SUB/ES/DCT

MEDIUM VOLTAGE SUBSEA ELECTRICAL CONNECTION SYSTEMS

INDEX OF REVISIONS

REV	DESCRIPTION AND/OR AFFECTED SHEETS
0	Original issued for internal review.
A	First release.
B	Item 6.26
C	Voltage classes, Frequency, Internal and external environments for TYPE 1 Connector, Lock mechanism, Qualification program review, Interfacing part tests, Design documentation.
D	Petrobras departments names update in the header

Júlia Gomes Ázara de Oliveira — Assinado de forma digital por Júlia Gomes Ázara de Oliveira Dados: 2021.01.21 17:50:25 -03'00'

Carlos Antonio Pereira Viana — Assinado de forma digital por Carlos Antonio Pereira Viana DN: cn=Carlos Antonio Pereira Viana, o=Petrobras, ou, email=capviana@petro [illegible] Dados: 2020.12.23 10:37:44 -03'00'

	ORIGINAL	REV. A	REV. B	REV. C	REV. D	REV. E
DATE	14/04/2010	25/08/2010	15/02/2011	04/11/2013	10/11/2020	
MADE BY	CXS2/K059	CXS2/K059	CXS2/K059	ES54	HMHT	
CHECKED	(see pag.2)	(see pag.2)	CLW4	CXS2	CLW4	
APPROVAL	K059	K059	K059	CXF0	TRNN	

CONTENTS

1. OBJECTIVE

1.1. This specification defines the minimum requirements for design, qualification, manufacturing and factory acceptance tests of MEDIUM VOLTAGE SUBSEA POWER CONNECTION SYSTEMS and its components, as the medium voltage power connectors, penetrators, cross-overs, cables, hoses and dielectric fluid in medium voltage power flying leads and pig-tails, that shall be part of a subsea electrical power system.

1.2. For sake of simplicity the subsea medium voltage power connectors, penetrators and cross-overs will be referred herein as “MV Connector” except when otherwise specified.

1.3. This ET applies for MV Connectors with rated voltage from 3.6/6.0(7.2)kV up to 26.0/45.0(52.0)kV and frequency up to 120Hz.

1.4. The Design Basis presented herein shall be complemented by the specific subsea power system Technical Specification (ET) and its related subsea equipment Material Requisition (RM) documents. Reference shall also be made to those documents for relevant electrical test connectors, dummy and parking connectors, spare parts and additional technical requirements according to the application.

1.5. This specification is mandatory for all MEDIUM VOLTAGE SUBSEA POWER CONNECTION SYSTEMS to be qualified after the date of the current revision. However, it shall not void previous qualifications approved by PETROBRAS prior to the date of the current revision except when stated otherwise in the subsea electrical system Technical Specifications (ET) or in its related Material Requisition (RM) documents.

2. REFERENCE CODES, STANDARDS AND DOCUMENTS

2.1. The latest revision of the following PETROBRAS documents shall be used where applicable to the MV Connector design, manufacture, testing and operation:

- ET-3000.00-1521-610-PAZ-001 – Projeto de Interfaces para Operações com ROV;
- PETROBRAS NI-2415 – Crude Oil Production – Production and Injection Wells Environment.

2.2. The latest edition of the following standards shall be used where applicable for the MV Connector design, manufacture, testing and operation:

- ASTM D1868: Standard Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems;
- ICEA S-68516: Ethylene-Propylene-Rubber Insulated Wire and Cable for Transmission and Distribution of Electric Energy
- IEC 60068-2-14: Environmental testing – Part 2-14: Tests – Test N: Change of temperature;
- IEC 60502-2: Power cables with extruded insulation and their accessories for rated voltages from 1kV (Um=1.2kV) up to 30kV (Um=36kV) – Part 2: Cables for rated voltages from 6kV (Um=7.2kV) up to 30kV (Um=36kV);

- IEC 61238-1: Compression and mechanical connectors for power cables for rated voltages up to 30kV (Um = 36kV) – Part 1: Test methods and requirements;
- IEC 61442: Test methods for accessories for power cables with rated voltages from 6kV (Um=7.2kV) up to 30kV (Um=36kV);
- IEEE 1017: Recommended Practice for Field Testing Electric Submersible Pump Cable;
- IEEE-1018: Recommended Practice for Specifying Electric Submersible Pump Cable – Ethylene-Propylene Rubber Insulation;
- IEEE-1019: Recommended Practice for Specifying Electric Submersible Pump Cable – Polypropylene Insulation;
- ISO 13628-6: Petroleum and natural gas industries – Design and operation of subsea production systems – Part 6: Subsea production control systems;
- NORSOK Standard M-710: Qualification of non-metallic sealing materials and manufacturers;
- NORSOK Standard U-001: Subsea production systems.
- API RP 11S6: Recommended Practice for Testing of Electric Submersible Pump Cable Systems.
- API RP 11S3: Recommended Practice for Electrical Submersible Pump Installations;
- API RP 11S5: Recommended Practice for Application of Electric Submersible Cable Systems;
- API 6A: Specification for Wellhead and Christmas Tree Equipment.
- NACE MR-0175/ISO 15156: Petroleum and natural gas industries—Materials for use in H2S-containing environments in oil and gas production;

3. DEFINITIONS AND ABBREVIATIONS

3.1. Electrical System Category C:

The subsea MV electrical power system is design to work continuously and indefinitely under the fault condition of one phase earthed, i. e., any phase conductor that comes in contact with earth or with an earth conductor will not cause the disconnection of the faulty circuit from the system.

3.2. Maximum Ambient Temperature – MaxAT (ºC):

Maximum expected ambient temperature where the MV Connector is going to be installed. This value does not include any temperature contribution due to the MV Connector itself.

3.3. Maximum Storage Temperature (ºC):

Maximum temperature the MV Connector can be subject during storage period with no degradation of its characteristics.

3.4. Minimum Ambient Temperature – MinAT (ºC):

Minimum expected ambient temperature where the MV Connector is going to be installed. This value does not include any temperature contribution due to the MV Connector itself.

3.5. MV Cross-Over:

An umbilical MV power cable interface.

A special type of double-ended MV power penetrator that shall provide the means to terminate subsea the MV power cable element of a subsea umbilical in a connector-like component that shall serve as a mechanical and electrical interface to one or more MV Connectors to be fitted in an UTA, UTU or umbilical VCM.

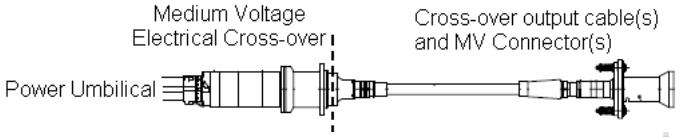

Figure 1 – MV Cross-over schematics

3.6. MV Power Flying Lead – MV-FL:

Medium voltage power flying lead (MV-FL) or MV power jumper is a length of MV single-phase cable(s) installed inside oil filled hose(s) (commonly one oil filled hose with three MV single-phase cables inside it or three oil filled hoses with one MV single-phase cable inside each hose), ended at both sides with wet mate female MV Connectors and intended to be diver or ROV operated.

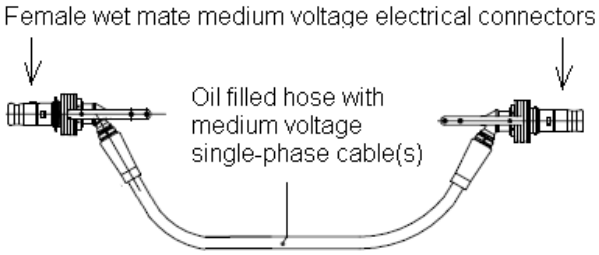

Figure 2 – Medium Voltage Power Flying Lead schematic

3.7. MV Power Pig-Tail:

Medium voltage power pig-tail is a length of MV single-phase cable(s) installed inside oil filled hose(s) (commonly one oil filled hose with three MV single-phase cables inside it or three oil filled hoses with one MV single-phase cable inside each hose), with at least one end terminated with dry mate MV power connector(s) or MV power penetrator(s) and intended to be resident in a subsea MV power equipment (not diver or ROV operated).

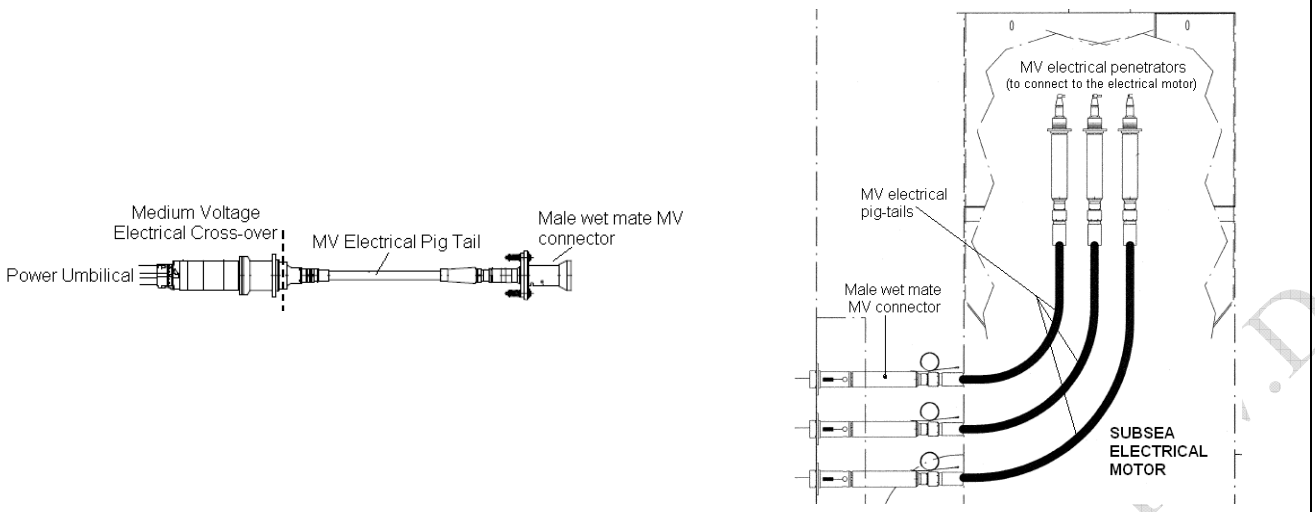

Figure 3 – Medium Voltage Electrical Pig-Tail schematics

3.8. Plug:

Female half of the MV Connector.

3.9. Rated Condition:

Operating condition defined by the MV Connector rated voltage, rated current and maximum ambient temperature for which the MV Connector is designed.

3.10. Rated Current - IR (A):

Current that can flow continuously through the MV Connector at rated condition during its designed life.

3.11. Rated Voltages – U_0/U (Um) kV:

Voltages that can be applied continuously at the MV Connector at rated condition during its design life, where:

- U_0 is the rated frequency voltage between conductor and earth or metallic screen for which the MV Connector is designed;
- U ($U=\sqrt{3}U_0$) is the rated frequency voltage between conductors for which the MV Connector is designed.
- Um ($Um=2U_0$) is the maximum rated frequency voltage between conductors for which the MV Connector is designed.

3.12. Receptacle:

Male half of the MV Connector.

3.13. Sea Water Temperature – SeaWT (°C):

Sea water temperature expected in the ambient where the MV Connector is going to be installed.

3.14. Steady-State Frequency Range - Δf (Hz):

Range of power system frequencies for which the MV Connector is designed.

3.15. Thermal Equilibrium:

The state reached when the temperature rises of the several parts of the MV Connector do not vary by more than a gradient of 2ºC per hour.

3.16. TYPE 1:

MV Connector that is exposed to fluids other than seawater (liquid and/or gas) at extreme environmental conditions.

3.17. TYPE 2:

MV Connector that is not exposed to produced fluids (oil and gas) at extreme environmental conditions.

3.18. Abbreviated Terms:

AC	Alternating Current
DC	Direct Current
DEL	Discharge Extinction Level
DIV	Discharge Inception Level
ESP	Electric Submersible Pump
ET	PETROBRAS Technical Specification document (*Especificação Técnica*)
FAT	Factory Acceptance Tests
HXT	Horizontal Subsea Christmas Tree
IR	Insulation Resistance
Max	Maximum
Min	Minimum
MOBO	Seabed pump module with an ESP installed in a dummy well
MPP	Multi-phase Pumping
MV	Medium Voltage
MV-FL	Medium Voltage Flying Leads
PD	Partial Discharge
RM	PETROBRAS Material Requisition (Requisição de Material) document
RWI	Raw Water Injection
ROV	Remote Operated Vehicle
S-BCSS	Skid with Electric Submersible Pump(s) installed at mudline
TH	Tubing Hanger
THD_V	Total Harmonic Distortion of Voltage Waveform
UTA	Umbilical Termination Assembly (umbilical power cable interface)
UTU	Umbilical Termination Unit (same as UTA)
VCM	Vertical Connection Module

4. SUBSEA ELECTRICAL MV CONNECTOR TYPES AND DESIGN DATA

4.1. TYPE 1 MV Connector have 2 distinct environments: internal and external. Internal environment denote that the connector may operate in contact with fluids other than sea water. As in the external environment it is understood that the connector will operate in contact with sea water but in high temperature area.

4.2. TABLE 1 and TABLE 2 below provide the design data for TYPE 1 MV Connector. Each application values shall be informed in the application's corresponding RM of which the present ET is one of the official specification documents.

4.3. Typical examples for TYPE 1 application are HXT TH MV Connector, MOBO Pump Hanger MV Connector, S-BCSS Capsule MV penetrator, Subsea Motor Penetrator.

TABLE 1 – TYPE 1 MV Connectors for Internal Applications Design Data

Number of terminals:	1 ( )	3 ( )
Rated Voltage U_0/U (U_m):	___ / ___ (___) kV	
Steady-State Frequency Range :	0 up to 120 Hz	
Steady-State Frequency:	Hz	
Maximum Ambient Temperature – MaxAT:	110 °C	
Minimum Ambient Temperature – MinAT:	2 °C	
Sea Water Temperature – SeaWT:	4 °C	
Maximum Storage Temperature:	60 °C	
Rated Current – I_R:	___ A	
Minimum number of on / off cycles per year:	65	
Maximum decompression ratio:	1,000 psi/minute	
Maximum operational pressure:	psi	
Gas seal:	Yes (X)	No ( )
Maximum MV Connector outside diameter:	___ mm	
Design life:	10 years	
Minimum number of wet-mating and de-mating operations:	100	
Maximum operating water depth:	3,000 m	
Subsea powerl system category (as IEC 60502-2)	Category C	
Maximum RMS single-phase short-circuit current	___ A	
Maximum RMS short-circuit current	___ kA	
Maximum short-circuit current duration	___ ms	

TABLE 2 – TYPE 1 MV Connectors for External Applications Design Data		
Number of terminals:	1 ( )	3 ( )
Rated Voltage U_0/U (U_m):	___ / ___ (___) kV	
Steady-State Frequency Range :	0 up to 120 Hz	
Steady-State Frequency:	Hz	
Maximum Ambient Temperature – MaxAT:	110 ºC	
Minimum Ambient Temperature – MinAT:	2 ºC	
Sea Water Temperature – SeaWT:	4 ºC	
Maximum Storage Temperature:	60 ºC	
Rated Current – I_R:	___ A	
Minimum number of on / off cycles per year:	65	
Maximum decompression ratio:	50 psi/minute	
Gas seal:	Yes ( )	No (X)
Maximum MV Connector outside diameter:	___ mm	
Design life:	10 years	
Minimum number of wet-mating and de-mating operations:	100	
Maximum operating water depth:	3,000 m	
Subsea powerl system category (as IEC 60502-2)	Category C	
Maximum RMS single-phase short-circuit current	___ A	
Maximum RMS short-circuit current	___ kA	
Maximum short-circuit current duration	___ ms	

4.4. TYPE 2 Connectors are direct in contact with sea water outside the subsea equipment, as MV Crossover and Flying Leads. TABLE 3 below provides the design data for TYPE 2 MV Connector. Each application values shall be informed in the application's corresponding RM of which the present ET is one of the official specification documents.

TABLE 3 – TYPE 2 MV Connectors Design Data		
Number of terminals:	1 ( )	3 ( )
Rated Voltage U_0/U (U_m):	___ / ___ (___) kV	
Steady-State Frequency Range :	0 up to 120 Hz	
Maximum ambient temperature – MaxAT:	25 ºC	
Minimum ambient temperature – MinAT:	2 ºC	
Seawater temperature – SeaWT:	4 ºC	
Maximum storage temperature:	60 ºC	
Rated current – I_R:	___ A	
Minimum number of on / off cycles per year:	65	
Maximum decompression ratio:	50 psi/minute	
Maximum MV Connector outside diameter:	___ mm	
Design life:	20 years	
Minimum number of wet-mating and de-mating operations:	100	
Maximum operating water depth:	3,000 m	
Subsea electrical system category (as IEC 60502-2)	Category C	
Maximum RMS single-phase short-circuit current	___ A	
Maximum RMS short-circuit current	___ kA	
Maximum short-circuit current duration	___ ms	

4.5. Supplier shall refer to the application's corresponding PETROBRAS RM of which the present ET is one of the official specification documents for the exact classification (TYPE 1 internal/external or TYPE 2) of each MV Connector in the scope of supply. TYPE 1 shall be the default classification for all subsea MV Connectors in the scope of supply except when explicit stated otherwise in the subsea electrical system specifications and in the corresponding PETROBRAS RM.

5. SUBSEA ELECTRICAL MV CONNECTOR SPECIFICATIONS

5.1. The MV Connector shall be designed, manufactured and qualified to operate continuously immersed in sea water (TYPE 1 external and TYPE 2) and other fluids (TYPE 1 internal). The Design Water Depth shall be at least 3,000 meters. It will be energized (turned on) and de-energized (turned off) throughout its designed life.

5.2. Unless specified otherwise, all subsea MV power connectors specified in this ET are wet mateable.

5.3. The MV Connector Plug shall have a controlled environment with at least 2 independent barriers to protect the electrical contact(s) from sea water (TYPE 1 external and TYPE 2) and other fluids (TYPE 1 internal). At least one of such barriers shall consist of a pressure balanced chamber filled with a suitable dielectric fluid, with a pressure port to allow it to be filled and tested. Each independent barrier shall be capable to block and withstand sea water (TYPE 1 external and TYPE 2) and other fluids (TYPE 1 internal) getting into the electrical contact(s). The MV Connector shall be able to operate with one of such barriers degraded.

5.3.1. In case of a different philosophy of a Plug controlled environment the design shall be approved by Petrobras. Furthermore, additional qualification tests may be required for these particular designs.

5.4. The MV Connector Receptacle shall have the terminal(s). It is strongly recommended that the receptacle have its own means to protect its terminal(s) from complete exposure to sea water while unmated. Receptacles shall be capable to stay at least 30 days unmated at sea water with no additional protection and with no degradation of its characteristics.

5.5. Both MV Connector Receptacle and Plug shall have at least 2 independent barriers to protect the electrical contact between each terminal and the respective cable conductor in the electrical cable termination interface from exposure to sea water (TYPE 1 external and TYPE 2) and other fluids (TYPE 1 internal). At least one of such barriers shall consist of a pressure balanced chamber filled with a suitable dielectric fluid, with a pressure port to allow it to be filled and tested, except for TYPE 1 connectors for internal applications. Each independent barrier shall be capable to block and withstand a possible sea water (TYPE 1 external and TYPE 2) and other fluids (TYPE 1 internal) migration from the insulated conductors of the electrical cable to the interface between each conductor and its terminal. The MV Connector shall be able to operate with one of such barriers degraded.

NOTE: The use of 2 or more O-rings in series shall count as one barrier only.

5.6. On the umbilical side, the MV cross-over shall have at least 2 independent barriers to protect the electrical contact between each cable conductor and the respective penetrators terminal from exposure to sea water. At least one of such barriers shall consist of a pressure balanced chamber filled with a suitable dielectric fluid, with a pressure port to allow it to be filled and tested. Each independent barrier shall be capable to block and withstand a possible sea water migration from the insulated conductors of the electrical cable to the interface between each

conductor and their respective penetrator's terminal. The MV Connector shall be able to operate with one of such barriers degraded.

NOTE: The use of 2 or more O-rings in series despite of different models and/or materials shall count as one barrier only.

5.7. The MV cross-over shall have a detachable cap that provides a mechanical interface (preferably JIC standard size) for its oil filled hose(s). The detachable cap shall have a pressure port to allow the hose(s) and the penetrator chamber to be filled with dielectric oil and tested after the connection and complete assembly of the MV cross-over cable conductors to their respective penetrator terminals.

5.7.1. Typically, one oil filled hose with three MV power single-phase cables is used for three terminals MV connectors, while three individual oil filled hoses with a MV power single-phase cable inside each hose may be used for interface with three single terminal MV connectors. The configuration chosen depends on the subsea electrical system specifications.

5.7.2. For interface among equipments from different vendors, a standard JIC size shall be specified.

5.8. The MV Connector shall be able to operate continuously with no damage or degradation of its performance characteristics with one phase shorted to ground (any one phase in earthed fault condition), provided the subsea electrical system voltage between each unfaulted phases and the ground remains equal or less than the MV Connector rated voltage U_0.

5.9. The MV Connector and its accessories shall be manufactured with materials strong enough to withstand all the environmental and operational conditions they will be exposed during its designed life and in accordance with NACE MR-0175/ISO 15156. They shall also withstand all the impacts envisaged during transportation, installation and operation.

5.10. The rear part of the MV Connector terminals shall allow several connections with MV electrical cable conductors with no damage.

5.11. MV Connector Supplier shall not use materials that need a time to finish the curing process during the MV Connector field assembly, except in cases where potting is considered absolutely necessary to provide extra strength against rapid decompression.

5.12. The MV Connector Supplier shall present electrical analysis of the complete MV Connector solution, demonstrating that the insulation materials used will work properly throughout its designed life. These analysis shall consider the electrical field distribution in all MV connection system components and materials, the influence of maximum ambient temperature and temperature rise during operation at rated condition and the power system characteristics.

5.12.1. The mechanical and dielectric stresses analysis due to rapid temperature change from MinAT to MaxAT and from MaxAT to MinAT for TYPE 1 MV Connectors shall be presented.

5.13. The MV Connector Supplier shall demonstrate compliance with the MV power cable, not generating neither suffering any degradation of its mechanical and electrical characteristics during its designed life.

5.14. All TYPE 1 MV Connectors for internal applications shall have at least one independent barriers designed for gas sealing.This barrier shall be designed mechanically and electrically to work properly, throughout the MV Connector designed live.

5.15. All TYPE 1 MV Connectors for internal applications shall be prepared to provide gas sealing of its external body against the subsea equipment body. This gas sealing shall be qualified and provided by the connector supplier unless otherwise specified.

5.16. Boot seals shall not permit creep of the insulation of any conductor attached to the MV Connector terminals nor permit leakage of dielectric fluid through the layers of the single-phase MV power cable.

5.17. MV Connector design shall include easily visible phases identification (letters or colors code).

5.18. The connector assembly shall have self-evident means to indicate that the connector assembly is fully mated; i.e. a positive fully mated indication shall be part of the design. Visual indication shall be clearly visible from ROV camera.

5.19. The mechanical transition between the connector and the hose on the Medium Voltage Electrical Flying Lead shall have a bend restrictor.

5.20. Voltage ratings

5.20.1. The values of Um for connector assemblies shall be according to the standard values of the highest voltage for the equipment, as defined in IEC 60038 and standard for cable selection IEC 60138, as presented in TABLE 4.

5.20.2. In exception cases, voltage rates 2.9/5(5.8)kV, 4.6/8(9.2)kV and 5/8.7(10)kV may be requested to fulfill obsolescence management requirements.

TABLE 4 – Rated Voltages U_0 / U (U_m) kV

3.6/6.0(7.2)	6.0/10.0(12.0)	8.7/15.0(17.5)	12.0/20.0(24.0)	18.0/30.0(36.0)	26.0/45.0(52.0)

5.21. Current Ratings

5.21.1. The rated current Ir of connector assemblies shall be in accordance with current classes given in IEC 60059 at MaxAT, as presented in TABLE 5.

5.21.2. In exception cases, different current rates for 2.9/5(5.8)kV, 4.6/8(9.2)kV and 5/8.7(10)kV connectors may be requested to fulfill obsolescence management requirements.

TABLE 5 – Rated Current (A@MaxAT)

100	200	250	315	400	500	630	800	1,000	1,250	1,600	2,000	2,500

5.22. The connector assembly shall comprise proven materials and components, which are qualified and suitable for relevant equipment, applications and environments, and the design life.

5.23. The connector assembly shall be compatible with relevant and interfacing fluids/materials as per operational requirements, throughout design service life.

5.24. All polymeric materials shall be compatible with the service environment.

5.25. Each connector assembly and its individual parts shall be documented as 100 % traceable, enabling comparison and rectification on similar connector assemblies. Hence,

materials, manufacturing records and recording of test results shall ensure full traceability for each connector assembly.

5.26. The connector assembly shall be designed for water-jet cleaning of marine growth in the mated condition, or with a dummy connector/protection cap installed. The potential risks of performing this water jetting shall be clearly defined and documented.

6. MV CONNECTOR TEST SPECIFICATIONS

6.1. Section 6 herein gives the general specifications for all electrical, mechanical, thermal and environmental tests to be performed during the MV Connector qualification and factory acceptance tests programs.

6.2. As a general directive, each electrical test presented below shall be performed between each MV Connector phase and ground on completely mated connectors. Although tests on individual materials, components, connector assemblies, male and/or female connector halves and/or on partially mounted connectors may also be performed where applicable.

6.3. As a general directive, each mechanical, environmental and thermal test below shall be performed on mated MV Connectors. Although tests on individual materials, components, connector assemblies, male and/or female connector halves and/or on partially mounted connectors may also be performed where applicable.

6.4. As a general directive, each mechanical, environmental and thermal test shall be preceded and followed by electrical tests:

(a) Electrical Resistance Measurement (see item 6.8);

(b) DC Insulation Resistance Measurement (see item 6.9);

(c) Power Frequency Voltage Test (see item 6.10);

(d) Partial Discharge Test (see item 6.11).

6.5. Cable MV Connector Pull Test:

The strength of all types of cable-MV Connector interfaces foreseen in the MV Connector scope of supply (e.g. power umbilical cable conductors, ESP cables, ROV jumpers, etc.) shall be verified against the MV Connector Supplier design basis.

At least three samples shall be tested for each type of cable. Each cable sample shall be assembled to a test frame with a fixed male or female MV Connector (provided they have identical cable interfaces) and then the cable shall be pulled with the loads recorded until the maximum design load is achieved.

Testing shall be carried out as outlined in IEC 61238-1, section 7, for through connectors. The tensile force applied (in Newtons) shall be minimum 60 times the conductor cross section area (mm2 Cu) or 2.5kN, whichever is greater.

Then, an Helium Leak test shall be performed in the connector for verification of all seals integrity. It is strongly advised that the MV Connector Supplier performs a similar test with the loads recorded until failure to verify the robustness of the cable-MV Connector interface design.

Acceptance criteria:

- No slipping shall occur during the last minute of the test.
- The seals shall maintain its integrity.
- In case of MV Flying Lead, the jumper shall return to the original length (pre pull test) after sufficient relaxation period.

6.6. Temperature Rise Test:

A temperature rise test at rated current and frequency shall be performed before the qualification program commence. The objective is to locate and determine the highest local temperatures within the connector assembly, to determine the current to be used for the Extended Heating Cycles Rated Condition Test (item 6.28).

The ambient temperature during the test shall be continuously monitored and maintained constant equal to the MV Connector MinAT ± 2ºC. Temperature rise shall be recorded, at least, at 30%, 50%, 75%, 90% and 100% of I_R.

The MV Connector electrical current shall be gradually increased from 0 to 30% of I_R and maintained constant until the MV Connector reaches thermal equilibrium and test values recorded. Then, the MV electrical current shall be gradually increased from 30% to 50% of I_R and maintained constant until the MV Connector reaches thermal equilibrium and test values recorded. Then, the MV electrical current shall be gradually increased from 50% to 75% of I_R and maintained constant until the MV Connector reaches thermal equilibrium and test values recorded. Then, the MV electrical current shall be gradually increased from 75% to 90% of I_R and maintained constant until the MV Connector reaches thermal equilibrium and test values recorded. Then, the MV electrical current shall be gradually increased from 90% to 100% of I_R and maintained constant until the MV Connector reaches thermal equilibrium and test values recorded. The current shall then be increased to reach a stable temperature 5-10 ºC above steady state temperature at rated current. The current determined from this test shall be used as basis for the Extended Heating Cycles Rated Condition Test described on item 6.28.

After the test at ambient temperature equal to MinAT, the MV Connector shall be carefully disassembled for signs of damage or deterioration.

The complete test procedure shall be repeated with the ambient temperature equal to MaxAT ± 2ºC.

This test shall be performed in, at least, 2 prototypes and the temperatures registered at each point of measurement in the prototypes shall not diverge in more than 3%. If this requirement is not met, new prototypes shall be assembled in order to meet this requirement and to guarantee the repeatability of the connectors' assembly.

Since the temperature rise test connector has intrusive sensors and it will not be used for the other qualification tests, it is extremely necessary that the contacts, cable crimps and assembly accuracy are the same for all other prototypes of the qualification program.

The detailed procedure applied to assembly these prototype connectors shall be registered and used for all future assemblies throughout qualification and manufacturing processes.

6.7. Helium Leak Test:

The objective of the helium leak test is to verify that all sealing barriers are correctly fitted and do not leak. Each of the 2 required barriers shall be independently tested.

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 10exp-9 mbar l/s. Temperature (ambient) and pressure (vacuum) shall be continuously recorded.

An outline procedure/sequence should be as follows:

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

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

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

Acceptance Criteria: The reading shall not increase with more than 5x10exp-8 mbar l/s during purging with helium.

6.8. Electrical Resistance Measurement:

Measurements of contact electrical resistance shall be made at stages throughout the qualification and factory acceptance tests programs.

This test shall be performed according to IEC 61238-1, Class B, through connector type.

6.9. DC Insulation Resistance Measurement:

Measurements of DC insulation resistance of each phase to ground shall be made at stages throughout the qualification and factory acceptance tests programs.

The insulation resistance against earth shall be measured on each electrical contact individually, with all other electrical contacts not in test and conductive parts earthed. The readings for 1 min, 5 min and 10 min, along with the ambient temperature and humidity, shall be presented. The dc voltage to be applied during the test shall be as indicated in TABLE 6:

TABLE 6 – Insulation Resistance Voltage Test	
Maximum System Voltage (Um)	Minimum Test Voltage (Vdc)
Um < 7,200V	2,500Vdc
Um ≥ 7,200V	5,000 Vdc

6.10. Power Frequency Voltage Test:

The Power Frequency Voltage Test shall be performed at stages throughout the qualification and factory acceptance tests program.

This test shall be performed according to IEC 60502-2, item 16.4.

For three-phase connectors, three-phase test voltage shall be applied in all three pins simultaneously.

If three-phase test voltage is not available, single-phase test voltage shall be used. Single-phase test voltage 3.5U shall be applied between each pair of pins and test voltage $3.5U_0$ be applied between all pins and earth.

6.11. Partial Discharge Test:

The Partial Discharge Test shall be performed at stages throughout the qualification and factory acceptance tests program.

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

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

Acceptance Criteria: PD level < 5 pC @ 1.73 x U_0.

6.12. Impulse Test:

A standard lightning-impulse (1.2/50) withstand voltage (BIL) test, in accordance with IEC 60060-1. Unless otherwise agreed between manufacturer and purchaser, impulse voltage peak levels shall be according to the TABLE 7.

TABLE 7 – Impulse Voltage Test

U_m (kV)	3,6	7,2	12,0	17,5	24,0	36,0
U_{peak} (kV)	20,0	40,0	60,0	75,0	95,0	145,0

6.13. 4 hours Power Frequency Voltage Test:

This test shall be performed according to IEC 60502-2, item 18.1.8.

The ambient temperature during the test shall be continuously monitored and maintained constant equal to the MV Connector MaxAT ± 2oC.

For three-phase connectors, three-phase test voltage shall be applied in all three pins simultaneously.

If three-phase test voltage is not available, single-phase test voltage shall be used. Single-phase test voltage 4U shall be applied between each pair of pins and test voltage $4U_0$ be applied between all pins and earth.

6.14. Shock Test:

Mechanical shock test shall be performed according to ISO 13628-6, item 11.2.5.2.1 with shock level Q1 (30 g acceleration, 11 ms half sine) on a complete MV Connector.

6.15. Vibration Test:

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

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

The outline test specification is as follows:

1. Sweep test of 25 mm/s (rms) in the frequency range 5 – 190 Hz, in all directions (X-Y-Z). The 25 mm/s is based on worst case level vibrations (normally 5 mm/s) and that a safety margin of 5 normally is used for accelerated vibration testing.

2. Sweep test of 3 g acceleration in the frequency range 190 – 1,000 Hz.

3. Endurance testing to prove calculated fatigue properties, where the test procedure shall reflect design service life. The endurance test shall be performed at the worst case mechanical frequency identified during the sweep tests in point 1 and 2 above. Number of cycles shall be minimum 107. A fatigue level safety margin of 2.5 shall be verified.

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

Acceptance Criteria

1. No resonances with amplification > 10 in the frequency range 5 – 1,000 Hz.

2. No fractures or visible signs of fatigue induced cracks.

3. No signs of fretting, deterioration of seals or seal leakages.

4. No reduction in pretension of mechanical parts.

6.16. Drop Test:

The male and the female halves of the MV Connector shall be dropped from at least 1 meter above a concrete floor covered with a 5 mm rubber mat. No cracks or other damage that shall harm the MV Connector operation shall be observed.

Then, both male and female halves shall be mated and dropped from at least 1 meter above a concrete floor covered with a 5 mm rubber mat. Again, no cracks or other damage that shall harm the MV Connector operation shall be observed.

6.17. Thermal Short-Circuit Tests:

This test shall be performed according to IEC 61442, items 10 and 11.

6.18. Thermal Shock Test:

This test shall verify if the MV Connector can withstand thermal shocks between extremes temperatures.

The connector assembly shall be tested in its unmated condition, at atmospheric pressure. Three high temperature cycles shall be conducted

High Temperature: The temperature shall be raised to MaxAT and maintained for a period of four hours. The connector assembly shall then be rapidly cooled by immersion in water, which shall have a temperature between 0 and 2 ˚C. Water volume shall be sufficient to ensure a rapid cooling. Allow the connector assembly to return to ambient room temperature.

6.19. Extended Heating Cycles Rated Condition Test:

This test shall be performed according to IEC 61442, item 9 with the following modifications and additions:

(a) The maximum test temperature shall be MaxAT plus the MV Connector temperature rised by the current determined on the Temperature Rise Test (item 6.6);

(b) The minimum test temperature shall be MinAT;

(c) The number of cycles shall be 200;

(d) MV Connector rated voltage and current determined on Temperature Rise Test (item 6.6) shall be turned on just before the heating period starts and turned off just before the beginning of the cooling period (see IEC 61442:2005 Figure 7 – Heating cycle as reference);

(e) MaxAT shall be achieved in the shortest possible time from start.

6.20. Dynamic Thermal & Electrical Fatigue Test:

MV Connector Supplier shall consider the feasibility of performing the Extended Heating Cycles Rated Condition Test in item 6.31 above with the MV Connector inside a pressure vessel at 110% of the equivalent Design Water Depth. In case of this option, the Extended Heating Cycles Rated Condition Test in item 6.31 will not be required.

6.21. Mate & De-mate Force Test:

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

- Correct operation of the connector assembly at specified worst case angles/speed/misalignment during mating and de-mating shall be demonstrated, where the maximum misalignment tolerances, speed and mating forces are used. All reasonable attempts to mate and lock the connector assembly with various worst case angles/speed/misalignment shall be performed.

- Correct operation of the locking mechanism shall be demonstrated. The locking mechanism shall be checked for correct operation/position both in locked and unlocked positions.

- This test shall verify that applicable forces needed to mate/demate and lock/unlock the connector assembly at all applicable conditions are within the defined envelope for each applicable force. The needed forces shall be thoroughly tested and reported. This applies to rotational and axial alignment tolerances and indications for both mating and locking.

NOTE: This test not apply to MV Penetrators.

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

6.22. Static Pressure Test:

This test shall demonstrate that the MV Connector is suitable for the Design Water Depth with at least a 110% of safety margin for robustness for MV Connector in direct contact with seawater (TYPE 1 external and TYPE 2) and 150% of safety margin for robustness for MV Connector in contact with other fluids (TYPE 1 internal). Pressure balanced MV Connectors (i.e. MV Connectors that does not require withstanding a differential pressure) shall be placed as a mated pair inside a pressure vessel for at least 24 hours. The procedure described here shall be repeated in the connector unmated.

Testing of MV Connectors that are specified to withstand the full differential pressures, for example, between atmospheric and maximum working pressure, shall be performed with one half of the MV Connector used as the pressure vessel electrical penetration interface and the other half completely inside the vessel mated with its pair. The MV Connector shall be submitted to the test for at least 24 hours while in the vessel pressurized at 150% of the equivalent Design Water Depth for MV Connector in contact with other fluids (TYPE 1 internal) and 110% for MV Connector in direct contact with seawater (TYPE 1 external and TYPE 2).

6.23. Hyperbaric Sand & Silt Mate/Demate Test:

This test shall demonstrate that the MV Connector can be mated and de-mated according to the design maximum number of cycles specified at the required maximum water depth inside an hyperbaric vessel with Artificial Sea Water as described below. A suitable remote connection rig shall be fitted inside the pressure vessel for this purpose. Testing of MV Connectors that are specified to withstand the full differential pressures, for example, between atmospheric and maximum working pressure shall be performed with one half of the MV Connector used as the pressure vessel barrier interface, with the other half completely inside the vessel and fitted to the remote connection rig. Both halves of the MV Connector shall be mated and de-mated at least the minimum number of wet-mating and de-mating operations while in the vessel pressurized at 110% of the equivalent Design Water Depth. Electrical measurements shall be taken at regular intervals.

Artificial sea water

- Artificial sea water shall be according to ASTM D1141-98
- Salinity to be approx. 35,000 ppm (sea salt plus mains water) containing approximately 1.5 per cent by weight sand and silt.
- The particle size distribution shall be according to ISO 12103-A4, Coarse test dust.
- The composition and temperature of the seawater shall be established, recorded and verified prior to testing, and circulation shall be provided and maintained during testing.

The water shall be continuously agitated while performing the tests to ensure that solids remain in suspension and are evenly distributed.

6.24. Pressure Cycling Test

This test shall demonstrate the capability of the connector sealing barriers to withstand pressure cycles. It shall be performed 30 pressure cycles. A pressure cycle consists of:

(a) Maintain the connector in atmospheric pressure for 10 minutes.

(b) Raise the pressure to 110% of the equivalent Design Water Depth for Type 2 and Type 1 external application connectors or 150% of the maximum operational pressure for Type 1 internal application connector.

(c) Maintain the connector in above specified pressure for 10 minutes.

(d) Decrease the pressure to atmospheric pressure.

The ratio of pressure increase / decrease to time shall be defined by the supplier.

6.25. Flooded Static Pressure Test:

This test shall demonstrate that the MV Connector electrical cable interface secondary barriers are able to work in a flooded environment. A test set up similar to the Static Pressure Test on item 6.18. shall be used, except that the MV Connector cable interfaces shall be left to be flooded inside the pressure vessel.

6.26. Flooded Pressure Cycling Test

This test shall demonstrate that the MV Connector electrical cable interface secondary barriers are able to work in a flooded environment with pressure cycles. A test set up similar to the Pressure Cycling Test in item 6.18 above shall be used, except that the MV Connector cable interfaces shall be left to be flooded inside the pressure vessel.

6.27. Gas Seal Test:

This test shall demonstrate that TYPE 1 MV Connector for internal applications is gas tight, including its external sealing elements.

It shall be tested the gas sealing barrier to avoid gas migration into the connector and the gas sealing barrier against the subsea equipment body.

A gas mixture shall be pressurized against the connector sealing barriers with 5,000 psi for 24 hours.

This test shall be performed at ambient temperature equal to MinAT plus the MV Connector temperature rise at rated condition in thermal equilibrium.

Then the test shall be repeated at ambient temperature equal to MaxAT plus the MV Connector temperature rise at rated conditions in thermal equilibrium.

6.28. Rapid Decompression Test:

This test shall be applied for TYPE 1 MV Connector for Internal Applications. The objective is to verify that the connector assembly can withstand the specified decompression rate.

To perform this test the gas seals must be retrieved from the connector in order to permit the gas to migrate within the connector.

The vessel should be pressurized with 145 psi (10 bar) using the test gas mixture (80% N2 + 20% CO2) at ambient temperature.

Temperature shall then be bought to MaxAT and kept constant throughout the test. After the test temperature has been reached and stabilized the pressure of the vessel shall be slowly increased to 1000 psi and held for 15 minutes.

The pressure shall then be slowly raised to 5,000 psi and held for 72 hours. Once 72 hours has been completed a rapid de-compression shall be done. Pressure shall be decreased at a rate of 1,000 psi per minute from 5,000 psi until 500 psi is achieved. The pressure shall then be held at 500 psi for 2 hours. After the 2 hours the pressure shall slowly be increased to 1000 psi and held for 15 minutes.

The pressure shall then be slowly increased to 5,000 psi and held for 23 hours, at which point the connector should go through a rapid decompression again. The total amount of RGD cycles shall be 10.

6.29. ROV Handling Trials:

Depending on the MV Connector's size and weight (including jumpers), the MV Connector Supplier will be required to perform ROV handling trials in water to verify and rectify any possible constraint for remote connections subsea. A ROV simulator frame with a working manipulator shall be used to test all possible connection scenarios foreseen to be performed subsea..

6.30. High Voltage Breakdown Test:

This test shall verify the maximum design breakdown voltage of the MV Connector assembly. Voltage shall be carefully increased in steps until breakdown occurs, after which the MV Connector shall be disassembled to determine the exact point of failure. The breakdown voltage shall be higher than 500% of MV Connector U_0 voltage.

6.31. 8 Hours Operation Test:

The Operation Test consist of applying nominal current and voltage at nominal frequency for a minimum period of 8 hours continuously. There shall be no breakdown of flash over, the leakage current shall remain constant during the test and no physical damage, tracking or defects shall be found during the visual inspection.

7. MV CONNECTOR TEST MATRIX

7.1. For MV Connector(s) not previously qualified according to this ET, MV Connector Supplier shall perform a Qualification Program according to TABLE 8, column "Qualification" as a minimum on, at least, three samples of each kind of MV Connector in the scope of supply. The same connector assembly shall be used throughout qualification testing without refurbishment. Any replacement or modifications of parts (e.g. boot seals, seal rings) during the qualification test program shall be agreed with PETROBRAS and recorded.

7.2. For MV Connector(s) previously qualified by PETROBRAS, MV Connector Supplier shall perform the Qualification Program on samples of each kind of MV Connector in the scope of supply, according to TABLE 8 under Petrobras requests anytime it is needed. This qualification may be integral or partial depending on each case.

7.3. MV Connector Supplier shall perform a Factory Acceptance Testing Program according to TABLE 8, column "FAT" as a minimum in all MV Connectors in the scope of supply.

7.4. For Qualification Program, a power cable, similar to the one to be used at the end application, shall be terminated at each MV power connector half. Preferably, each cable sample might be 5m long.

7.5. The type of power cable to be used at Qualification Program shall be agreed between PETROBRAS and manufacturer.

7.6. The manufacturer shall present to PETROBRAS the test procedures, including the sequence of test, the required number of samples and the MV power connector samples preparation at least 90 (ninety) days before the test realization.

7.7. The test procedures, including their acceptance criteria, shall be agreed between PETROBRAS and manufacturer.

7.8. TABLE 8 presents the qualification and factory acceptance tests to be performed.

Test Specification	Qualification	FAT
6.5 Cable MV Connector Pull Test	X	
6.6 Temperature Rise Test	X	
6.7 Helium Leak Test	X	X
6.8 Electrical Resistance Measurement	X	X
6.9 DC Insulation Resistance Measurement	X	X
6.10 Power Frequency Voltage Test	X	X
6.11 Partial Discharge Test	X	X
6.12 Impulse Test NOTE 1	X	
6.13 4 hours Power Frequency Voltage Test NOTE 1	X	
6.14 Shock Test NOTE 1	X	
6.15 Vibration Test NOTE 1	X	
6.16 Drop Test NOTE 1	X	
6.17 Thermal Short-Circuit Test NOTE 1	X	
6.18 Thermal Shock Test NOTE 1	X	
6.19 Extended Heating Cycles Rated Condition Test NOTE 1	X	
6.20 Dynamic Thermal & Electrical Fatigue Test NOTE 1	X	
6.21 Mate & De-mate Force Test NOTE 1	X	
6.22 Static Pressure Test NOTE 1	X	X
6.23 Hyperbaric Sand & Silt Mate/Demate Test NOTE 1	X	
6.24 Pressure Cycling Test NOTE 1	X	
6.25 Flooded Static Pressure Test NOTE 1	X	
6.26 Flooded Pressure Cycling Test NOTE 1	X	
6.27 Gas Seal Test NOTE 1	X	
6.28 Rapid Decompression Test NOTE 1	X	
6.29 ROV Handling Trials	X	
6.30 High Voltage Breakdown Test	X	
6.31 8 Hours Operation Test NOTE 1		X
NOTE 1 *– This test shall be preceded and followed by tests 6.8, 6.9, 6.10, 6.11.*		

8. MV CONNECTOR INTERFACING PARTS TEST MATRIX

8.1. A test program shall be performed for the MV Connector interfacing parts as the hoses, dielectric fluid and MV electric cables in MV-FL and MV electrical pig-tails to simulate functionality and integrity in the applicable environment, installation loads and installation tasks.

8.2. Absorption/Compensation test

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

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. For seawater applications, the test parameters shall be:

Vessel fluid: Sea water

Vessel fluid temperature: 55° C

Test pressure: Design Water Depth

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

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

The dielectric strength of the oil shall be recorded prior to and after the test.

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

- Vessel pressure
- Internal hose pressure
- Vessel temperature

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

Acceptance criteria

- The hose shall be free from damage or defects. All observations shall be documented within the qualification report.
- The dielectric strength of the compensating fluid within the hose shall remain unchanged to denote no water egress.

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

8.3. Ozone resistance

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

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 hose shall then be coiled to its minimum bend radius and held in position via cable ties.

The test shall be performed in 2 steps:

1. The assembly shall be placed within an ozone test chamber and the temperature increased to 40º C. Monitor the hose pressure and chamber temperature. Maintain the assembly at stable conditions for minimum 2 hours.

2. Expose the assembly to 50 pphm (parts per hundred million) ozone concentration for a minimum duration of 72 hours at 40º C ambient temperature. The hose pressure shall be monitored at the start and finish of the test and chamber temperature shall be monitored during the test.

Acceptance criteria

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

- The hose pressure shall not significantly change between test start and finish of the 72 hours test in step 2 above. All deviations shall be explained within the qualification report.

8.4. Ultraviolet resistance

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

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

The test shall be performed in 2 steps:

1. The assembly shall be placed within an UV test chamber and the temperature increased to 70º C. Monitor the hose pressure and chamber temperature. Maintain the assembly at stable conditions for minimum 2 hours.

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

Acceptance criteria

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

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

8.5. Thermal shock test

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

A hose assembly consisting of at least a 2 m length of hose, a pressure transducer (for monitoring hose internal pressure) and end caps, shall be filled with the relevant compensation fluid and pressurised to the specified internal pressure. The hose termination fittings shall be as per the type used in jumper assemblies. The hose shall then be coiled to its minimum bend radius and held in position via cable ties.

The tests shall be performed at atmospheric pressure.

The temperature shall be raised to 60 °C and maintained for a period of four hours. The connector assembly shall then be rapidly cooled by immersion in water, which shall have a temperature between 0 and 2 ˚C. Water volume shall be sufficient to ensure a rapid cooling. Allow the connector assembly to return to ambient room temperature.

Acceptance criteria

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

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

8.6. Destructive testing

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

A hose assembly consisting of at least a 2 meter length of hose, hose fittings and end caps, shall be filled with the relevant compensation fluid and pressurised to the specified internal pressure. The hose termination fittings shall be as per the type used in jumper assemblies.

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

- The hose elongation

- The applied tensile load at point of failure

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

Acceptance criteria

The hose assembly will be considered acceptable if the point of failure is greater than the specified minimum breaking strength (which shall be greater than 5,000 N).

8.7. Burst pressure

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

A hose assembly consisting of at least a 2 meter 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.

Acceptance criteria

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

8.8. Crush resistance

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

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

The following parameters shall be recorded:

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

Acceptance criteria

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

8.9. Outer sheath abrasion resistance

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

8.10. Hose kink test

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

A hose assembly consisting of at least a 2 meter length of hose, hose fittings and end caps, shall be filled with the relevant compensation fluid and pressurised to the specified internal pressure. The hose termination fittings shall be as per the type used in jumper assemblies.

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

Acceptance criteria

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

8.11. The manufacturer shall present in advance the test procedures, including the sequence of test, the required number of samples and the MV power connector samples preparation.

8.12. The test procedures, including their acceptance criteria, shall be agreed between PETROBRAS and manufacturer.

9. GENERAL QUALIFICATION REQUIREMENTS

9.1. MV Connector Supplier shall submit the complete qualification test program to PETROBRAS for comments and approval at least 90 (ninety) days in advance prior to the agreed scheduled start of the tests. Each test procedure shall detail equipments and facilities to be used and include its acceptance criteria. No test shall be performed without PETROBRAS representatives in attendance or without a written waiver by PETROBRAS. Preliminary test reports shall be sent to PETROBRAS immediately after the end of each test.

9.2. For MV Connectors and related accessories that have being qualified previously to other customer's similar specifications, the MV Connector Supplier may present the full qualification report for PETROBRAS evaluation in order to obtain a waiver to not repeat similar tests in the qualification program. However, PETROBRAS, at its own discretion, may reject any test or result deemed not suitable. Any previous qualification must have been witnessed by Certifying Authority to be eligible.

9.3. MV Connectors to be subjected to the Qualification program or to the Extended FAT program may not be refurbished for operational (i.e. subsea) use.

10. DOCUMENTATION

10.1. A Master Document Plan shall be provided by MV Connector Supplier, covering all relevant aspects of the MV Connector design, qualification, FAT and interface drawings. All documentation must be supplied in both written and digital formats. All documents and drawings shall be furnished, at least, in PDF format. Other formats such .DWG may be used as well for drawings.

10.2. Copies of all test reports and data taken during testing shall be provided to PETROBRAS. These include assembly and disassembly procedures, technical illustrations and/or instructions, dimensional data, maintenance and safety recommendation, care/storage and handling instruction, special tools and/or fixtures required.

10.3. Minimum design documentation to be provided shall be titled and contain information as described by the following table. Design documentation shall be revised such that it represents the present technology readiness level of the component. The documentation requirements listed in TABLE 9 are typical and shall not be limited to the following items:

TABLE 9 – DESIGN DOCUMENTATION

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

11. TECHNICAL PROPOSAL

11.1. The MV Connector Supplier technical proposal must be made in such a way to comply integrally with the requirements stated in this technical specification and the applicable drawings. If this procedure is not possible, the MV Connector Supplier must clearly indicate the deviations and exceptions in a list. The omission of such list indicates that the MV Connector Supplier technical proposal complies integrally with the material purchase and its enclosures.

11.2. The technical proposal shall include, at least, the following documents:

(a) General Arrangement Drawings;

(b) MV Connector Datasheets;

(c) Qualification Schedule;

(d) Mating Drawings (the MV Connectors in mating position);

(e) Complete technical description of the MV Connectors (male and female halves) characteristics and functionalities;

(f) Document List;

(g) Deviation List;

(h) Quality Plan;

(i) Spare Part List;

(j) Component and Equipment List;

11.3. The MV Connector Supplier drawings and documents, submitted to PETROBRAS or its representatives for approval, will not release the MV Connector Supplier of any responsibility for detailing, dimensional, equipment construction or specifications deviations.

12. MANUAL AND DATA BOOK

12.1. When all the final drawings and documents are issued and certified, the MV Connector Supplier shall deliver an organized Manual containing all MV Connectors and accessories AS BUILT documentation. This Manual shall include, at least:

(a) All documents in the final technical proposal, item 11.2, in is AS BUILT revision;

(b) The Qualification program test reports (for each MV Connector part number);

(c) The FAT program test reports (for each MV Connector serial number);

(d) Assembling procedures;

(e) Test procedures: at surface and subsea.

12.2. During the Qualification and FAT programs, relevant data shall be requested by PETROBRAS to be included in the Manual.

12.3. All documents in the Manual shall be presented for PETROBRAS, at least, 30 days before the MV Connectors delivery. Afterwards, one hard copy and 2 electronic (PDF) copies shall be provided.

13. RESPONSABILITY AND GUARANTEE

13.1. The approval on the part of PETROBRA'S in anyone phase does not exempt or diminishes the total responsibility of the supplier how much the quality, the result and the performance of the product and design during the life for which the MV Connector is designed.