INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	Original
A	All pages, including document title
B	General revision
C	Differentiation between verification tests and residual tests on functional components Inclusion of the crush test for umbilical prototypes Changes on fatigue tests procedures Minor changes along the document

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	SEP/2010	MAY/2014	JUN/2017	APR/2021					
DESIGN	IPP/ES	IPP/ES	SUB/ES/DCT	SUB/ES/DCT					
EXECUTION	FBA	BF6S	BF6S	Gustavo					
CHECK	YR / AAG	CSMP / CJME	CSMP	Athayde					
APPROVAL	CASP	LPH6	JGLV	Lancelotti					

INDEX

1 Scope

This specification defines the qualification program of subsea umbilicals to be supplied to PETROBRAS. Whether it is a functional component prototype or an umbilical prototype, it must be qualified according to this specification and the documents referenced herein. It is applicable to subsea umbilicals either for static or dynamic service.

This specification does not apply to umbilicals for completion/workover riser systems. However, the functional components of such equipment (electric cables and hoses) may be qualified according to the stated herein in the lack of specific documentation.

2 References

NOTE: Unless otherwise stated, the latest revision of the following documents must be considered.

2.1 International standards

[1] ISO 13628-5, *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 5: Subsea umbilicals*

[2] IEC 60793-1-46, *Optical fibres, Part 1-46: Measurement methods and test procedures – Monitoring of changes in optical transmittance*

2.2 PETROBRAS specifications

[3] I-ET-3000.00-1519-29B-PZ9-002, *Low voltage/signal electric cables and terminations for subsea umbilical systems*

[4] I-ET-3500.00-1500-721-PAZ-003, *Electrical power cable element & testing*

[5] I-ET-3000.00-1500-29B-PAZ-005, *Metallic tubes for subsea umbilical systems*

[6] I-ET-3000.00-1500-29B-PAZ-003, *3/8” and 1/2" ID Hydraulic Hoses*

[7] I-ET-3000.00-1500-29B-PAZ-004, *1/2” ID Hoses for Chemical Injection*

[8] I-ET-3000.00-1519-29B-PZ9-003, *Subsea umbilical systems*

3 Terms, abbreviated terms and definitions

PETROBRAS adopts the same terms, abbreviated terms and definitions as in [1], with the amendments and supplements defined in this section.

3.1 Terms and definitions

abandonment cap
accessory specially designed to protect electric cable and optical-fiber cable terminations in case of temporary lay-down of the subsea umbilical on the seabed for later retrieval

accumulated fatigue damage
theoretical value – according to a design methodology – that accounts the fatigue damage due to the fluctuating stresses on the subsea umbilical materials. In this specification, unless otherwise stated, the accumulated fatigue damage is always related to fatigue design curves. In this specification, subsea umbilical accumulated fatigue

damage (or simply accumulated fatigue damage, or AFD) is always related to the component (functional or structural) with the highest accumulated fatigue damage

aged
condition of umbilical components (functional and structural) at the end of a prototype qualification test

design tensile load
maximum tensile load multiplied by the utilization factor associated to the failure mechanism that infringes the stress criterion or causes loss of performance considering the Normal Operation load condition. Due to the different utilization factors, the maximum tensile load and the design tensile load may be defined by different components.

fluid conduits
thermoplastic hoses and metallic tubes within a subsea umbilical

high collapse-resistant hose
thermoplastic hose with an interlocking carcass inside the liner to provide resistance to external hydrostatic pressure

hydraulic control hose
thermoplastic hoses intended for control functions

MANUFACTURER
subsea umbilical manufacturer

maximum allowable fatigue damage
maximum allowable fatigue damage for umbilicals with metallic tubes is AFD = 0.10. For umbilicals without metallic tubes, maximum allowable fatigue damage is AFD = 0.33

prototype
product which concept, constituent materials, design methodologies, manufacturing processes and/or prototype testing results have not been reviewed and accepted by an IVA and which performance has not been approved by PETROBRAS through results of theoretical complementary analyses and of prototype qualification tests. Considering an already qualified product, PETROBRAS understands that any change on configuration, geometry, dimensions, constituent materials, material suppliers and/or manufacturing equipment may imply in a new qualification program, i.e., the modified product is a prototype

sample failure
for a functional component prototype, it is its loss of performance due to the load(s) applied on a qualification test. For an umbilical prototype, it is the loss of performance of an umbilical component – functional or structural – or an umbilical ancillary equipment due to the load(s) applied on a qualification test.

SIGEM
PETROBRAS software system for the management of project documentation

SUPPLIER
subsea umbilical supplier. In some cases, SUPPLIER and MANUFACTURER can be the same entity

test rig
apparatus specially designed to perform one or more tests

structural components
components responsible to sustain the tensile loads in a subsea umbilical. Typical ones are steel wires, metallic tubes and fiber-reinforced plastic rods

3.2 Abbreviated terms

AFD	accumulated fatigue damage
HCR	high collapse-resistant
IVA	independent verification agent
LV	low voltage
MV	medium voltage
N/A	not applicable
SIGEM	Sistema Integrado de Gerenciamento de Empreendimentos (Integrated System for Project Management, in Portuguese)

4 Communication channels

Unless otherwise informed, communication relative to technical matters of subsea umbilical qualification processes (request for information, clarifications, technical discussions etc.) must be sent via the e-mail address *qualificacao.umb@petrobras.com.br*.

Documents that need PETROBRAS approval in the process [test procedures (section 5.5), Qualification Plan (section 5.7.2) and Qualification Report (section 5.8)] must be sent via SIGEM. PETROBRAS will give guidance to SUPPLIER on how to use the document management system.

5 Qualification program

The qualification program must follow the requirements of [1], considering the replacements, amendments and supplements stated on this specification and on the documents referenced herein.

The qualification of a subsea umbilical and its functional components is a necessary activity for the reliable application of the product. It consists of evaluating and attesting that the product has the minimum characteristics to ensure its safe use for the intended functional requirements (hydraulic power, chemical injection, electrical power and/or communication).

5.1 Objectives

The first objective of the qualification program is to evaluate the feasibility of the subsea umbilical to operate on a scenario (or scenarios) defined by PETROBRAS – withstanding the loads for which it is designed to and that it has the properties it is predicted to have – through the execution of qualification tests. If a qualification test result does not comply with the respective acceptance criterion(a), SUPPLIER may try to demonstrate that the prototype is fit-for-purpose according to the design methodology, subject to PETROBRAS approval. Otherwise, the product must be redesigned, and the new prototype must go through the whole qualification program. The qualification tests results must not be understood as the structural capacity of the prototype.

The second objective of the qualification program is to verify the design methodology applied by MANUFACTURER to evaluate the structural capacity of the umbilical. Whenever the qualification test results are outside the specified range for the predicted values obtained by its design methodology, MANUFACTURER must submit to Petrobras a plan to adjust and validate the design methodology including new prototype tests in order to demonstrate that. In addition, this plan shall include all the corrective actions to address the observed issues, those from the manufacturing, materials or design.

5.2 General

In this specification, the subsea umbilical qualification is divided into functional component prototype qualification (section 5.6) and umbilical prototype qualification (section 5.7). PETROBRAS considers a subsea umbilical qualified only when both are successfully completed.

Whenever a qualification test fails, PETROBRAS must be informed as soon as possible. If feasible, the prototype shall not be disassembled from the test rig and no further action shall be taken until SUPPLIER, IVA and PETROBRAS come to an agreement on how to treat the event. PETROBRAS reinforces the need of technically based arguments for the evaluation of the test failure.

5.3 IVA

The qualification program must be followed by an IVA, to be contracted by SUPPLIER. The selected IVA must have demonstrated experience on the design, manufacturing and testing of subsea umbilicals.

The IVA must fully review the documentation generated under the scope of the qualification program. The IVA analysis on any document must be prior to PETROBRAS review, i.e., only when IVA and SUPPLIER come to an agreement on the content of any document, this must be sent to PETROBRAS. In the cases where SUPPLIER performs any changes on a document due to PETROBRAS comments on it, this new version must be sent to the IVA for another round of reviewing.

The IVA must witness all the tests within the scope of the qualification program, whether it is for a functional component prototype or an umbilical prototype. SUPPLIER and IVA are free to decide if the IVA will attend the test facilities or if it will remotely witness the tests, by any means they mutually agree.

On the completion of the qualification program, the IVA must issue a certificate summarizing the results of the qualification process and demonstrating that the proposed product fulfills the requirements of this specification.

5.4 Tests schedule

The schedule for the execution of qualification tests must be provided to PETROBRAS. Due to its inherent nature, usually the tests schedule is very dynamic during the course of a qualification program, so PETROBRAS must be kept updated of the changes on the schedule. PETROBRAS must be informed of any test date at least 15 (fifteen) in advance if the test is going to be performed in Brazil. For tests being performed in other countries, PETROBRAS must be informed of any test date at least 45 (forty-five) days in advance.

PETROBRAS may witness or not the qualification tests at its own discretion and will inform SUPPLIER. Nevertheless, as stated in section 5.3, the IVA must witness all the tests within the scope of the qualification program.

5.5 Test procedures

Specific procedures for the qualification tests required on this technical specification – and the documents referenced herein – must be presented to PETROBRAS, both for functional component prototype and for umbilical prototype.

The procedure for a specific test must be available to PETROBRAS at least 15 (fifteen) days before the execution of the test itself. As stated in section 5.3, the IVA analysis on any procedure must be prior to PETROBRAS review on it.

Test procedures must fulfill the test requirements defined in sections 5.6 and 5.7 – including dissection when applicable – and must have PETROBRAS approval prior to the start of the respective qualification test.

5.6 Functional component prototype qualification

5.6.1 Low voltage electric cables (signal cables)

The qualification tests of a low voltage electric cable, its connectors and abandonment caps must follow the requirements of [3].

5.6.2 Medium voltage electric cables (power cables)

The qualification tests of a medium voltage electric cable and its abandonment caps must follow the requirements of [4].

5.6.3 Metallic tubes

The qualification tests of a metallic tube and its end fittings must follow the requirements of [5].

5.6.4 Optical-fiber cables

SUPPLIER must refer to project documentation where the qualification requirements of an optical-fiber cable, its connectors and abandonment caps are established.

5.6.5 Thermoplastic hoses

The qualification tests of a thermoplastic hose and its end fittings must follow the requirements of [6] or [7].

5.7 Umbilical prototype qualification

Umbilical prototype qualification tests subject the umbilical samples to predefined loads in order to verify its mechanical properties and/or to evaluate the specified design limits in terms of extreme loads and fatigue.

5.7.1 General requirements

Some of the umbilical prototype qualification tests have acceptance criteria defined by PETROBRAS. SUPPLIER can propose to extend the ranges of these criteria, provided that this proposal is strictly based on technical arguments. Additionally, it may suggest modifications on the test methodologies described hereafter – in order to suit them to available facilities and equipment, due to personnel safety reasons etc. – or even the inclusion of new tests to better investigate failure modes that may applicable to the adopted design. The test can only start after

SUPPLIER and PETROBRAS come to an agreement on these modifications and inclusions. It is highly desirable that the IVA joins these discussions.

Umbilical prototype samples must be representative of the manufacturing process of the product. The end terminations used on the qualification tests must have the outer sheath locking system required in [8], and a failure of this system invalidates the qualification test. The end terminations can be specially designed for the umbilical prototype qualification tests, either to make the assembling on the test rig feasible or to facilitate their dissection – or both, but they must have similar dimensions to those to be supplied to PETROBRAS, especially with relation to the inner conic surface.

All tolerances expressed in percentage within this specification are relative to direct reading and do not account the uncertainties of the measuring equipment.

5.7.2 Qualification Plan

The Qualification Plan must provide information that will enable IVA and PETROBRAS to follow and evaluate the results of the umbilical prototype qualification tests detailed in section 5.7.5. It must be available to PETROBRAS at least 15 (fifteen) days before the start of the first qualification test.

Expected results informed on the Qualification Plan must be compared to the tests results on the Qualification Report (section 5.8). Thus, it is highly recommended that SUPPLIER details the adopted methodologies to calculate these expected results by informing the assumed theory, technical references, software tools etc.

Sections from 5.7.2.1 to 5.7.2.7 detail the minimum required information on the Qualification Plan for each umbilical prototype qualification test.

5.7.2.1 Maximum tensile load test

- respective test procedure (reference to its coding number);
- longest lay length for a structural component within the umbilical structure;
- total sample length;
- drawings of the end terminations that will be mounted on the test sample;
- load blocks as required in section 5.7.5.1. It must be clearly stated the number of load blocks and the load increments within these blocks and
- theoretical maximum tensile load.

5.7.2.2 Torsion balance test

- respective test procedure (reference to its coding number);
- longest lay length for a structural component within the umbilical structure;
- total sample length;
- drawings of the end terminations that will be mounted on the test sample;
- load blocks as required in section 5.7.5.2. It must be clearly stated the number of load blocks and the load increments within these blocks;
- design tensile load and

- if the test is going to be performed in combination with the maximum tensile load test. In such case, the minimum information from both tests (sections 5.7.2.1 and 5.7.2.2) must be on the Qualification Plan.

NOTE: it is desirable to have the expected rotation values on the Qualification Plan.

5.7.2.3 Axial stiffness test

- respective test procedure (reference to its coding number);
- longest lay length for a structural component within the umbilical structure;
- total sample length;
- drawings of the end terminations that will be mounted on the test sample;
- load-up method as required in section 5.7.5.3. It must be clearly stated the number of load blocks and the load increments within these blocks;
- theoretical axial stiffness value(s) in a Tension x Displacement graphical form and
- if the test is going to be performed in combination with the torsion balance test. In such case, the minimum information from both tests (sections 5.7.2.2 and 5.7.2.3) must be on the Qualification Plan.

5.7.2.4 Bending stiffness test

- respective test procedure (reference to its coding number);
- longest lay length for a structural component within the umbilical structure;
- total sample length;
- load-up method as required in section 5.7.5.4. It must be clearly stated the number of load blocks and the load increments within these blocks and
- theoretical bending stiffness value(s) in a Moment x Curvature graphical form.

5.7.2.5 Crush test

- respective test procedure (reference to its coding number);
- number of samples that will be used in the test and which test stages will be performed on each of them;
- sample(s) total length(s);
- tension x crushing capacity curve as defined in [8];
- tension-crushing pairs for the test stages as required in section 5.7.5.5 and
- proposed load steps within each test stage as required in section 5.7.5.5.

5.7.2.6 Tension and bending dynamic fatigue test

- respective test procedure (reference to its coding number);
- longest lay length for a structural component within the umbilical structure;
- total sample length;
- drawings of the end terminations that will be mounted on the test sample;

- load blocks as required in section 5.7.5.6. It must be clearly stated the number of load blocks, the tension-angle pairs within these blocks and the associated fatigue damage for both mean and design fatigue curves for all umbilical components.

5.7.2.7 Tension-to-tension dynamic fatigue test

- respective test procedure (reference to its coding number);
- longest lay length for a structural component within the umbilical structure;
- total sample length;
- drawings of the end terminations that will be mounted on the test sample;
- load blocks as required in section 5.7.5.7. It must be clearly stated the number of load blocks, the tension pairs within these blocks and the associated fatigue damage for both mean and design fatigue curves for all umbilical components.

5.7.3 Functional component verification tests

Functional components might be subjected to verification tests as part of the umbilical prototype qualification tests, and the requirements of when they must be performed are stated in section 5.7.5. When possible and convenient, they can be performed with the sample assembled on the test rig.

5.7.3.1 Fluid conduits

The fluid conduits within the sample must be subjected to a proof pressure test following the same parameters as defined in [1] for the FAT, i.e., 1.50 x DWP for the thermoplastic hoses and 1.25 x DWP for the metallic tubes, over a minimum period of 4 (four) hours.

These pressurization values must be continuously monitored and recorded.

5.7.3.2 Low voltage electric cables (signal cables)

LV cables within the sample must be subjected to the following verification tests:

- DC conductor resistance and
- DC insulation resistance

DC insulation resistance test shall be performed without the requirements of immersion in town-mains water under pressure, hence the 22 (twenty-two) hours waiting time is unnecessary.

Acceptance criteria defined in [1] apply to both tests.

5.7.3.3 Medium voltage electric cables (power cables)

MV cables within the sample must be subjected to the following verification tests:

- DC conductor resistance
- partial discharge
- voltage and
- insulation resistance at ambient temperature

NOTE: insulation resistance at ambient temperature test procedure is described below:

1) clean up all three cable ends where the insulation tester probe will be fixed;

2) electrically interconnect all three metallic screens and two cable cores and the guard terminal to drain any surface current between the conductor under test and the metallic screen;

3) fix one probe of the insulation tester on the free cable core and the other probe on the other point electrically interconnected to the metallic screens and the other two cable cores;

4) perform the test applying 5kV dc voltage for 10 minutes using an insulation tester capable to register the test current and the insulation resistance continuously throughout the test. Also register the ambient temperature. It must be presented a graph current x insulation resistance x test time or a table with the values. It must be marked the results for 30 (thirty) seconds, 1 (one) minute and 10 (ten) minutes;

5) repeat steps 1 to 4 for the other two cable cores in order to complete the insulation test of phases against each other and the earth;

6) there are no acceptance criteria for insulation resistance at ambient temperature test. Significant changes in the results (before and after the umbilical prototype qualification test) require cause investigation.

5.7.4 Functional component residual tests

Functional components might be subjected to residual tests as part of the umbilical prototype qualification tests, and the requirements of when they must be performed are stated in section 5.7.5. Residual tests must be performed on component samples extracted from aged umbilical prototype samples during dissection.

5.7.4.1 Medium voltage electric cables (power cables)

MV cables within the sample must be subjected to the following residual test:

- tan δ measurement (see Notes 1, 2 and 3 below)

NOTE 1: tan δ measurement test must be performed only for cables of rated voltage 6/10 (12) kV and above.

NOTE 2: a tan δ measurement test must be performed on a unaged cable sample from the same cable spool used to manufacture the umbilical prototype samples. This value must be used as a reference for comparison with the results of aged samples (see Note 3).

NOTE 3: there are no acceptance criteria for this test. Significant changes in the results (before and after the umbilical prototype qualification test) require cause investigation.

5.7.4.2 Metallic tubes

After the subsea umbilical prototype qualification test, one sample shall be taken from each tube within the umbilical bundle and the following residual tests must be performed:

- visual and dimensional check;
- pressure test;
- burst test and
- non-destructive examination of the welds

The same procedures and acceptance criteria defined in [1] and [5] for unaged representative samples apply for these residual tests.

All samples must be subjected to visual and dimensional check. All welds must be subjected to NDE. Two samples must be subjected to pressure test and the remaining samples shall be subjected to burst test.

5.7.4.3 Thermoplastic hoses

After the subsea umbilical prototype qualification test, one sample shall be taken from each thermoplastic hose within the umbilical bundle and the following residual tests must be performed:

- visual and dimensional check;
- leakage test;
- burst test;
- collapse test (only for HCR hoses) and
- volumetric expansion test (only for hydraulic control hoses)

The same procedures and acceptance criteria defined in [1], [6] and [7] for unaged representative samples apply for these residual tests.

All samples must be subjected to visual and dimensional check. For the other tests, the number of samples is defined according to Table 1and Table 2.

Table 1 - Distribution of HCR hose samples for residual tests

	Number of HCR hose samples to be tested		
Total number of HCR hoses within the umbilical bundle	**Leakage test**	**Collapse test**	**Burst test**
Less than 3	PETROBRAS must be consulted		
3 or 4	1	1	remaining sample(s)
More than 4	1	2	remaining sample(s)

Table 2 - Distribution of hydraulic control hoses for residual tests

	Number of hydraulic control hoses to be tested		
Total number of hydraulic control hoses within the umbilical bundle	**Leakage test**	**Volumetric expansion test**	**Burst test**
Less than 3	PETROBRAS must be consulted		
3 or 4	1	1	remaining sample(s)
More than 4	2	1	remaining sample(s)

5.7.5 Umbilical prototype qualification tests

5.7.5.1 Maximum tensile load test

5.7.5.1.1 Objective

Evaluate the performance of the umbilical prototype under pure tension when loaded up to the theoretical maximum tensile load.

5.7.5.1.2 General guidelines

The minimum sample length must be at least equal to 2 (two) lay lengths, considering the structural component with the longest lay length. This sample length must disregard the lengths inside the end terminations (i.e., it must be measured between the bottom faces of the end terminations).

Prior to the execution of the umbilical prototype test itself, LV and MV cables must be subjected to the verification tests specified in sections 5.7.3.2 and 5.7.3.3.

The umbilical prototype sample must be assembled on a test rig with one end fixed and the other free to rotate. The tensile load must be slowly applied until it reaches the minimum value enough to keep the sample at a stable straight position. This preload tension must be recorded and informed on the Qualification Report (section 5.8). Then the fluid conduits must be pressurized up to the DWP. This pressure value must be maintained during the whole test (see section 5.7.5.1.3).

After preloading the sample and pressurizing the fluid conduits, the tensile load must be increased from the preload tension up to the theoretical maximum tensile load. The ramp-up must be divided in a minimum of 10 (ten) load blocks, with approximately equal increments. Within each load block, the tensile load must be increased at a rate sufficiently low in order to not introduce shock loads, and the hold time duration at each load step must be at least 5 (five) minutes, except for the last block – where the theoretical maximum tensile load is reached. Hold time duration for the last block must be at least 60 (sixty) minutes. After that period, the prototype sample must be unloaded. The ramp-down must adopt the same load blocks adopted for loading the sample, including the hold time duration time of 5 (five) minutes at each load step. Within each load block, the tensile load must be decreased at a rate sufficiently low in order to not introduce shock loads.

Loading and unloading cycles to achieve stable rotation readings are allowed, as long as the tensile load is increased at a rate sufficiently low in order to not introduce shock loads.

After unloading the sample, the functional components must be subjected to the verification tests specified in section 5.7.3.

Lastly the sample must be dissected following the guidelines stated in section 5.7.6. A MV cable sample must proceed to the residual test specified in section 5.7.4.1.

5.7.5.1.3 Sample monitoring

- It must be adopted a direct way of measuring the applied tension and continuously monitor and record it throughout the test;
- fluid conduits must be pressurized at DWP during the test and the pressure values must be continuously monitored and recorded. It is allowed to use a pressure supply unit to maintain the fluid conduits internal pressure within the defined range (see section 5.7.5.1.4);

- LV and MV cables conductor resistance must be continuously monitored during test. LV conductors can be connected in series for this measurement. MV conductors can be connected in series for this measurement and
- optical-fiber cables must be subjected to continuous monitoring of their attenuation throughout the test, according to Method A specified in [2].

5.7.5.1.4 Acceptance criteria

- no sample failure at any step of the test, including verification tests on functional components and dissection appraisal;
- fluid conduits internal pressure must be maintained with a maximum variation of ± 500 psi during the test.

5.7.5.2 Torsion balance test

5.7.5.2.1 Objective

Measure the rotation characteristics and evaluate the performance of the umbilical prototype under pure tension when loaded up to the design tensile load.

5.7.5.2.2 General guidelines

The minimum sample length must be at least equal to 2 (two) lay lengths, considering the structural component with the longest lay length. This sample length must disregard the lengths inside the end terminations (i.e., it must be measured between the bottom faces of the end terminations).

Prior to the execution of the umbilical prototype test itself, LV and MV cables must be subjected to the verification tests specified in sections 5.7.3.2 and 5.7.3.3.

The umbilical prototype sample must be assembled on a test rig with one end fixed and the other free to rotate, with a rotation measurement system mounted on it. The rotation measurement system must have a minimum resolution of 0.1 deg. Rotation of the sample must be measured by means of two points over the most external layer of structural components within the umbilical, using devices that do not induce significant radial compression over the prototype structure. For armoured umbilicals, the most external layer of structural components is typically the most external layer of armour wires. In situations where this identification is not obvious, SUPPLIER, IVA and PETROBRAS must come to an agreement on how to measure the twist of the sample. Special caution must be taken on where to place the measuring devices, in order to avoid the influence of end effects.

The tensile load must be slowly applied until it reaches the minimum value enough to keep the sample at a stable straight position. This preload tension must be recorded and informed on the Qualification Report (section 5.8). Then the fluid conduits must be pressurized up to the DWP. This pressure value must be maintained during the whole test (see section 5.7.5.2.3).

The sample must be kept under this preload tension and with fluid conduits pressurized at DWP for a minimum of 15 (fifteen) minutes. After that time, the rotation measurement system must be reset.

After preloading the sample, pressurizing the fluid conduits and resetting the rotation measurement system, the tensile load must be increased from the preload tension up to the theoretical design tensile load. The ramp-up must be divided in a minimum of 5 (five) load blocks, with approximately equal increments. Within each load block, the tensile load must be increased at a rate sufficiently low in order to not introduce shock loads, and the hold time duration at each load step must be at least 5 (five) minutes, except for the last block – where the theoretical design tensile load is reached. Hold time duration for the last block must be at least 15 (fifteen) minutes.

After 15 (fifteen) minutes under the design tensile load, the prototype sample must be unloaded down to the preload tension. The ramp-down must adopt the same load blocks adopted for loading the sample, including the hold time duration time of 5 (five) minutes at each load step. Within each load block, the tensile load must be decreased at a rate sufficiently low in order to not introduce shock loads. When the preload tension is reached, the sample must be kept under this tensile load for a minimum of 15 (fifteen) minutes.

On all load blocks, after the hold time, the rotation must be measured and informed on the Qualification Report (section 5.8). These values are for information only, except for the readings made under the design tensile load and the preload tension after unloading, for which the acceptance criteria stated on Table 3 apply.

Loading and unloading cycles to achieve stable rotation readings are allowed, as long as the tensile load is increased at a rate sufficiently low in order to not introduce shock loads.

After 15 (fifteen) minutes under preload tension, the functional components must be subjected to the verification tests specified in section 5.7.3.

Lastly the sample must be dissected following the guidelines stated in section 5.7.6. A MV cable sample must proceed to the residual test specified in section 5.7.4.1.

5.7.5.2.3 Sample monitoring

- It must be adopted a direct way of measuring the applied tension and continuously monitor and record it throughout the test;
- if possible, it is desirable that the sample rotation can be monitored and recorded in a continuous manner;
- fluid conduits must be pressurized at DWP during the test and the pressure values must be continuously monitored and recorded. It is allowed to use a pressure supply unit to maintain the fluid conduits internal pressure within the defined range (see section 5.7.5.2.4);
- LV and MV cables conductor resistance must be continuously monitored during test. LV conductors can be connected in series for this measurement. MV conductors can be connected in series for this measurement and
- optical-fiber cables must be subjected to continuous monitoring of their attenuation throughout the test, according to Method A specified in [2].

5.7.5.2.4 Acceptance criteria

- maximum sample measured rotation as per Table 3:

Table 3 - Acceptance criteria for sample rotation

At design tensile load (°/m)	At preload tension, after unloading (°/m)
0.4	0.2

- no sample failure at any step of the test, including verification tests on functional components and dissection appraisal;
- fluid conduits internal pressure must be maintained with a maximum variation of ± 500 psi during the test.

5.7.5.2.5 Considerations

The torsion balance test can be performed in combination with the maximum tensile load test. There are three possible ways to perform the tests in combination:

1) perform the torsion balance test following the guidelines in section 5.7.5.2.2 until the sample is unloaded, kept under the preload tension for at least 15 (fifteen) minutes, have its rotation measured and the verification tests on functional components are executed. After that, the maximum tensile load test must be performed following the guidelines in section 5.7.5.1.2, including verification tests, dissection and residual test on MV cables. In this case, if a functional component fails during the maximum tensile load test and dissection indicates that no other failure has occurred, then the intermediate verification tests validate the torsion balance test.

2) perform the torsion balance test following the guidelines in section 5.7.5.2.2 until the sample is unloaded, kept under the preload tension for at least 15 (fifteen) minutes and have its rotation measured (not executing intermediate verification tests on functional components). After that, the maximum tensile load test must be performed following the guidelines in section 5.7.5.1.2, including verification tests, dissection and residual test on MV cables. In this case, a sample failure at any step of the maximum tensile load test implies that both tests (torsion balance and maximum tensile load) failed.

3) perform the torsion balance following the guidelines in section 5.7.5.2.2 until the sample is loaded up to the design tensile load, kept under that load for a minimum of 15 (fifteen) minutes and have its rotation measured. After that, the tensile load must ramp up to the theoretical maximum tensile load following the guidelines in section 5.7.5.1.2. After unloading down to the preload tension, the sample must be kept under that load for a minimum period of 15 (fifteen) minutes and then have its rotation measured. Verification tests must be performed afterwards, the sample must be dissected following the guidelines stated in section 5.7.6 and residual test on MV cables must be performed. It is important to highlight that, for this procedure, the load blocks must be carefully defined since the design tensile load becomes one load step to reach the theoretical maximum tensile load, and the minimum number of load blocks defined in sections 5.7.5.1.2 and 5.7.5.2.2 must be considered. In this case, a sample failure at any step implies that both tests (torsion balance and maximum tensile load tests) failed.

5.7.5.3 Axial stiffness test

5.7.5.3.1 Objective

Measure the axial stiffness of the umbilical prototype and compare it to the provided theoretical value(s).

5.7.5.3.2 General Guidelines

The minimum sample length must be at least equal to 2 (two) lay lengths, considering the structural component with the longest lay length. This sample length must disregard the lengths inside the end terminations (i.e., it must be measured between the bottom faces of the end terminations).

The umbilical prototype sample must be assembled on a test rig with one end fixed and the other free to rotate, with an elongation measurement system mounted on it. The elongation measurement system must have a minimum resolution of 1.0 mm. Elongation of the sample must be measured by means of two points over the most external layer of structural components within the umbilical, using devices that do not induce significant radial compression over the prototype structure. For armoured umbilicals, the most external layer of structural components is typically the most external layer of armour wires. In situations where this identification is not obvious, SUPPLIER, IVA and PETROBRAS must come to an agreement on how to measure the elongation of the sample.

The tensile load must be slowly applied until it reaches the minimum value enough to keep the sample at a stable straight position. This preload tension must be recorded and informed on the Qualification Report (section 5.8).

A load-up method (number of load blocks, loading increments and hold times duration) must be proposed to perform the test. Loading and unloading cycles to achieve stable elongation readings are allowed, as long as the tensile load is increased at a rate sufficiently low in order to not introduce shock loads. Additionally, it must be informed at which tension range the tension-displacement relationship is deemed to be valid (notably at lower tensions the axial stiffness behavior is erratic). As stated in section 5.5, the test procedure must have PETROBRAS approval prior to the test execution. Both the theoretical and the experimental axial stiffnesses must be presented in a graphical form (Tension x Displacement) on the Qualification Report (section 5.8).

5.7.5.3.3 Sample monitoring

- It must be adopted a direct way of measuring the applied tension and continuously monitor and record it throughout the test;
- if possible, it is desirable that the sample elongation can be monitored and recorded in a continuous manner.

5.7.5.3.4 Acceptance criterion

Experimental value(s) obtained in the test must be within ± 15% of the provided theoretical value(s) for every point on the Tension x Displacement graph.

5.7.5.3.5 Considerations

The axial stiffness test can be performed in combination with the torsion balance test. In this case, the following remarks apply:

1) the load blocks, loading increments and hold times duration of the axial stiffness test will be the same as the ones for the torsion balance test.

2) the axial stiffness test will be performed with functional components continuously monitored, as required for the torsion balance test (section 5.7.5.2.3).

3) a sample failure at any step of the torsion balance test (including verification tests, dissection and residual test on MV cables) invalidates the axial stiffness test.

Moreover, as stated in section 5.7.5.2.5, the torsion balance test can be performed in combination with the maximum tensile load test, i.e., it is allowed to simultaneously perform the 3 (three) tests with the same umbilical prototype sample. In such case, SUPPLIER shall proceed according to one of the three possible ways detailed on section 5.7.5.2.5.

5.7.5.4 Bending stiffness test

5.7.5.4.1 Objective

Measure the bending stiffness of the umbilical prototype and compare it to the provided theoretical value.

5.7.5.4.2 General guidelines

If possible, it is highly desirable that the minimum sample length is equal to at least 1 (one) lay length – as specified in [1] – considering the structural component with the longest lay length. This sample length must disregard the lengths inside the fixing mechanisms adopted to perform the test.

The umbilical prototype sample must be subjected to a transverse load and flexed down to the specified MBR. The bending radius measurement system must have a minimum resolution of 1.0 mm.

A load-up method (number of load blocks, loading increments and hold times duration) and a test setup must be proposed to perform the test. Loading and unloading cycles to achieve stable readings are allowed, as long as the transverse load is increased at a rate sufficiently low in order to not introduce shock loads. It must be informed at which moment range the moment-curvature relationship is deemed to be valid. As stated in section 5.5, the test procedure must have PETROBRAS approval prior to the test execution.

The test must be performed twice on the same umbilical prototype sample: considering a certain bending plane, the load-up method must be applied on the sample on 2 (two) opposite directions (180 deg from each other). Both sets of measurements and results must be separately presented on the Qualification Report (section 5.8). Both the theoretical and the experimental bending stiffnesses must be presented in a graphical form (Moment x Curvature), also on the Qualification Report.

5.7.5.4.3 Sample monitoring

If possible, it is desirable that the applied load and the bending radius can be monitored and recorded in a continuous manner.

5.7.5.4.4 Acceptance criterion

Experimental value(s) obtained in the test must be within ± 20% of the provided theoretical value(s) for every point on the Moment x Curvature graph.

5.7.5.5 Crush test

5.7.5.5.1 Objective

Evaluate the performance of the umbilical prototype under tensile and crushing loads, combined with each other, according to the tension x crushing capacity curve required in [8].

5.7.5.5.2 General guidelines

The test is divided in 3 (three) stages:

- on Stage 1, the prototype sample must be subjected to a preload tension and the respective maximum crushing load according to the provided tension x crushing capacity curve;
- on Stage 2, the prototype sample must be loaded up to halfway between the preload tension and the design tensile load. The crushing load must be equal to the respective maximum crushing load according to the provided tension x crushing capacity curve and
- on Stage 3, the prototype sample must be loaded up to the design tensile load. The crushing load must be equal to the respective maximum crushing load according to the provided tension x crushing capacity curve.

Table 4 summarizes the applicable loads on each stage of the test.

Table 4 - Loads for the crush test stages

Test stage	Tensile load	Crushing load
Stage 1	preload tension	respective maximum crushing load according to the tension x crushing capacity curve required in [8]
Stage 2	halfway between the preload tension and the design tensile load	
Stage 3	design tensile load	

The test may be performed on 1 (one), 2 (two) or 3 (three) prototype samples. When performing 2 (two) or all 3 (three) stages on the same sample, they must be executed on different sections of the sample, at least 1 m apart from each other. Additionally, these sample sections must also be at least 1 m apart from the end terminations.

The crushing loads must be applied by a device that simulates the tensioner of a laying vessel with 4 (four) tracks, each track with a minimum length of 1 m and a shoe contact angle of 160 deg.

Thus, considering the distance requirements and the minimum length for the tracks of the crushing device, the minimum sample lengths disregarding the lengths inside the end terminations (i.e., measuring between the bottom faces of the end terminations) are:

- 3 m, if only 1 (one) test stage is performed on the prototype sample;
- 5 m, if 2 (two) test stages are performed on the prototype sample and
- 7 m, if all 3 (three) test stages are performed on the prototype sample.

Prior to the execution of the umbilical prototype test itself, LV and MV cables of the sample(s) must be subjected to the verification tests specified in sections 5.7.3.2 and 5.7.3.3.

The umbilical prototype sample(s) must be assembled on a test rig with one end fixed and the other free to rotate. The tensile load must be slowly applied until it reaches the minimum value enough to keep the sample at a stable straight position. This preload tension must be recorded and informed on the Qualification Report (section 5.8). Then the fluid conduits must be pressurized up to 300 psi for sake of failure monitoring. This pressure value must be maintained in all stages of the test (see section 5.7.5.5.3).

For stages 2 and 3, the tensile and crushing loads should ideally be applied/relieved on small increments, following the tension x crushing capacity curve. If this kind of automation is not available, then load steps must be proposed to reach the tensile and crushing loads respective to each stage. These load steps must be available on the Qualification Plan (section 5.7.2.5).

For each test stage, after reaching the respective tensile and crushing loads, the sample must stay under this condition for a minimum period of 60 (sixty) minutes, within a reasonable load variation range. After that time, the sample must be unloaded.

If only 1 (one) stage is supposed to be performed on the sample, then the LV and MV cables of the sample must be subjected to the verification tests specified in sections 5.7.3.2 and 5.7.3.3, and then proceed the sample to dissection following the guidelines stated in section 5.7.6, when the component samples for the residual tests must be extracted and the tests performed following the requirements of section 5.7.4.

However, if 2 (two) or all 3 (three) stages are to be performed on the sample, then the test must proceed to the next stage without verification testing. LV and MV cables of the sample must be subjected to the verification tests specified in sections 5.7.3.2 and 5.7.3.3 only after all predicted stages have been performed on the sample. Then

the sample must be dissected following the guidelines stated in section 5.7.6, when the component samples for the residual tests must be extracted and the tests performed following the requirements of section 5.7.4.

It is important to emphasize that when performing 2 (two) or all 3 (three) test stages on the same sample, a failure at any step of the test (including verification tests, dissection and residual tests) invalidates the results from all stages executed on that sample.

5.7.5.5.3 Sample monitoring

- it must be adopted a direct way of measuring the applied tension and continuously monitor and record it throughout the test;
- the applied crushing load must be measured and continuously monitored and recorded throughout the test;
- fluid conduits must be pressurized at 300 psi during the test and the pressure values must be continuously monitored and recorded. It is allowed to use a pressure supply unit to maintain the fluid conduits internal pressure within the defined range (see section 5.7.5.5.4);
- LV and MV cables conductor resistance must be continuously monitored during test. LV conductors can be connected in series for this measurement. MV conductors can be connected in series for this measurement and
- optical-fiber cables must be subjected to continuous monitoring of their attenuation throughout the test, according to Method A specified in [2].

5.7.5.5.4 Acceptance criteria

- no sample failure at any step of the test, including verification tests, dissection appraisal and residual tests;
- fluid conduits internal pressure must be maintained with a maximum variation of ± 100 psi during the test.

5.7.5.6 Tension and bending dynamic fatigue test

5.7.5.6.1 Objective

Evaluate the behaviour of the umbilical prototype when subjected to tensile and bending cyclic loads, combined with each other, until fatigue failure is reached.

5.7.5.6.2 General guidelines

The minimum sample length must be at least equal to 2 (two) lay lengths, considering the structural component with the longest lay length. This sample length must disregard the lengths inside the end terminations (i.e., it must be measured between the bottom faces of the end terminations).

Prior to the execution of the umbilical prototype test itself, LV and MV cables must be subjected to the verification tests specified in sections 5.7.3.2 and 5.7.3.3.

The umbilical prototype sample and its bend stiffener must be assembled on a test rig with one end fixed and the other free to rotate. The tensile load must be slowly applied until it reaches the minimum value enough to keep the sample at a stable straight position. This preload tension must be recorded and informed on the Qualification Report (section 5.8). Then the fluid conduits must be pressurized up to the DWP. This pressure value must be maintained until umbilical prototype failure (see section 5.7.5.6.3).

The test is divided in 4 (four) different phases, namely Maximum Service Life Phase, Maximum Fatigue Life (Stage 1) Phase, Maximum Fatigue Life (Stage 2) Phase and Damage Phase. On the Maximum Service Life Phase, AFD must be led from 0.00 to maximum allowable fatigue damage. On the Maximum Fatigue Life (Stage 1) Phase, AFD must be led from maximum allowable fatigue damage to 0.90. On the Maximum Fatigue Life (Stage 2) Phase, AFD must be led from 0.90 to 1.00. Then, if fatigue failure is not reached, the test enters the Damage Phase. On the Damage Phase, AFD must be led from 1.00 until fatigue failure is reached.

SUPPLIER must propose the number of load blocks for the test and, for each load block, the tension-angle pairs, the number of cycles and associated fatigue damage. For the Maximum Service Life Phase, the minimum number of load blocks is 2 (two) and the minimum required number of cycles is 200,000 (two hundred thousand). For the Maximum Fatigue Life (Stage 1) Phase, the minimum number of load blocks is 3 (three) and the minimum required number of cycles is 1,000,000 (one million). For the Maximum Fatigue Life (Stage 2) Phase, the minimum number of load blocks is 2 (two) and the minimum required number of cycles is 200,000 (two hundred thousand). The Damage Phase must have at least 1 (one) load block, and there is no requirement for a minimum number of cycles within this(these) block(s). Table 5 summarizes the requirements for the different phases. PETROBRAS emphasizes that, in every load block, the prototype sample must be subjected to tensile and bending loads; load blocks with only tensile loads are not acceptable. Additionally, the tension-angle pairs must differ from each other in the different load blocks.

At the end of the Maximum Service Life Phase (i.e., AFD = maximum allowable fatigue damage), at the end of the Maximum Fatigue Life (Stage 1) Phase (i.e., AFD = 0.90) and at the end of the Maximum Fatigue Life (Stage 2) Phase (i.e., AFD = 1.00), the application of dynamic loads must be stopped, and the functional components must be subjected to the verification tests specified in section 5.7.3. There is no requirement to perform verification tests after fatigue failure is reached.

Test frequency must not exceed 1.0 Hz, with a recommended value of 0.2 Hz.

There must be provided means to monitor and identify the sample failure, especially when it is related to an armour failure. In the course of the test, it is a SUPPLIER's decision when dynamic loading must stop and the prototype sample be disassembled from the test rig.

Lastly the sample must be dissected following the guidelines stated in section 5.7.6.

Table 5 - Phase requirements for dynamic fatigue tests

Test Phase	AFD (from – to)	Minimum number of load blocks	Minimum number of cycles
Maximum Service Life	0.00 – 0.10/0.33	2	200,000
Maximum Fatigue Life (Stage 1)	0.10/0.33 – 0.90	3	1,000,000
Maximum Fatigue Life (Stage 2)	0.90 – 1.00	2	200,000
Damage	1.00 – Fatigue Failure	1	N/A

5.7.5.6.3 Sample monitoring

- It must be adopted a direct way of measuring the applied tension and continuously monitor and record it throughout the test;

- the applied angle must be continuously monitored and recorded throughout the test;
- the number of cycles must be recorded throughout the test;
- fluid conduits must be pressurized at DWP during the test and the pressure values must be continuously monitored and recorded. It is allowed to use a pressure supply unit to maintain the fluid conduits internal pressure within the defined range (see section 5.7.5.6.4);
- LV and MV cables conductor resistance must be continuously monitored during test. LV conductors can be connected in series for this measurement. MV conductors can be connected in series for this measurement and
- optical-fiber cables must be subjected to continuous monitoring of their attenuation throughout the test, according to Method A specified in [2].

5.7.5.6.4 Acceptance criteria

- no sample failure (including verification tests on the functional components) during Maximum Service Life and Maximum Fatigue Life (Stage 1) phases and
- fluid conduits internal pressure must be maintained with a maximum variation of ± 500 psi.

5.7.5.6.5 Considerations

In order to accelerate the test execution, it is allowed to adopt fatigue mean curves for the load blocks on the Damage Phase, i.e., only for AFD > 1.00. It must be clearly stated on the Qualification Plan (section 5.7.2), for all load blocks, the fatigue damages associated to the design and mean curves.

5.7.5.7 Tension-to-tension dynamic fatigue test

5.7.5.7.1 Objective

Evaluate the behaviour of the umbilical prototype when subjected to pure tensile cyclic loads until fatigue failure is reached.

5.7.5.7.2 General guidelines

The minimum sample length must be at least equal to 2 (two) lay lengths, considering the structural component with the longest lay length. This sample length must disregard the lengths inside the end terminations (i.e., it must be measured between the bottom faces of the end terminations).

Prior to the execution of the umbilical prototype test itself, LV and MV cables must be subjected to the verification tests specified in sections 5.7.3.1 and 5.7.3.3.

The umbilical prototype sample must be assembled on a test rig with one end fixed and the other free to rotate. The tensile load must be slowly applied until it reaches the minimum value enough to keep the sample at a stable straight position. This preload tension must be recorded and informed on the Qualification Report (section 5.8). Then the fluid conduits must be pressurized up to the DWP. This pressure value must be maintained until umbilical prototype failure (see section 5.7.5.7.3).

The test is divided in 4 (four) different phases, namely Maximum Service Life Phase, Maximum Fatigue Life (Stage 1) Phase, Maximum Fatigue Life (Stage 2) Phase and Damage Phase. On the Maximum Service Life Phase, AFD must be led from 0.00 to maximum allowable fatigue damage. On the Maximum Fatigue Life (Stage 1) Phase, AFD must be led from maximum allowable fatigue damage to 0.90. On the Maximum Fatigue Life (Stage 2) Phase,

AFD must be led from 0.90 to 1.00. Then, if fatigue failure is not reached, the test enters the Damage Phase. On the Damage Phase, AFD must be led from 1.00 until fatigue failure is reached.

SUPPLIER must propose the number of load blocks for the test and, for each load block, the tension values (minimum and maximum), the number of cycles and associated fatigue damage. For the Maximum Service Life Phase, the minimum number of load blocks is 2 (two) and the minimum required number of cycles is 200,000 (two hundred thousand). For the Maximum Fatigue Life (Stage 1) Phase, the minimum number of load blocks is 3 (three) and the minimum required number of cycles is 1,000,000 (one million). For the Maximum Fatigue Life (Stage 2) Phase, the minimum number of load blocks is 2 (two) and the minimum required number of cycles is 200,000 (two hundred thousand). The Damage Phase must have at least 1 (one) load block, and there is no requirement for a minimum number of cycles within this(these) block(s). Table 5 summarizes the requirements for the different phases.

At the end of the Maximum Service Life Phase (i.e., AFD = maximum allowable fatigue damage), at the end of the Maximum Fatigue Life (Stage 1) Phase (i.e., AFD = 0.90) and at the end of the Maximum Fatigue Life (Stage 2) Phase (i.e., AFD = 1.00), the application of dynamic loads must be stopped, and the functional components must be subjected to the verification tests specified in section 5.7.3. There is no requirement to perform verification tests after fatigue failure is reached.

There must be provided means to monitor and identify the sample failure, especially when it is related to an armour failure. In the course of the test, it is a SUPPLIER's decision when dynamic loading must stop and the prototype sample be disassembled from the test rig.

Lastly the sample must be dissected following the guidelines stated in section 5.7.6

5.7.5.7.3 Sample monitoring

- It must be adopted a direct way of measuring the applied tension and continuously monitor and record it throughout the test;
- the number of cycles must be recorded throughout the test;
- fluid conduits must be pressurized at DWP during the test and the pressure values must be continuously monitored and recorded. It is allowed to use a pressure supply unit to maintain the fluid conduits internal pressure within the defined range (see section 5.7.5.7.4);
- LV and MV cables conductor resistance must be continuously monitored during test. LV conductors can be connected in series for this measurement. MV conductors can be connected in series for this measurement and
- optical-fiber cables must be subjected to continuous monitoring of their attenuation throughout the test, according to Method A specified in [2].

5.7.5.7.4 Acceptance criteria

- no sample failure (including verification tests on the functional components) during Maximum Service Life and Maximum Fatigue Life (Stage 1) phases and
- fluid conduits internal pressure must be maintained with a maximum variation of ± 500 psi.

5.7.5.7.5 Considerations

In order to accelerate the test execution, it is allowed to adopt fatigue mean curves for the load blocks on the Damage Phase, i.e., only for AFD > 1.00. It must be clearly stated on the Qualification Plan (section 5.7.2), for all load blocks, the fatigue damages associated to the design and mean curves.

5.7.6 Samples dissection

After umbilical prototype qualification tests, the samples must proceed to dissection – except for the axial stiffness and bending stiffness tests. For the maximum tensile load, torsion balance and crush tests, the objective when dissecting the samples is to look for unpredicted failures in the umbilical components, since these are non-destructive tests. On the other hand, for the samples from the dynamic fatigue tests, dissection aims to verify if the predicted failure mode actually occurred.

It must be taken care when disassembling the samples from the test rigs, in order to not cause damages that are not related to the test loads and may lead to a mistaken evaluation. The prototype samples must be fully inspected, i.e., the umbilical body, the end terminations and the bend stiffener from the tension and bending dynamic fatigue test.

Sample bodies must be completely stripped down, allowing access to the umbilical components. For the functional components, inspection shall look for excessive wear and unexpected behaviour of these components within the umbilical bundle, unless a possible failure was detected by the monitoring system during the test (including verification tests); in such cases, dissection must clearly define the umbilical section where the failure occurred and possibly determine the root cause for it.

Special focus must be given to the strength members of the samples, such as steel wires and fiber-reinforced rods, since these are not directly monitored during the tests. Dissection shall fully inspect these components looking for wear, deformation, buckling, cracks, rupture, and any other possible damages.

It is important to emphasize that the dissection of the umbilical body includes the sections inside the end terminations. It is allowed to cut off both extremities of the sample to make it easier to remove the end terminations and get access to the umbilical components therein. Again, special care must be taken in order to not cause damages that are not related to the test loads and may lead to a mistaken evaluation.

The end terminations must be inspected too, including their outer sheath locking system. The product applied to anchor the strength members – usually resin – must be inspected looking specially for voids and other defects that might happen during material injection inside the end terminations.

The bend stiffener from the tension and bending dynamic fatigue test must be disassembled from the umbilical sample and its inner and outer surfaces must be inspected looking for wear, cracks, or any other damages. Before removing the sample from the test rig, the neutral and/or the bending plane(s) must be marked on the outer sheath for investigation of the sample failure. After disassembling the bend stiffener, marking some other distinguished sections on the outer sheath may also help during the failure investigation, such as the end of the metallic insert, the beginning and the end of the tapered region, and the stiffener end.

NOTE: in some cases, the end of the metallic insert is coincident with the beginning of the tapered region and/or the end of the tapered region is coincident with the stiffener end.

All relevant observations made during dissection must be documented and presented on the Qualification Report.

5.8 Qualification Report

The Qualification Report gathers the results of all the qualification tests performed on a prototype and compares them to the respective acceptance criteria defined on this specification and documents referenced herein.

Sections 5.8.1 and 5.8.2 detail the minimum required information on a Qualification Report, either for a functional component or a subsea umbilical prototype qualification.

5.8.1 Functional component prototype Qualification Report

For any functional component, at least the following information must be on the Qualification Report:

- functional component drawing and data sheet;
- respective test procedures (reference to their coding numbers);
- test results with acceptance criteria (when applicable) and
- all comments made by the IVA during the qualification process, including the Qualification Report.

5.8.2 Subsea umbilical prototype Qualification Report

Every subsea umbilical prototype qualification test is followed by the dispatch of a test report, to be sent to PETROBRAS as soon as possible, compiling all information relative to the specific test. The objective of the subsea umbilical prototype Qualification Report is to gather the information from all subsea umbilical qualification tests in one single document.

For any subsea umbilical, at least the following information must be on the Qualification Report:

- subsea umbilical drawing and data sheet;
- reference to the coding numbers of the Qualification Reports of the functional components within the umbilical bundle;
- all comments made by the IVA during the qualification process, including the Qualification Report.

Additionally, sections from 5.8.2.1 to 5.8.2.7 detail the minimum required information on the Qualification Report for each umbilical prototype qualification test.

5.8.2.1 Maximum tensile load test

- respective test procedure (reference to its coding number);
- results from the functional components verification tests performed before the umbilical qualification test, with acceptance criteria (when applicable);
- adopted preload tension value;
- evidence of the sample monitoring, with acceptance criteria;
- evidence that the load blocks proposed on the Qualification Plan (section 5.7.2.1) were obeyed, including hold time durations;
- results from the functional components verification and residual tests performed after the umbilical qualification test, with acceptance criteria (when applicable) and
- dissection appraisal

5.8.2.2 Torsion balance test

- respective test procedure (reference to its coding number);
- results from the functional components verification tests performed before the umbilical qualification test, with acceptance criteria (when applicable);
- adopted preload tension value;
- evidence of the sample monitoring, with acceptance criteria;
- evidence that the load blocks proposed on the Qualification Plan (section 5.7.2.2) were obeyed, including hold time durations;
- sample rotation values in all load blocks, with acceptance criteria according to Table 3;
- results from the functional components verification and residual tests performed after the umbilical qualification test, with acceptance criteria (when applicable) and
- dissection appraisal

NOTE: if the torsion balance test was performed in combination with the maximum tensile load test, the minimum information required on sections 5.8.2.1 and 5.8.2.2 can be presented together on the Qualification Report.

5.8.2.3 Axial stiffness test

- respective test procedure (reference to its coding number);
- adopted preload tension value;
- evidence that the load blocks proposed on the Qualification Plan (section 5.7.2.3) were obeyed and
- theoretical and the experimental axial stiffnesses presented in a graphical form (Tension x Displacement).

NOTE: if the axial stiffness test was performed in combination with the torsion balance test, the minimum information required on sections 5.8.2.2 and 5.8.2.3 can be presented together on the Qualification Report.

5.8.2.4 Bending stiffness test

- respective test procedure (reference to its coding number);
- evidence that the load blocks proposed on the Qualification Plan (section 5.7.2.4) were obeyed and
- theoretical and the experimental bending stiffnesses presented in a graphical form (Moment x Curvature).

5.8.2.5 Crush test

- respective test procedure (reference to its coding number);
- results from the functional components verification tests performed before the umbilical qualification test, with acceptance criteria (when applicable);
- adopted preload tension value;
- evidence of the sample monitoring, with acceptance criteria;
- evidence that the tension-crushing pairs proposed on the Qualification Plan (section 5.7.2.5) were obeyed, including the time during which the loads were applied;

- results from the functional components verification and residual tests performed after the umbilical qualification test, with acceptance criteria (when applicable) and
- dissection appraisal

5.8.2.6 Tension and bending dynamic fatigue test

- respective test procedure (reference to its coding number);
- results from the functional components verification tests performed before the umbilical qualification test, with acceptance criteria (when applicable);
- adopted preload tension value;
- evidence of the sample monitoring, with acceptance criteria;
- evidence that the load blocks proposed on the Qualification Plan (section 5.7.2.6) were obeyed;
- results from the functional components verification tests performed during the umbilical qualification test – at hold points defined in 5.7.5.6 – with acceptance criteria (when applicable) and
- dissection appraisal

5.8.2.7 Tension-to-tension dynamic fatigue test

- respective test procedure (reference to its coding number);
- results from the functional components verification tests performed before the umbilical qualification test, with acceptance criteria (when applicable);
- adopted preload tension value;
- evidence of the sample monitoring, with acceptance criteria;
- evidence that the load blocks proposed on the Qualification Plan (section 5.7.2.7) were obeyed;
- results from the functional components verification tests performed during the umbilical qualification test – at hold points defined in 5.7.5.7 – with acceptance criteria (when applicable) and
- dissection appraisal

6 Qualification certificate

As stated on section 5.3, if the qualification program is successfully accomplished, the IVA must issue a certificate testifying that the prototype fits the requirements of this specification and the documents referenced herein.

PETROBRAS will issue its own certificate for internal control, referencing the IVA certificate. It can be made available to MANUFACTURER upon request.