. (13)	Recommended *) For limit refer to Table 23	Information
Return loss (two directions)	Reference requirement For limit refer to equ. (2)	Mandatory For limit refer to equ. (11)	Mandatory For limit refer to equ. (14)	Mandatory For limit refer to equ. (7)	Information
NEXT loss pair-to-pair (two directions)	Reference requirement For limit refer to equ. (3)	Mandatory For limit refer to equ. (12)	Mandatory For limit refer to equ. (15)	Mandatory For limit refer to equ. (8)	Information
NEXT loss power sum	Information	Information	Information	Information	Information
ELFEXT, pair-to-pair (ACRF)	Information	Information	Information	Information	Information
ELFEXT, power sum	Information	Information	Information	Information	Information
Propagation delay	Reference requirement For limit refer to equ. (6)	Information	Mandatory For limit refer to equ. (16)	Information	Information
Propagation delay skew	Reference requirement	Information	Mandatory	Information	Information
Length	Information	Information	Information	Information	Information
Wire map	Reference requirement	Information	Mandatory	Information	Information

Table 29: Acceptance criteria for qualification testing

Reference req. Reference requirement is the Cat5 specification originally from 802.3-2012, section 2, clause 25.4.9 and ANSI/TIA/EIA-568-A:1995 (Cat5) and ISO/IEC 11801:1995 (Class D). Due to the full link segment not being available for verification of physical characteristics sub-segments as specified above shall be verified.

Mandatory Measurement is required and shall fulfill the limit specified in order to achieve the target on the complete link

Recommended Measurement is required and should fulfill the limit specified in order to achieve the target on the complete link

Information Measurement is for information only. No requirements specified here. Test equipment may provide misleading results.

*) this requirement is recommended only due to accuracy limits in measurement equipment.

© 2010 All rights reserved

Transmission, coupling and Installation parameters	SIIS Link Segment 100BASE-TX TP1-TP6 Reference requirement Cat5	SIIS Link segment Assembly TP2-TP5 Cable with connectors (male + female)	SIIS SCM/Sensor TP1-TP3; TP4-TP6 (Single direction, from TP3 into SCM and from TP4 into ISD)
Insertion loss	Reference requirement For limit refer to equ. (1)	Mandatory For limit refer to equ. (13)	n/a
Return loss	Reference requirement For limit refer to equ. (2)	Mandatory For limit refer to equ. (14)	Mandatory For limit refer to equ. (11)
NEXT loss pair-to-pair	Reference requirement For limit refer to equ. (3)	Mandatory For limit refer to equ. (15)	Mandatory For limit refer to equ. (12)
NEXT loss power sum	Information	Information	n/a
ELFEXT, pair-to-pair (ACRF)	Information	Information	n/a
ELFEXT, power sum	Information	Information	n/a
Propagation delay	Reference requirement For limit refer to equ. (6)	Mandatory For limit refer to equ. (16)	n/a
Propagation delay skew	Reference requirement	Mandatory	n/a
Length	Information	Information	n/a
Wire map	Reference requirement	Mandatory	n/a

Table 30: Acceptance criteria for FAT on SCM (TP1-TP3), cable with connectors (TP2-TP5), ISD (TP4-TP6)

Reference req. Reference requirement is the Cat5 specification originally from 802.3-2012, section 2, clause 25.4.9 and ANSI/TIA/EIA-568-A:1995 (Cat5) and ISO/IEC 11801:1995 (Class D). Due to the full link segment not being available for verification of physical characteristics sub-segments as specified above shall be verified.

Mandatory Measurement is required and shall fulfill the limit specified in order to achieve the target on the complete link

Recommended Measurement is required and should the limit specified in order to achieve the target on the complete link

Information Measurement is for information only. No requirements specified here. Test equipment may provide misleading results.

© 2010 All rights reserved