PETROBRAS	**TECHNICAL SPECIFICATION**	Nº I-ET-3010.00-5529-854-PEK-004	
	CLIENT PETROBRAS		SHEET 1 of 21
	JOB FLEXIBLE RISER SYSTEMS		
	AREA FLOATING PRODUCTION UNITS		
SUB	TITLE **MODA RISER MONITORING SYSTEM – RISER SCOPE**		**PUBLIC**
			SUB/ES/EECE/ECE

REVISION INDEX

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	Original
A	Adjusted according to the comments from flexible risers specialists

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E
DATE	01/07/2021	01/12/2021				
DESIGN	ECE	ECE				
EXECUTION	Y5UJ	BYE8				
CHECK	BYE8	Y5UJ				
APPROVAL	UR6A	UR6A				

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1. SUBJECT

This document presents the Technical Specification of the riser scope of an integrity monitoring system applicable for flexible risers, named as MODA RISER MONITORING SYSTEM.

2. ABBREVIATION

AC	Alternating Current
APC	Angle Polished Connector
DAU	Data Acquisition Unit
DC	Direct Current
DMZ	Demilitarized Zone
FAT	Factory Acceptance Test
FBG	Fiber Bragg Grating
FO	Fiber Optic
FPSO	Floating Production, Storage and Offloading
FPU	Floating Production Unit
GTD	General Technical Description
I/O	Input/Output
IP	Ingress Protection
JB	Junction Box
LSZH	Low Smoke Zero Halogen
MODA	*Monitoramento Óptico Direto no Arame* (Optical Monitoring Directly on the Wire)
PBOF	Pressure Balanced Oil-Filled
SIT	System Integration Test
TSP	Twisted Shielded Pair

3. REFERENCE DOCUMMENTS, CODES AND STANDARDS

This section lists standards and external documents applicable to the design of the MODA system.

[1] ;

[2] I-ET-3010.00-1500-960-PPC-014 REV C – Spyhole end fitting;

[3] Patent BR PI1100228-0;

[4] ITU-T G.652 – Characteristics if a single-mode optical fiber and cable;

[5] ITU-T L.12 – Optical fiber splices.

[6] IEC 60529 (latest revision) - Degrees of Protection Provided by Enclosures (IP Code)

4. DEFINITIONS

RISER CONTRACTOR	The company contracted by PETROBRAS to supply the flexible risers including the FBG sensors mounted at the wires inside the spyhole endfitting
FPU CONTRACTOR	The company contracted by PETROBRAS to supply the FPU or the topside scope of the FPU
SUBCONTRACTOR	The company contracted by RISER CONTRACTOR in order to provide and install MODA system, or RISER CONTRACTOR itself if it has the required capability to provide and install the system.
FPU OPERATOR	The company responsible for the FPU topside operations.
PETROBRAS	Oil operator that uses the MODA system for riser integrity management. Any information to be exchanged with PETROBRAS shall be addressed to the subsea engineering group
MODA OPERATOR	The technical company contracted by PETROBRAS responsible for the support/maintenance of the MODA system during risers life
MAY	Is used when alternatives are equally acceptable
SHOULD	Is used when a provision is not mandatory, but is recommended as a good practice
SHALL	Is used when a provision is mandatory
DRY-MATE [CONNECTOR]	Connector designed for plugging/mating in dry area but is applicable for wet/underwater environments
COVERAGE INTERVAL	Interval containing the set of true values of a measured quantity with a stated probability, based on the information available
COVERAGE PROBABILITY	Probability that the set of true values of a measured quantity is contained within a specified COVERAGE INTERVAL

5. TECHNICAL REQUIREMENTS

5.1. SYSTEM OVERVIEW

5.1.1. The MODA system consists of an optical extensometer system based on fiber Bragg grating sensors, which monitors the deformations/stresses acting on the external tensile armor wires of the flexible risers to identify broken and/or compromised wires. An optical fiber Bragg grating sensor is installed on each wire of the external tensile armor layer with which an initial installation reference is made, and from then on, new acquired data is constantly compared with this value.

5.1.2. The Fiber Bragg grating sensors work in a similar way to electrical resistance extensometers measuring mechanical deformations and are installed in a similar manner through surface bonding with adhesives. However, unlike electrical extensometers, the absolute values of the Fiber Bragg grating sensors in wavelength are recorded, allowing the initial installation references to be updated and changed depending on the type of analysis to be performed or the type of information to be displayed to the user.

5.1.3. Among the general characteristics of optical fiber sensors, which favor the installation of the MODA system in classified areas of FPUs, the following stand out:

- It is a passive system, as it uses optical sensors that use only light and does not need another auxiliary energy source;
- Sensors, fibers and optical cables do not have metallic components;
- The system can monitor up to 30 sensors per optical fiber;
- The power commonly used in interrogation equipment (Class 1 Laser), gives it the classification of intrinsically safe;
- Optical interrogation equipment can be installed over long distances and in an unclassified location.

5.1.4. MODA System in Spyhole Type End-Fittings

5.1.4.1. The top end-fittings of the spyhole type already provide access to the external armor layer through its access windows. The sensors can be installed on the surface of the external wires using adhesives, and this process can be done either in onshore facilities or in the field.

5.1.4.2. In projects with spyhole end-fittings, optical connectors are foreseen to link the sensors to the optical cable responsible for transporting the signals between the sensors and the optical interrogation equipment, Figure 1.

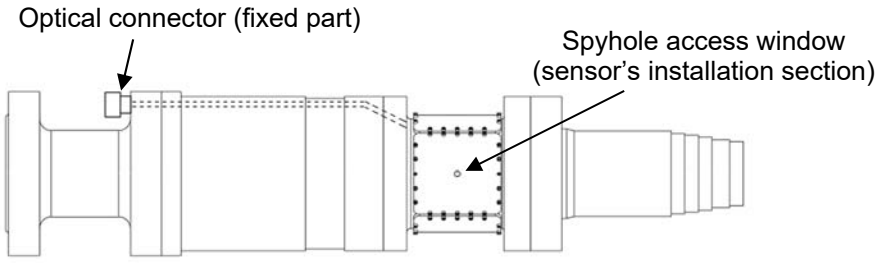

Figure 1: Schematic drawing of MODA basic components for Spyhole end fitting.

5.1.5. State and Event Detection with MODA System

5.1.5.1. The MODA system can identify changes in the state of the wire in the tensile armor layer through permanent changes associated with relaxation in the state of deformation/tension of the broken wires and overloads in the remaining wires adjacent to the broken one.

5.1.5.2. In addition, the MODA system can identify breakage events through dynamic analysis of the load variation in the wires. Although more complex, this type of analysis can indicate the occurrence of ruptures in the internal armor layers of the riser by detecting the transient disturbance propagated in the external armor.

Figure 2 – Spyhole End Fitting with MODA sensors.

5.1.6. The RISER CONTRACTOR shall supply the FBG sensors (attached to the wires inside the Spyhole End Fitting, see Figure 2), cable conduits, optical cables and a submersible dry-mate optical connector mounted at the shoulder of the Top End Fitting body.

5.1.7. The RISER CONTRACTOR shall supply to PETROBRAS the Riser Optical Cable to interconnect riser dry-mate connector at Top End Fitting and FPSO splice box.

5.2. RISER SCOPE MODA COMPONENTS

5.2.1. The MODA components in RISER CONTRACTOR scope are presented on this document as a standard to perform all sensors installation. The guidelines described here shall be strictly obeyed by the RISER CONTRACTOR. When, for any reason, a component substitution is possible or a recommendation is altered, it will be informed by PETROBRAS in a revision of this specification.

5.2.2. The MODA components in RISER SCOPE are:

- Fiber Bragg grating sensors;
- Submersible dry-mate optical connector;
- Epoxy adhesives;
- Riser Optical Cable

5.3. FIBER BRAGG GRATING SENSORS

5.3.1. The optical fiber sensors shall comply with the following requirements:

5.3.1.1. The sensors shall be based on DTG technology (Draw Tower Gratings);

5.3.1.2. The sensors shall have a minimum linear elastic strain range of 1% (1.10^4με) or greater;

5.3.1.3. The sensors shall be grouped in sets;

5.3.1.4. The sensors on sets shall be aligned continuously in a single fiber without intermediate splices;

5.3.1.5. Low bend loss fiber type;

5.3.1.6. Reflectivity: > 30%;

5.3.1.7. FWHM: ≤ 200pm;

5.3.1.8. Wavelength range: 1510 to 1590nm;

5.3.1.9. Wavelength accuracy: ≤ 0.5nm;

5.3.1.10. Relative wavelength accuracy: ≤ 0.3nm;

5.3.1.11. Side lobe suppression: ≥10dB;

5.3.1.12. Sensor size: 10mm (approximately);

5.3.1.13. Fiber attenuation: 8.6dB/km (approximately);

5.3.1.14. Mode fiber diameter: 6μm;

5.3.1.15. Numerical aperture: 0.26;

5.3.1.16. Cladding diameter: 125μm ± 1μm;

5.3.1.17. Coating type: ORMOCER®;

5.3.1.18. Coated fiber diameter: 195μm (approximately);

5.3.1.19. Tensile load at break: >50N (> 5% strain);

5.3.1.20. Operational temperature range: -180ºC to +200ºC;

5.3.1.21. The sensors, as built, shall have a signal to noise ratio greater than 30dB, measured in an optical sensing interrogator with a dynamic range of 40dB or greater;

5.4. SUBMERSIBLE DRY-MATE OPTICAL CONNECTOR

5.4.1. The optical connector shall comply with the following requirements:

5.4.1.1. The connector shall have optical ferrules twice the number of sensors sets at least;

5.4.1.2. The optical connector shall be supplied in a complete configuration (fixed and free parts);

5.4.1.3. Designed for single mode fibers only;

5.4.1.4. The optical connector shall have a watertight pressure protector cup for installation operations;

5.4.1.5. Dry-mate type;

5.4.1.6. Resistant up to 3000m water depth (4260psi);

5.4.1.7. Operational temperature: -30ºC to +100ºC (air);

5.4.1.8. Insertion loss: < 1.0dB @1550nm;

5.4.1.9. Return loss: <-30dB @1550nm;

5.4.1.10. Design life: ≥ 30 years.

5.4.2. The optical connector free part shall be employed to verify and test the full end-fitting instrumentation at the end of the installation. Although this Technical Specification refers only to the MODA components on the end fitting, PETROBRAS considers the free part of the optical connector as a part of it and, therefore, shall be supplied by the manufacturer (for example, the protective cap).

5.5. EPOXY ADHESIVES

5.5.1. Due to different purpose aspects and physical-chemical properties, sensor adhesion on steel armor wires is made applying two distinct epoxy adhesives. The two purposes are mechanical anchorage and chemical protection.

5.5.2. Mechanical Anchorage Adhesive

5.5.2.1. The adhesive responsible for the mechanical anchorage shall comply with the following specifications:

- Strain range capacity under the foreseen mechanical loads (including pull-in operations);
- A linear elastic behavior under the designed strain range;
- High strength and high peel resistance;
- Room temperature cure (25ºC) or accelerated cure under specified conditions;

- Adhesive's service temperature compatible with flexible riser design service temperature (recommended T_g-20ºC).

5.5.2.2. To quantify such recommendations, typical properties and performance values of the epoxy adhesive are recommended in Table 1.

Table 1: Mechanical anchorage adhesive properties/performance typical values*.

Property/Performance	Typical Values
Tensile Lap Shear (25ºC)	≥3,500psi
Tensile Peel Strength (25ºC)	≥20lb/in
Tensile Strength (25ºC)	≥3,800psi
Tensile Modulus (25ºC)	≥300ksi
Shear Modulus (25ºC)	≥130ksi
Elongation at Break (25ºC)	≥5%
Shore D Hardness (25ºC)	≥75
T_g (glass transition temperature)	≥80ºC

(*) For flexible pipes bore operating temperature up to 60ºC.

5.5.2.3. Any alteration in this recommendation shall be fully qualified by the RISER CONTRACTOR, to prove equivalent or superior properties and performance values. Alterations shall be previously notified to PETROBRAS which reserves the right to accept it or not, and all its information (including specifications and properties/performance data) shall be included in the MODA components installation report.

5.5.3. Chemical Resistant Adhesive

5.5.3.1. For protection against chemical contaminants and humidity on the edge between the first epoxy layer and the steel wire, a second layer of epoxy adhesive shall be applied. The chemical resistant adhesive shall comply with the following specifications:

1. Good heat, chemical and steam resistance;
2. Room temperature cure (25ºC) or accelerated cure under specified conditions;
3. Good resistance to acids, alkalis and solvents;
4. Do not contain solvents;
5. Service temperature equal or superior than the mechanical anchorage adhesive.

5.5.3.2. To quantify such recommendations, typical properties and performance values of the epoxy adhesive are recommended in Table 2.

Table 2: Chemical resistance adhesive properties/performance typical values*.

Property/Performance	Typical Values
Tensile Lap Shear (23.8ºC)	≥2,000psi
Tensile Strength (23.8ºC)	≥12,000psi
Tensile Modulus (23.8ºC)	≥350ksi
Elongation (23.8ºC)	≤5%
Shore D Hardness (25ºC)	≥75
T_g (glass transition temperature)	≥80ºC

(*) For flexible pipes bore operating temperature up to 60ºC.

5.5.3.3. Any alteration in this recommendation shall be fully qualified by the RISER CONTRACTOR, in order to prove equivalent or superior properties and performance values. Alterations shall be previously notified to PETROBRAS which reserves the right to accept it or not, and all its information (including specifications and properties/performance data) shall be included in the MODA components installation report.

5.6. RISER OPTICAL CABLE

5.6.1. The Riser Optical Cable is an optical cable piece (with 8 single mode optical fibers inside a PBOF hose). A subsea dry-mate optical connector (male part that matches with the connector installed at the Top End Fitting) shall be mounted at one end of the Riser Optical Cable. At the other end of the Riser Optical Cable shall be delivered with an unterminated optical pigtails with a Female JIC 37° ¾" tube fitting (37º JIC size 12) mounted at the end of the PBOF. This optical pigtails (as illustrated in Figures 3 and 4) shall be spliced or connectorized during the installation offshore inside the Riser Balcony JB at the upper riser balcony. All optical pigtails shall be tagged identifying its correspondence with subsea dry-mate optical connector pins.

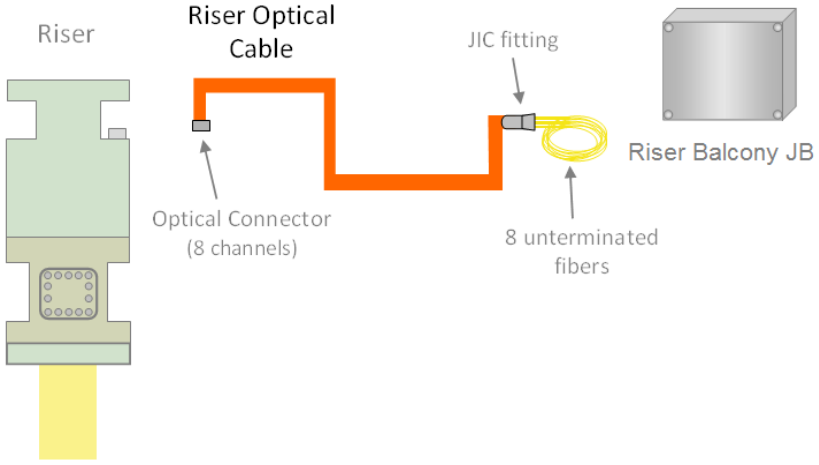

Figure 3 – Riser Optical Cable Schematic.

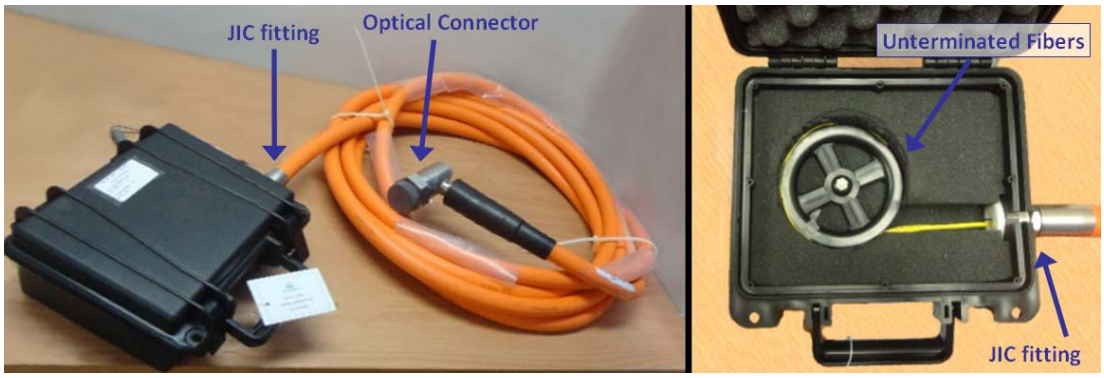

Figure 4 – Riser Optical Cable Picture | Unterminated End Picture.

5.6.2. After the pull-in of each riser/jumper, RISER CONTRACTOR shall go on board the FPU and execute the following services:

- Install the Riser Optical Cable optical connector on the riser;
- Lay the Riser Optical Cable at the upper balcony (i.e., on a cable tray). See sketch at Figure 6;
- Splice the optical pigtails of the Riser Optical Cable with the fibers of a Cabinet Optical Cable and protect them inside the MODA junction box;
- Check and certify the integrity of all the splices (i.e., optical return loss <=-50dB and optical insertion loss <= 1.5dB of fibers) from MODA Cabinet.

5.6.3. For information, this Cabinet Optical Cable runs from the upper riser balcony directly to the MODA Cabinet(s), located on non-classified and temperature controlled area, as illustrated in Figures 5 and 6.

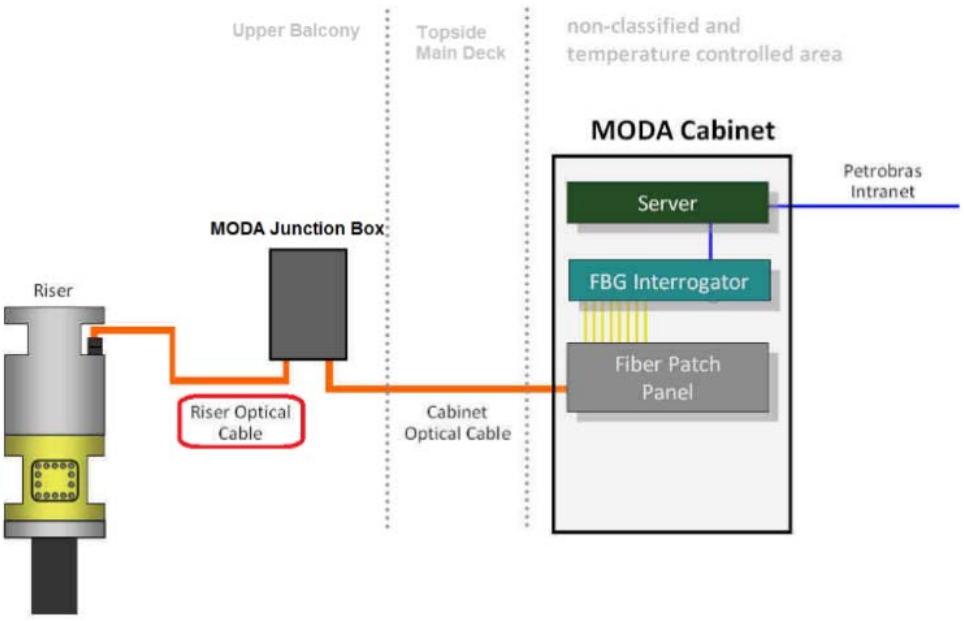

Figure 5 – MODA interconnection schematic

5.6.4. The Junction Box shall have one 3/4 inch outside diameter male 37°flare tube fitting (37º JIC size 12) (example reference: SS-1210-6-12AN). Therefore, the Riser Optical Cable connection that connect to the Junction Box shall be JIC 37° size 12 female.

5.6.5. The Riser Optical Cable shall have a minimum length of 10 m.

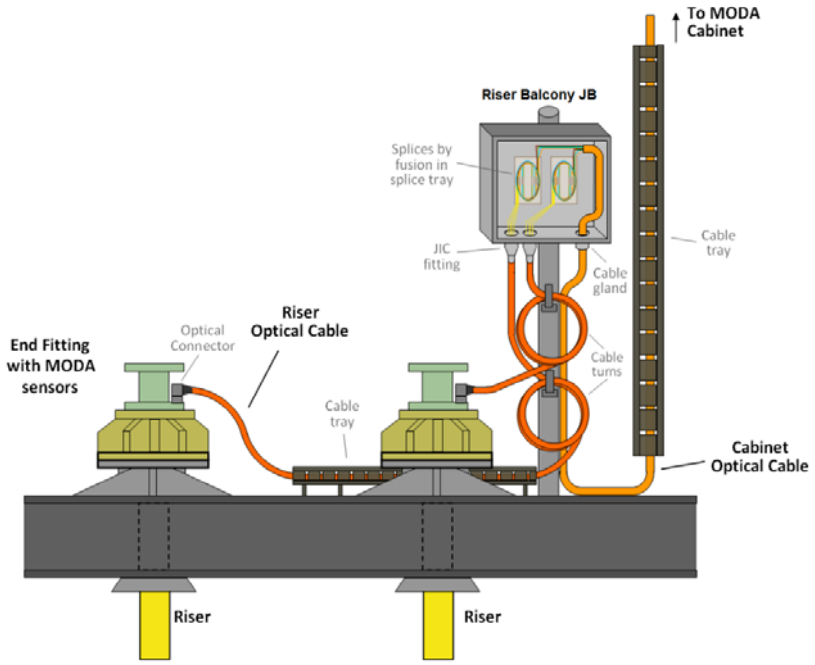

Figure 6 – Sketch of two risers connected to the MODA Cabinet

5.6.6. On the MODA Cabinet, the optical cable is terminated on a FO patch panel and the fibers are connected to a FBG interrogators that reads the sensors installed on the risers. The data collected by the FBG interrogators shall be processed on server computers installed on the MODA Cabinet and transmitted onshore through PETROBRAS Networks (normally DMZ), as illustrated in Figure 5.

6. INSTALLATION

6.1. INSTALLATION DESIGN OF COMPONENTS INSIDE THE END-FITTING

6.1.1. The installation design shall describe how the sensors are divided on the external tensile armor wire layer and how the optical connector is linked to them. The decision of how many sensors each sensor set contains is a tradeoff between the sensor's wavelength range requirements, wavelength spam available in the interrogator equipment, foreseen strains and handling difficulty for large sensors sets.

6.1.2. All wires on the external tensile armor layer shall have, at least, 1 (one) FGB sensor installed on its surface dedicated for strain measurements.

6.1.3. The sensors in sensor sets shall be aligned continuously in a single fiber without any

intermediate splice. Spaces between sensors and inlet/outlet fiber lengths shall be considered in the sensor set design, Figure 6.

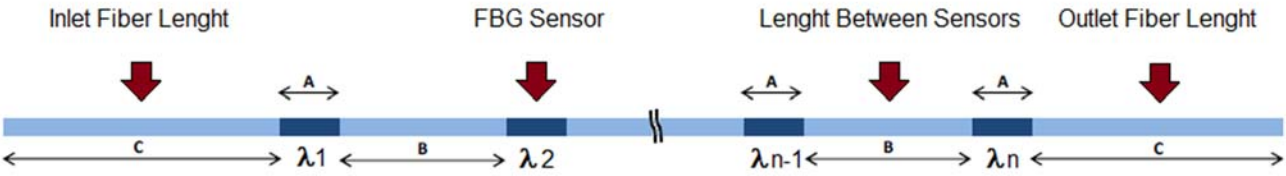

Figure 6: FBG sensor layout design.

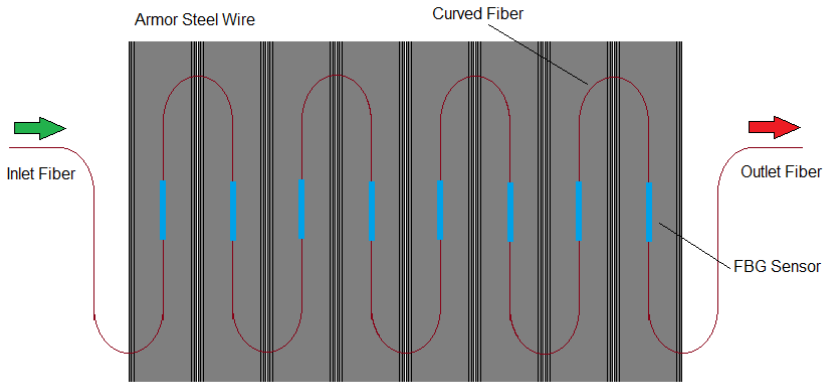

Figure 7: Fiber path.

6.1.4. The nominal dimensions of A and B, on Figure 67, shall be calculated according to the flexible pipe structure (*i.e*. wire width, armor angle, etc.), the available physical space and the fiber minimum curvature, which shall not exceed the minimum value recommended by the sensor manufacturer.

6.1.5. Each sensor is fixed on its respective wire through a fiber “zigzag” path, Figure 7. Limitations on the sensor path width, dictated by the minimum required space inside the Spyhole end fitting, shall be observed.

6.1.6. At least 1 (one) FBG sensor for temperature monitoring shall be included in the installation. All temperature compensation sensors shall be clearly identified in the installation design.

6.1.7. As the optical connector position is dependent on each end fitting design, the dimensions and layout of inlet and outlet fibers, legend C on Figure 66, shall be designed by the RISER CONTRACTOR.

6.1.8. Summarizing, the basic variables for an installation design are:

- Sensor's wavelength;
- Number of strain sensors;
- Number of temperature compensation sensors;
- Number of sensors sets;
- Sensor's size;
- End fitting design;
- Number of optical channels;
- Dimension of the wires;
- Armor wires angle;
- Fiber minimum bending radius;
- Fiber overlength for inlet and outlet splicing;
- Optical connector specifications;
- Number of optical splices.

6.2. INSTALLATION PROCESS OF COMPONENTS INSIDE END-FITTING

6.2.1. Sensor's installation

6.2.1.1. Prior to the installation all sensor sets shall be verified. The sensors shall have its signal to noise ratio measured in an optical sensing interrogator with a minimum dynamic range of 40dB or grater. The measurements of such verifications shall be recorded and documented along with the sensor set serial number and the interrogator equipment specifications for traceability purposes.

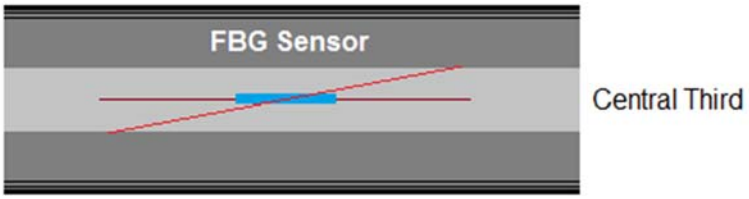

Figure 8: Sensor position.

6.2.1.2. Steel wires surface shall be prepared according to epoxy adhesive recommendations. The flexible riser manufacturer shall be consulted about the surface preparation procedures and shall formally agree with such procedures.

6.2.1.3. Sensors shall be placed longitudinally to each wire aligned to its axis (0º±5º), and the sensors position on the wire width shall be within the central third, Figure 8. For sensors positioning, adhesive tapes may be used. The compatibility between adhesive tapes and steel wires material shall be verified with the RISER CONTRACTOR.

6.2.2. Adhesive application

6.2.2.1. With sensors in position the first epoxy layer, the mechanical anchorage adhesive, shall be applied. After the first layer is cured, the second epoxy layer, the chemical resistant adhesive, shall be applied, Figure 9. The environmental conditions and the cure requirements (cure time, temperature and humidity) for both epoxy layers shall be strictly obeyed according to the adhesive's specifications and recommendations. The compatibility between the adhesive and steel wires material shall be verified with the RISER CONTRACTOR.

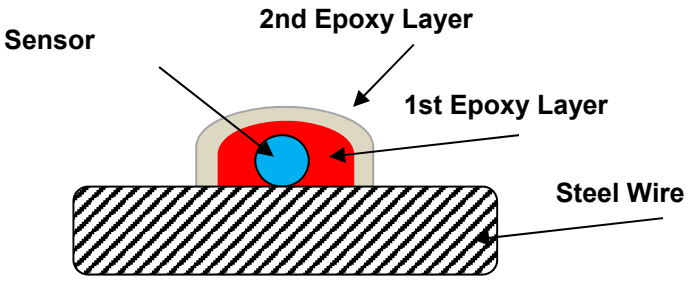

Figure 9: Sensor bonding scheme.

6.2.3. Splice operations

6.2.3.1. Splices are critical points on MODA components installation, as they affect not only the quality of measurements, but also their entire operation. All sensor sets shall be linked to the optical connector through electric arc fusion splices. The sensor sets shall be spliced into optical connector ferrules in both of its ends, Figure 10, considering the inlet fiber side as the same as the lower wavelength sensor side.

6.2.3.2. The splices for MODA installation are regular arc fusion splices for single mode fibers. The standard ITU recommendations for fiber splicing shall be followed [5].

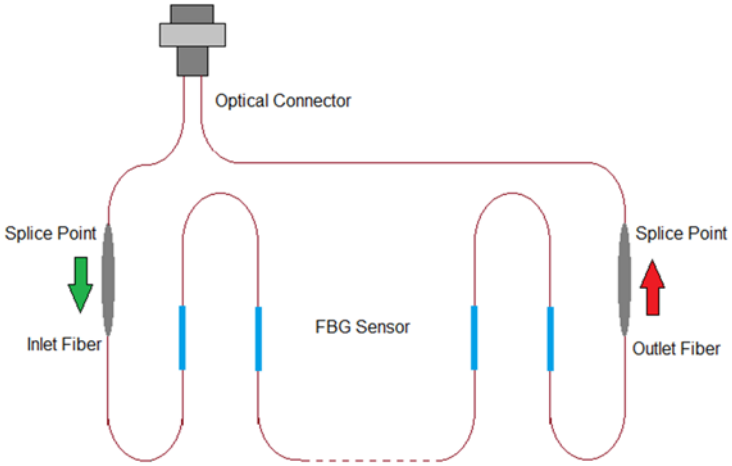

Figure 10: Sensor set with both ends spliced.

6.2.4. Optical connector assembly

6.2.4.1. The optical connector assembly on the Spyhole end fitting shoulder shall be executed following the connector manufacturer's recommendations. Sealing verification tests shall be executed according to end fitting design specifications.

6.2.4.2. All mechanical tools and force-pressure equipment shall be calibrated by an INMETRO's accredited laboratory, if applicable.

6.2.5. Anticorrosion finishing

6.2.5.1. After the sensor installation is concluded, a thin layer of lubricant shall be applied over the steel wires for corrosion protection. The compatibility between the lubricant and steel wires material shall be verified with the RISER CONTRACTOR.

7. VERIFICATION AND ACCEPTANCE TESTS

7.1.1. After installation procedures executed (section 6.2), two tests shall be performed by the RISER CONTRACTOR. The Installation Verification Test (IVT) and the Factory Acceptance Test (FAT). The installation shall be approved on both tests.

7.2. INSTALLATION VERIFICATION TEST (IVT)

7.2.1. The purpose of the Installation Verification Test is to ensure that all sensor sets are installed properly. Due to natural fiber curvatures between sensors and splices, some attenuation is expected, but shall not compromise the perfect readings of the sensors.

7.2.2. The Installation Verification Test shall be executed with the optical connector already installed on the end fitting. Tests performed without the optical connector are not acceptable. The acceptance criterion for the Installation Verification Test is 100% of the sensors with signal to noise ratio better than 20dB (defined as the power difference between sensor's peak and noise floor) measured using an optical interrogator with a swept wavelength laser and dynamic range minimum of 40dB

(defined as laser launch power minus detection laser noise floor).

7.2.3. PETROBRAS recommends the use OTDR to check fiber optic channels integrity (FO connectors/cabling/optical splices) for MODA sensors operation. Typical measurements to check optical integrity are an optical insertion loss (OIL) better or equal to 1.5dB @1550nm and an optical return loss (ORL) better or equal than -50dB @1550nm.

7.2.4. A report including all IVT data shall be issued.

7.3. FACTORY ACCEPTANCE TEST (FAT)

7.3.1. The purpose of the Factory Acceptance Test is to verify the correct adhesion of sensors on flexible riser steel wires. For this, a mechanical or thermal load shall be applied generating a minimum wavelength variation. Depending on if mechanical or thermal load methodology is chosen, some conditions shall be observed and followed.

7.3.2. For FAT performed using mechanical loads, the applied strain shall sensitize 100% of steel wires. However, a set of different loads capable of sensitizing wires partly are acceptable as long the manufacturer, or RISER CONTRACTOR (as per contract), prove that all wires are tested. The minimum wavelength variation required is 100pm in each wire.

7.3.3. For FAT performed using thermal loads, the applied temperature gradient shall sensitize 100% of steel wires. The test shall prove that wavelength variations are due to steel wire thermal expansion only and not from coupled thermal effects on FBG sensors and epoxy's self-thermal expansion. The minimum wavelength variation required is 100pm in each wire.

7.3.4. The Factory Acceptance Test shall be executed with the optical connector already installed on the end fitting. **Tests performed without the optical connector are not acceptable**. **The FAT acceptance criterion for both methods is 100% of the sensors with adhesion proven, with signal to noise ratio better than 20dB** (defined as the power difference between sensor's peak and noise floor) measured using an optical interrogator with a swept wavelength laser and dynamic range minimum of 40dB (defined as laser launch power minus detection laser noise floor).

7.3.5. PETROBRAS recommends the use OTDR to check fiber optic channels integrity (FO connectors/cabling/optical splices) for MODA sensors operation. Typical measurements to check optical integrity are an optical insertion loss (OIL) better or equal to 1.5dB @1550nm and an optical return loss (ORL) better or equal than -50dB @1550nm.

7.3.6. A report including all FAT data shall be issued.

7.4. INSTALLATION REPORT

7.4.1. After tested and accepted, the MODA components installation is considered complete. An Installation Report shall be issued by the RISER CONTRACTOR to PETROBRAS including the following:

- Complete installation design of MODA components inside end fitting;
- All components information, specifications, serial numbers and data sheets;
- Component drawings (if applicable);
- Component's qualification (if applicable);
- All sensor sets readings recorded before the installation – Spectrum measurement and sensor peak streaming (≥1min), including digital media;
- A detailed description of the installation procedure (section 6.2);
- Detailed photographic register of all installation stages;
- A full reading of all sensors sets recorded after the installation – Spectrum measurement and sensor peak streaming (≥1min), including digital media.

7.5. ACCEPTANCE REQUIREMENTS

7.5.1. The following acceptance requirements are established for the installation steps of the MODA system.

7.5.2. Installation of MODA System – Riser Scope

- The sensors shall have reflectivity greater than 30%;
- The sensors shall have FWHM (Full Width Half Maximum) less than 1.5nm;
- Two subsequent sensors, on the same optical fiber, shall have a difference greater than 3nm in wavelength;
- After installing the sensors, the signal-to-noise ratio of the complete system (including sensors and optical connector) shall be better than 20dB, measured using an optical interrogator with a swept wavelength laser and dynamic range minimum of 40dB;
- In MODA systems with a Spyhole end fitting, the optical connector shall have an insertion loss of less than 1.00dB and a return loss of better than 30dB.

7.5.3. PETROBRAS recommends the use OTDR to check fiber optic channels integrity (FO connectors/cabling/optical splices) for MODA sensors operation. Typical measurements to check optical integrity are an optical insertion loss (OIL) better or equal to 1.5dB @1550nm and an optical return loss (ORL) better or equal than -50dB @1550nm.

7.5.4. Any deviations to meet these criteria shall be previously discussed and justified with PETROBRAS, and acceptance of these new conditions is exclusively up to PETROBRAS.

7.6. STORAGE REQUIREMENTS

7.6.1. As the MODA components installed within the spyhole end fitting are sealed and protected, the storage requirements are to prevent damages in the optical connector's pressure cap. All necessary protection covers shall be applied to avoid mechanical damages in this component during the whole period of storage.

7.6.2. All riser optical cables (which are supplied along with the riser) shall be supplied inside IP-65 boxes, all of them shall be identified for traceability purposes, and before riser installation, stored by RISER CONTRACTOR in a dry, dust free environment at ambient temperature. These components shall also be protected against damaging effects like thermal radiation, direct solar radiation, mechanical damage, and solvent organic influence. All spare riser optical cables with IP-65 boxes shall be supplied to PETROBRAS storehouse defined during contract.

8. SCOPE OF RISER CONTRACTOR

8.1. SCOPE OF SUPPLY

8.1.1. RISER CONTRACTOR shall supply, for each flexible riser with Spyhole End Fitting in its scope:

- MODA sensors installed at spyhole End Fitting as detailed in items 5 and 6.
- Submersible dry-mate optical connector as detailed in item 5.4.
- Optical cabling to interconnect FBG sensors and dry-mate connector.
- Riser Optical Cable to interconnect dry-mate connector and FPU structure.

8.1.2. RISER CONTRACTOR shall supply any special tool needed to install Riser Optical Cable (onshore and offshore).

8.1.3. RISER CONTRACTOR shall provide all documentation as detailed in item 10.

8.1.4. RISER CONTRACTOR shall supply one Spare Riser Optical Cable for each 4 supplied.

8.1.4.1. If scope of RISER CONTRACTOR is smaller of four riser optical cable, one spare shall be provided.

8.2. SCOPE OF SERVICE

8.2.1. RISER CONTRACTOR shall install MODA sensors observing installation requirements of item 6.

8.2.2. RISER CONTRACTOR shall perform all tests as required in item 7.

8.2.3. RISER CONTRACTOR shall install riser optical cable as detailed in item 5.6.

8.2.4. In all storage over its responsibility, RISER CONTRACTOR shall observe storage requirements at item 7.6.

8.3. GENERAL SCOPES AT FPU

8.3.1. General overview scopes from RISER CONTRACTOR, FPU CONTRACTOR/OPERATOR and MODA OPERATOR are presented in Figure 11.

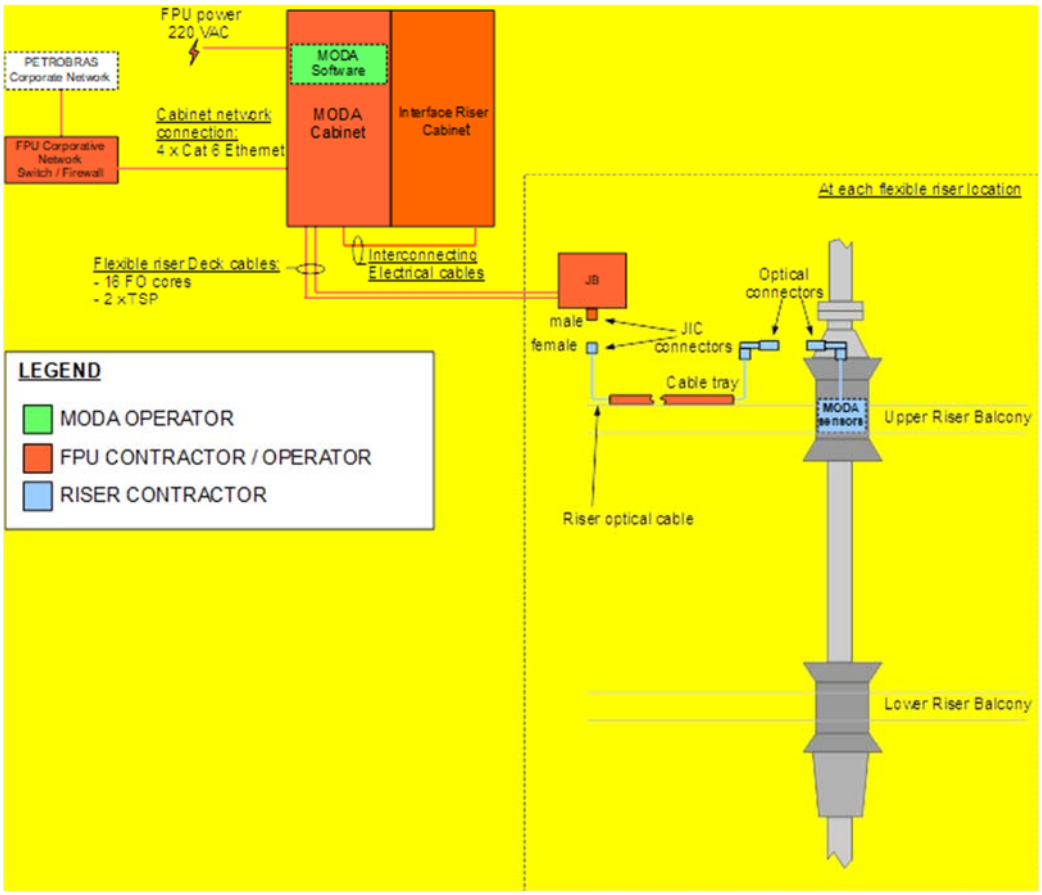

Figure 11: General Scopes at FPU.

9. SUBCONTRACTOR REQUIREMENTS

9.1.1. The MODA system SUBCONTRACTOR shall meet the following criteria:

a) Have knowledge to install Fiber Bragg grating sensors;
b) Have experience with measurement with Fiber Bragg grating sensors;
c) Qualification demonstrated with PETROBRAS;
d) Have trained and qualified technicians and in sufficient number to work in marine facilities;
e) Have the ability to calibrate the sensors;
f) Have the ability to assemble optical components (connectors);
g) Have the ability to perform quality and loss verification tests;
h) Have the ability to specify cables and optical fibers;
i) Have all the necessary equipment and tools to perform the activities.

9.1.2. Any deviations to meet these criteria shall be previously discussed and justified with PETROBRAS, and acceptance of these new conditions is exclusively up to PETROBRAS.

10. DOCUMENTATION REQUIREMENTS

10.1.1. In accordance with PETROBRAS' specifications, the supplier shall deliver, in a detailed and complete manner, the following documents referring to the MODA System – Riser Scope:

- System specifications;
- Project reports;
- Technical drawings;
- Materials and components specifications;
- System installation procedures;
- System maintenance procedures;
- Qualification testing reports and procedures;
- Test report of optical components (sensors and optical connector);
- Test reports of optical components (sensors and optical connector) after installation.

10.1.2. During the executive design shall be issued to PETROBRAS approval a Technical Proposal of the RISER CONTRACTOR scope, including Datasheets, manuals and certificates for all equipment/cabling supplied by RISER CONTRACTOR.