PETROBRAS	**TECHNICAL SPECIFICATION**	Nº I-ET-3010.00-1300-279-PEK-001	
	CLIENT PETROBRAS		SHEET 1 of 33
	JOB DIVERLESS BELL MOUTH		
	AREA –		
SUB	TITLE **SPECIFICATION OF HYDRAULIC ACTUATOR SYSTEM FOR BSDL-SI**		**INTERNAL** SUB/ES/EECE/ECE

REVISION INDEX

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	Original
A	Revised items 3.2.2, 6.2.8.5 and 7.1.5. Included item 6.2.15.
B	Revised all references to BSDL-SI and items 3.2.2 and 6.3.8.6
C	Included monitoring system
D	Increasing the operation safety using PUPS. Detailing of Umbilical fixation and materials. Detailing of tubings fixation and materials.
E	Revised from lessons learned from PBREF and PBAC projects.

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	29/06/2020	09/07/20	14/07/20	25/03/22	29/03/23	18/06/24			
DESIGN	ECE	ECE	ECE	ECE	ECE	ECE			
EXECUTION	BYE8/Y5UJ	BYE8/Y5UJ	BYE8/Y5UJ	Y5UJ	Y5UJ	BYE8			
CHECK	CX4H	CX4H	CX4H	CX4H	CX4H	DVHV			
APPROVAL	BFN7	UR6A	UR6A	UR6A	UR6A	BERL			

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1 SUBJECT

This document presents the Technical Specification of Hydraulic Actuator System for Diverless Bell Mouth – Standard Interface (BSDL-SI) and its topside automation system requirements.

2 ABBREVIATION

BSDL-SI	Diverless Bell Mouth - Standard Interface (Portuguese acronym)
DL	Diverless
FAT	Factory Acceptance Test
FPU	Floating Production Unit
HPU	Hydraulic Power Unit

3 REFERENCE DOCUMMENTS, CODES AND STANDARDS

This section lists standards and documents applicable to the design of the monitoring system:

3.1 International Standards

[1] API 6A - Specification for Wellhead and Christmas Tree Equipment

[2] API 17E – Specification for Subsea Umbilicals

[3] API 17F - Standard for Subsea Production Control Systems

[4] API 17Q - Recommended Practice on Subsea Equipment Qualification

[5] ASME B16.5:2013 - Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service

[6] ASME B16.5:2013 - Pipe Flanges and Flanged Fittings

[7] DNVGL-RP-B401:2017 - Cathodic Protection Design

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

[9] ISO 13628-6:2006 - ISO 13628-6:2006

3.2 Petrobras documents

3.2.1 Hydraulic actuation system documents

[10] I-DE-3010.00-1300-279-PEK-001 - HYDRAULIC CIRCUIT FOR BSDL-SI

[11] I-DE-3010.00-1300-279-PEK-002 - HYDRAULIC ACTUATOR ASSEMBLY FOR BSDL-SI

[12]

[13] I-DE-3010.00-1300-279-PEK-003 - 5K HYDRAULIC ACTUATOR ASSEMBLY FOR BSDL

3.2.2 BSDL-SI documents

[14] I-LI-3010.00-1300-279-PPC-350 – BSDL-SI PART LIST

[15] I-ET-3010.00-1300-279-PPC-350 - DIVERLESS BELL MOUTH STANDARD INTERFACE SUPPLY SPECIFICATION

3.2.3 Subsea fasteners documents

[16] I-ET-3000.00-1500-251-PEK-001 – HIGH-STRENGTH LOW-ALLOY STEEL FASTENERS FOR SUBSEA APPLICATIONS

3.2.4 Tubing and Topside fasteners documents

[17] I-ET-3010.00-1200-800-P4X-015 - REQUIREMENTS FOR TUBING AND FITTING (ALIGNED TO IOGP-JIP33 S-716)

[18] I-ET-3010.00-1200-251-P4X-001 - REQUIREMENTS FOR BOLTING MATERIALS

3.2.5 Umbilical documents

[19] I-ET-3000.00-1500-29B-PAZ-003 - 3/8" & 1/2" ID HYDRAULIC HOSES

[20] I-ET-3000.00-1519-29B-PZ9-002 - LOW VOLTAGE/SIGNAL ELECTRIC CABLES AND TERMINATIONS FOR SUBSEA UMBILICAL SYSTEMS

[21] I-ET-3000.00-1519-29B-PZ9-012 - TOPSIDE ARRANGEMENT AND INTERFACES WITH SUBSEA UMBILICAL SYSTEMS

[22] I-ET-3010.00-1300-172-PEK-001 - PORTABLE UMBILICAL PRESSURIZATION SYSTEM (PUPS) – FPU SCOPE

[23] I-ET-3010.00-5537-850-PEA-001 - POSITIONING AND NAVIGATION SYSTEMS

4 DEFINITIONS

FPU CONTRACTOR	The company contracted by PETROBRAS to construct the FPU
DIVING TEAM	The party responsible for execution of diving-related tasks, to be defined during the bidding phase.
MAY	It is used when alternatives are equally acceptable
SHOULD	It is used when a provision is not mandatory, but is recommended as a good practice
SHALL	It is used when a provision is mandatory
SUBCONTRACTOR	Company contracted by FPSO CONTRACTOR, to supply hydraulic actuator system for BSDL.

5 TECHNICAL CARACTERISTICS

5.1 Design and fabrication

5.1.1 All subsea control components, like umbilical lines and hydraulic system, shall be designed in accordance with API 17E and API 17F.

5.1.2 Selection of materials for all subsea structures shall be in accordance with DNVGL-RP-B401:2017 item 5.5 and be designed for the same design life as the riser.

5.1.3 All enclosures and equipment to be placed in hazardous areas shall comply and be certificated according to IEC 60079 (latest revision).

5.1.4 All enclosures with a required degree of ingress protection shall comply with IEC 60529 (latest revision).

5.2 Qualification

5.2.1 Hydraulic cylinder shall be designed according to API 6A and API 17F.

5.2.2 All subsea equipment shall be qualified in accordance with API 17Q or ISO 13628-6:2006.

5.2.3 FPSO CONTRACTOR shall consider SUBCONTRACTORS with experience in subsea hydraulic actuators.

6 TECHNICAL REQUIREMENTS

6.1 System overview

6.1.1 BSDL-SI is a device designed to support flexible line bend stiffener loads and allow diverless pull-in and pull-out operations. Three nominal sizes of BSDL-SI are considered: 32”, for umbilical lines, 46” and/or 48” for flexible production, service, export or gas/water injection lines. Figure 1 shows BSDL-SI with hydraulic actuator system on right side and without hydraulic actuator on left side.

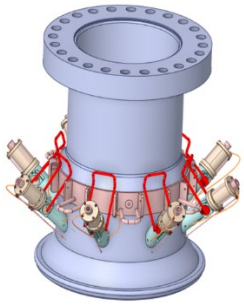

Figure 1 –BSDL-SI with hydraulic actuator system.

6.1.2 Hydraulic actuation system comprises simple action hydraulic actuators installed on BSDL-SI round blocks, tubings, umbilical and FPSO panels as shown in ref.[10] that provide means for remote control to unlock BSDL-SI during diverless pull-in operation. The number of actuators for each BSDL-SI depends upon its nominal size as ref. [14].

6.1.3 The scope of this document covers only the hydraulic actuator system, monitoring system and hullside umbilical. The bell mouth itself it is not scope of this specification; however, it is FPU CONTRACTOR scope as ref. [14] and [15].

6.1.4 Figure 2 presents a general diagram of the hydraulic actuator system for BSDL-SI.

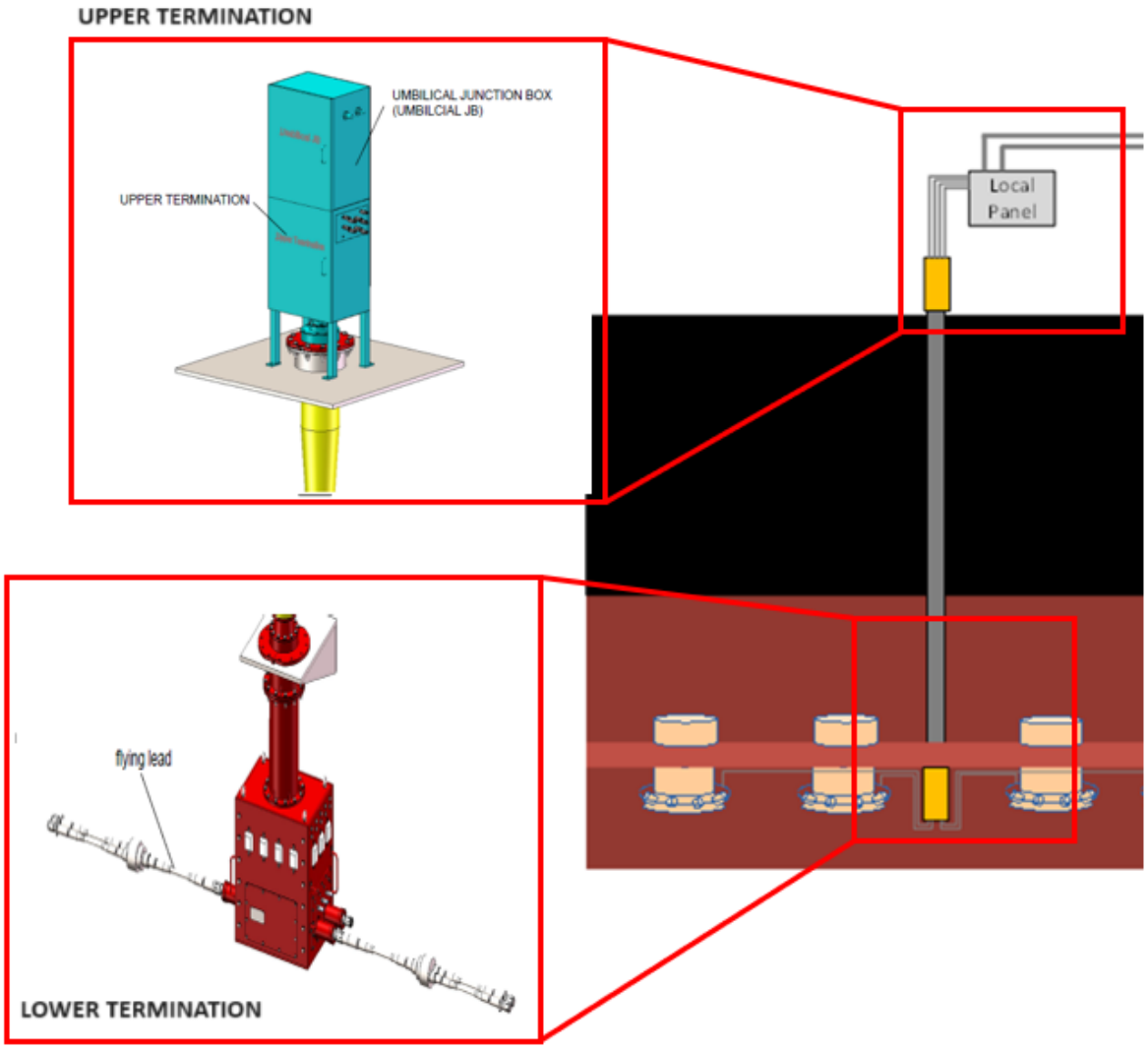

Figure 2 – General Diagram from hullside umbilical.

6.2 Subsea Tubings and fittings

6.2.1 Subsea Tubings, fittings and supports shall be made of super austenitic stainless steel (SS alloy with 6% molybdenum) shall comply with DNV RP B401.

6.2.2 Fitting sealings type shall comply with medium pressure standard as defined in the ref [21].

6.2.3 Allowable working pressures shall be calculated according to ASME B31.3.

6.2.4 Tubing supports (at lower balcony) shall be installed at trays with distance L between each support measuring around 200 to 300 mm.

6.2.5 Topside tubings and fittings shall follow the specification of Ref [17]. Tubing supports (at topside) shall be installed at trays according to ref [17].

6.2.6 FPU Contractor shall provide trays to support hydraulic tubings and cabling installed below riser balcony and also at BSDLs' bodies.

6.2.7 Fasteners of Topside and Splash Zone shall follow the specification of Ref [16].

6.3 Hydraulic actuator assembly for BSDL

6.3.1 The hydraulic actuator is responsible primarily for diverless unlocking mechanism of the flexible line bend stiffener during pull-out operation.

6.3.2 The scope of hydraulic actuator assembly is separated from BSDL-SI as shown in Figure 3. The left figure presents the external view while the right one shows internal parts. The red parts represents the hydraulic actuator components and the blue parts are defined in BSDL-SI documentation as defined in ref. [14] and [15].

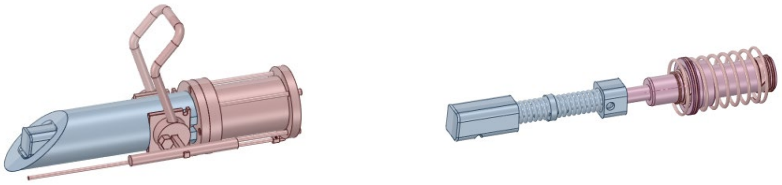

Figure 3 – Scope of BSDL-SI (blue) x scope of Hydraulic actuation System (red)

6.3.3 Drawing ref. [11] presents conceptual hydraulic actuator assembly and establishes detailed scope separation between BSDL-SI and hydraulic actuator.

6.3.4 Detailed design for actuators and tubing lines shall be submitted to Petrobras approval prior to start of hydraulics system components production; technical requirements described in following paragraphs shall be fulfilled as a minimum.

6.3.5 A minimum design documentation shall comprise assembly and component drawings with dimensional and tolerances, stress analysis and material description.

6.3.6 Stress analysis shall be performed, and allowable stress shall be considered according to API 6X.

6.3.7 Hydraulic actuator design shall be compatible with the following mode of operation for pull-in activity:

6.3.7.1 Mechanical automatic latching:

This is the primary mode of operation during pull-in activities and its latching/unlatching function is independent of hydraulic actuation. The BSDL-SI internal components provide all the necessary functionality for pull-in operation.

Handler remains at same position while latching bar moves towards inside by compressing de springs as shown in Figure 4. Driving force for the latch bar retraction is done by Cap DL (see ref. [14]) upwards movement during pull in operation.

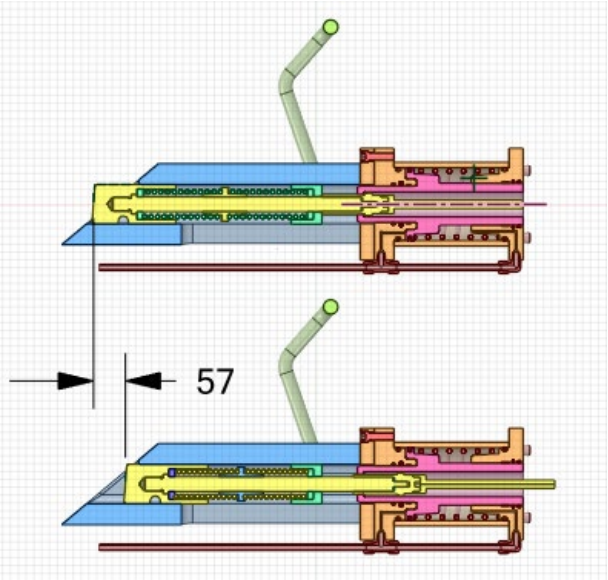

Figure 4 – Mechanical automatic latching during pull-in

Return of latching bar is performed by spring force after Cap DL reaches a level with reduced section releasing space for latching.

Actuator design shall have drilled rod to allow free movement of latch mechanism axis as shown in Figure 4 in yellow color.

6.3.8 Hydraulic actuator design shall be compatible with the following modes of operation for pull-out activities:

6.3.8.1 Manual override for diver-operated:

Latch bar retraction may be performed by handler movement operated by diver for pull-out activities. During override, the internal components highlighted in yellow color at Figure 4 moves towards right direction driven by eccentric/sliding plate mechanism.

Since including hydraulic actuator on round block prevents original handlers to perform whole rotation movement, then handle design needs to be adjusted accordingly.

Two alternatives are considered to adequate handlers:

6.3.8.1.1 Increased handler design option

The simplest solution for handler design may be just to increase handler length enough to be able to complete rotation movement as illustrated on Figure 5.

The consequence for increasing BSDL-SI handler is the resulting increased space required between BSDL-SI on balcony.

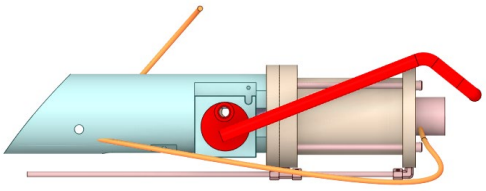

Figure 5 - increased length handler.

6.3.8.1.2 Couple of detachable handler design option

Other alternative is to design two types of handlers as shown in Figure 6 through 8:

- In plane with actuator, detachable handler is used to initiate rotation until 45.
- Lateral detachable handler is used to complete 180° rotation.

Regardless of handler type selection, the internal components shall be able to operate as Figure 6 through Figure 8 demonstrate.

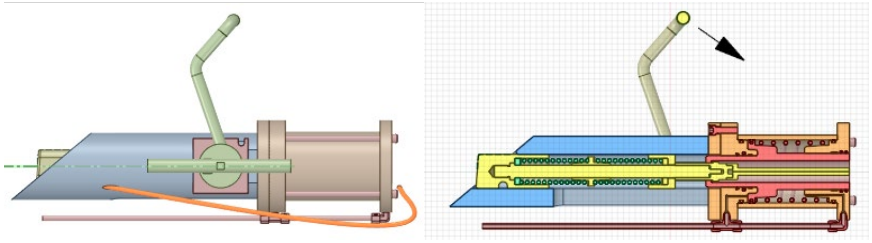

Figure 6 – Manual override diver operated for pull out activities.

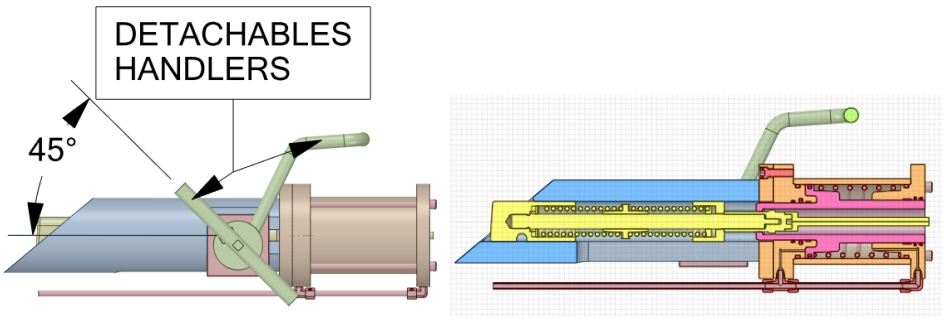

Figure 7 – Detachable in plane handler restricted rotation movement.

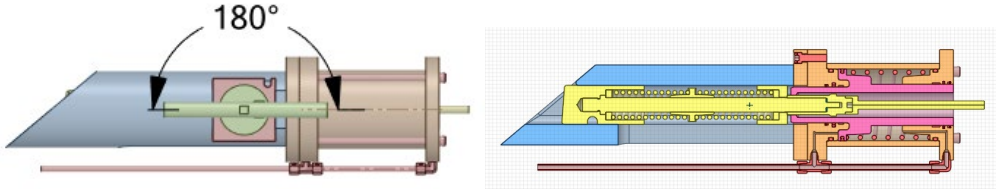

Figure 8 – 180° rotation performed by lateral detachable handler.

Note that, in override mode of operation, no spring is compressed since whole assembly moves together as shown in figure above. Internal moving parts are highlighted in yellow color.

Hydraulic actuator piston rod and internal cap shall leave enough free space for BSDL-SI reaction block stroke of at least 57mm, during override operation. Reference [14] shall be consulted for BSDL-SI assembly dimensions to be considered in hydraulic actuator design.

6.3.8.2 Diverless Hydraulic remote control:

BSDLs single action hydraulic cylinders with spring return shall be designed for regenerative hydraulic circuit. Only one tubing line is used for all cylinders at each BSDL.

During pull-in operation, the hydraulic actuator is aligned to PUPS atmospheric pressure tanks. The only remaining pressure acting over hydraulic actuator is due to 40m hydrostatic column and its FPSO dynamic effects from lower riser balcony to FPSO deck as shown in [10].

Hydraulic actuator is pressurized by FPSO valves in order to retract latch bars during pull-out operation and allowing to bend stiffener a downwards movement (see Figure 9).

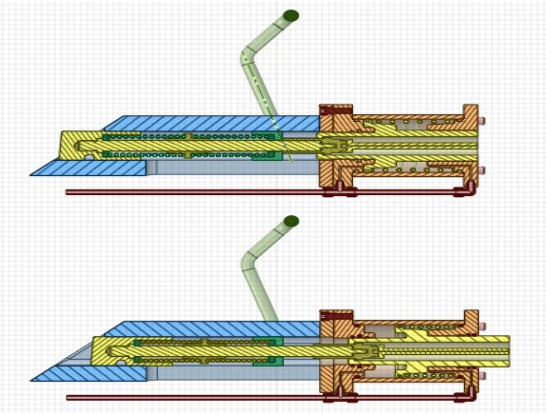

Figure 9 – Hydraulic actuation

6.3.9 BSDL/ACTUATOR interfaces and materials requirements

6.3.9.1 Bolting

Hydraulic actuator shall be hold to BSDL-SI round blocks by four ½-inch socket heads bolts.

A mounting plate may be used to fix hydraulic actuator in BSDL-SI round block.

Bolt materials, INCLUDING TIE RODS, shall comply with ref. [18]. if selected low alloy steel or corrosion resistant alloy.

Supplier shall consider bolt loosening prevention with proven and reliable methods due to dynamic loads imposed by sea waves and current on supports and cable connections. Among others: tab washer, wedge locking washer, castle nut with cotter pin, locking wire and adhesive are considered reliable for bolt loosening prevention.

6.3.9.2 Selection of materials (other than bolting) and cathodic protection

Subsea hydraulic actuator and tubings shall be compatible with sea water environment. A combination of cathodic protection and use of corrosion resistance alloys are required as described in following paragraphs.

Three regions of round block and hydraulic actuator shall be considered for cathodic protection:

- Moving parts highlighted in yellow color in Figure 10 shall have cathodic protection connected to round block by copper cable shown in Figure 11. Handlers also shall be connected by another copper cable to round block.
- Hydraulic actuator piston rod shall be made as a single part of corrosion resistant alloy due to long during sea water exposure and need to keep sealing dimensions. Also, calcareous deposit under cathodic protection in sea water environment, its possible harmful effects in rod surface and possible sealing failure need to be prevented. So, in this way, hydraulic actuator piston rod shall be insulated from cathodic protection by internal wear rings, insulating internal bush and gaps shown in ref. [11]. Additionally, resistance to biofouling needs to be considered and copper alloys are required to combine sea water and biofouling resistance. Beryllium-copper, UNS 17200, shall be considered for hydraulic actuator rod.
- Stationary parts like actuator tube and caps are connected to round blocks and thus are subjected to cathodic protection. Hydraulic actuator tube and caps may use either CRA alloys or low alloy steels with external painting. Internal hard coated in sliding surfaces provided that a numerical cathodic protection model (FEA type) using recognized software has been performed to show that regions like gaps between internal cap and rod will not be affected by calcareous deposit.

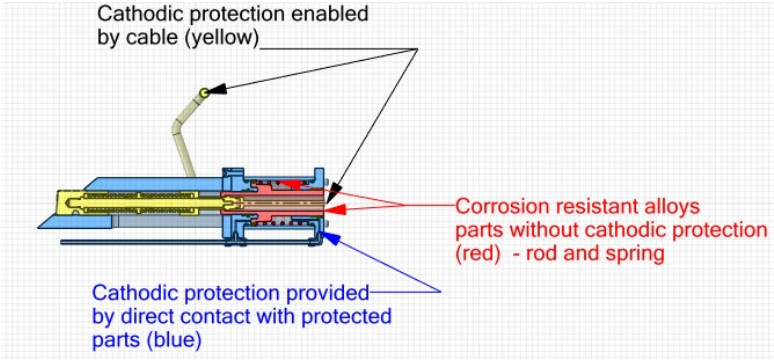

Figure 10 – Corrosion resistance and cathodic protection

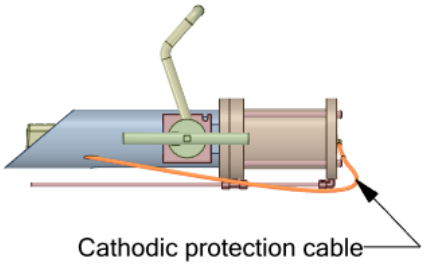

Figure 11 – Cathodic protection cable

Hydraulic actuator spring shall be made of alloy 718 with hardness limited to 35 HRC. Higher hardness than 35 HRC may be used if cathodic protection model reveals no susceptibility to hydrogen induced stress cracking effect inside cylinder tube chamber and shall be subjected to Petrobras approval.

6.3.9.3 Size restrictions

The hydraulic actuator length shall be limited to 300 mm or 357mm considering piston rod end of stroke.

6.3.9.4 For tubings and supports, requirements of item 6.1.2 shall be observed.

6.3.9.5 Sealings

Sealings shall be selected considering, at least:

- Hydraulic fluid (see 6.2.2.24)
- Sea water
- Minimum and maximum temperatures defined in 6.2.2.21 and 6.2.2.22.
- Maximum test pressure defined in 6.2.2.14.
- Sealing components for long-term period (until 30 years) are expected to have no movements. It is recommended to consider PTFE-faced seals.
- As a minimum, the sealing and wear rings configuration shall be considered as shown in [11].

6.3.9.6 Scope of supply includes procurement, construction, assembly, FAT. Detailed description of components to be supplied is defined in [11].

6.3.9.7 Hydraulic actuator manufacturing, quality control, storing and shipping shall comply with [1] considering PSL 3.

6.3.9.8 Performance Requirements level PR2 shall be fulfilled.

6.3.9.9 Manufacturing and quality control data book shall be issued including full traceability of materials used. Each hydraulic actuator shall be low stress stamped with serial number linked with tests and material certificates.

6.3.9.10 Hydraulic lines cleanness shall be from 6B through 6F from SAEAS4059 or according to ISO 4406 class 17/15/12 (formerly NAS 1638 Class 6).

6.3.9.11 Design data shall be considered as follows:

6.3.9.11.1 Maximum working pressure: 5000psi.

6.3.9.11.2 Integrity pressure: 7500psi (i.e., 1.5x maximum working pressure).

6.3.9.11.3 Factory test pressure: 5500psi (i.e., 1.1x maximum working pressure).

6.3.9.11.4 Maximum internal operating pressure at PUPS: 5000psi at FPU deck (40m above BSDL-SI level).

Note: See Appendix A for the Hydraulic Pressure Tests steps.

6.3.9.11.5 Minimal Spring force: 2,5 x rod hydraulic force due to pressure produced as a result of hydrostatic column in umbilical, considering 40m and fluid density. SUBCONTRACTOR shall present simulation and/or calculation for PETROBRAS technical approval before construction and demonstrate it during FATs.

6.3.9.11.6 Stroke: 57 mm

6.3.9.11.7 Minimum net rod force at 5000 psi internal pressure during initial stroke: 15kN. Net force is calculated subtracting the three spring forces, as follows, from hydraulic force:

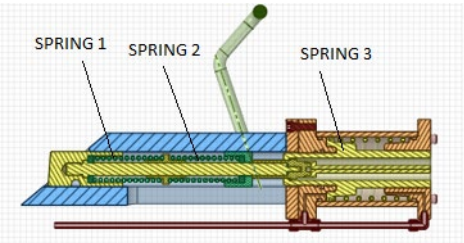

Figure 12

COMPRESSION SPRING

MATERIAL: ICONEL 718 (HARDNESS LESS THAN 35 HRC)				
LEFT HAND				
SQUARED AND GROUND END (*)				

I-TUBE		DN 48"/46"	DN 32"	
ACTIVE COILS	N	12	12	
TOTAL COILS	Nt	14	14	
WIRE DIAMETER	d	7,5	7,5	mm
OUTSIDE DIAMETER	De	57,5	52,5	mm
FREE LENGHT	L	167,6	156,2	mm
SOLID LENGHT	Ls	105,0	105,0	mm
TEST				
FORCE	F1	55,00	42,00	kgf
		539,6	412,0	N
LENGHT	L1	142,0	142,0	mm
FORCE	F2	119,5	130,5	kgf
		1172,6	1280,4	N
LENGHT	L2	112,0	112,0	mm

Figure 93 – Compression spring data

6.3.9.11.8 Minimum temperature: 20°C

6.3.9.11.9 Maximum temperature: 30°C

6.3.9.11.10 Maximum external pressure: 40m water column

6.3.9.11.11 Full compatibility with all of the following water-glycol based hydraulic control fluids: MacDermid HW443, MacDermid HW525P or Castrol Transaqua DW;

6.3.9.11.12 Design operational life: 30 years and 100 cycles.

6.3.9.12 Design Validation test shall be performed by subjecting a complete hydraulic cylinder assembly under sea water during at least 6 months to verify its functionality.

6.3.9.13 FPU CONTRACTOR shall guarantee the physical integration between hydraulic actuator and BSDL-SI itself. If these scopes are divided between two SUBCONTRACTORS, FPU CONTRACTOR shall coordinate the interface and integration.

6.4 Hydraulic circuit

6.4.1 The diagram of Hydraulic Circuit shall observe the drawing in ref. [13].

6.4.2 Considering the aggressive environment in splash zone, FPU CONTRACTOR shall provide umbilical lines in order to route the hydraulic circuits between lower and upper riser balcony (as represented in Figure 2).

6.4.3 Umbilical lines, detailed in section 6.3.3, shall aggregate up to 8 (eight) hydraulic circuits each one.

6.4.4 FPU Contractor shall consider the proximity between each BSDL-SIs and the umbilical line for routing purposes.

6.4.5 The Hydraulic Actuator System design shall guarantee pressurized supply of water-glycol based hydraulic control fluid, with cleanliness class according to Norm ISO 4406 CLASS 17/15/12. (Equivalent to class 6 from the old Norm NAS1638 Cleanliness Requirements used in Hydraulic Systems). The hydraulic circuit shall be supplied filled with the same hydraulic fluid defined for PUPS and Subsea HPU during FPSO detailing phase (MacDermid HW443; MacDermid HW525P or Castrol Transaque DW).

6.4.6 All hydraulic lines shall have individual identification. Identification may be numbers, letters and/or insulation color. Identification shall withstand handling and installation of hydraulic lines and umbilical system.

6.4.7 The hydraulic circuit between the BSDL-SI actuators and PUPS for subsea can be divided in four segments, detailed as follows:

- Connection between BSDL-SI and Hullside Umbilical;
- Hullside Umbilical;
- Topside hydraulic tubings;
- TUTU Plate, Local Panels and PUPS interface.

6.4.8 Connection between BSDL-SI and Hullside Umbilical

6.4.8.1 The hydraulic circuit between BSDL-SI and umbilical lower termination (plate) shall be made by steel tubing, observing item 6.1.4.

6.4.8.2 The supports and fasteners shall observe requirement at Ref [16].

6.4.8.3 The steel tubing shall have internal diameter of 1/2 inch.

6.4.8.4 The steel tubing shall be properly fixed and routed bellow lower riser balcony. The routing shall prioritize protected areas to avoid mechanical damage of tubing.

6.4.8.5 The distance between BSDL-SI and umbilical lower termination shall not exceed 20 meters. For distances higher than this, FPU CONTRACTOR shall provide another umbilical to route the hydraulic circuit.

6.4.8.6 FPU CONTRACTOR shall provide properly hydraulic connection between steel tubing and umbilical lower termination (plate), considering the environment and the life cycle.

6.4.9 Hullside Umbilical

6.4.9.1 FPU CONTRACTOR shall provide umbilicals in order to make the connection of hydraulic circuits from lower riser balcony to upper riser balcony.

6.4.9.2 FPU CONTRACTOR shall provide umbilical type with minimum requirement:

- Hydraulic control: 8 x 3/8” thermoplastic hoses (DWP = 7500 psi);
- Low voltage electrical cable: 8 QUADS x 2.5 mm² 0.6/1.0(1.2) kV.

6.4.9.3 The thermoplastic hose shall be designed and qualified following the requirements of Ref. [19].

6.4.9.4 The low voltage electrical cable shall be designed and qualified following the requirements of Ref. [20].

6.4.9.5 All thermoplastic hoses shall be supplied from umbilical factory filled with the same hydraulic fluid of PUPS (MacDermid HW443; MacDermid HW525P or Castrol Transaque DW) and plugged with hydraulic hose caps at both ends.

6.4.9.6 All thermoplastic hoses shall be flushed in order to guarantee supply of water-glycol based hydraulic control fluid with cleanliness class according to Norm ISO 4406 CLASS 17/15/12. (Equivalent to class 6 from the old Norm NAS1638 Cleanliness Requirements used in Hydraulic Systems) and ensure no air bubbles inside.

6.4.9.7 The umbilical lines shall be supplied with all accessories to protect both ends (for example: armor pots, bend stiffener etc) for umbilical line handling and fixation at riser balconies.

6.4.9.8 All hydraulic pigtails not used shall be filled with the hydraulic fluid and closed with caps at both ends.

6.4.9.9 Both ends shall be supplied with traction heads designed to handle umbilical lines installation at dry dock.

6.4.9.10 FPU CONTRACTOR shall provide bipartite hangoff structures to fix both ends of the umbilical lines at the upper & lower riser balconies supports.

6.4.9.11 FPU CONTRACTOR shall foresee all handling/installation at drydock accessories like slings, shackles etc.

6.4.9.12 The umbilical lines shall be terminated in plates at both sides. Each plate shall have connectors (Medium pressure standard tube fitting as ref [21]) to connect each pigtails thermoplastic hoses in a steel tubing. Both plates shall be designed for all pigtails thermoplastic hoses installation with minimum bending radius of 200mm.

6.4.9.13 The umbilical body shall be fixed along the hull side of FPSO by welded fixing/clamp supports at double plates. The fixing/clamp supports quantity, mechanical details and welded locations shall be submitted to PETROBRAS approval. A fixation concept is presented in Figure 14.

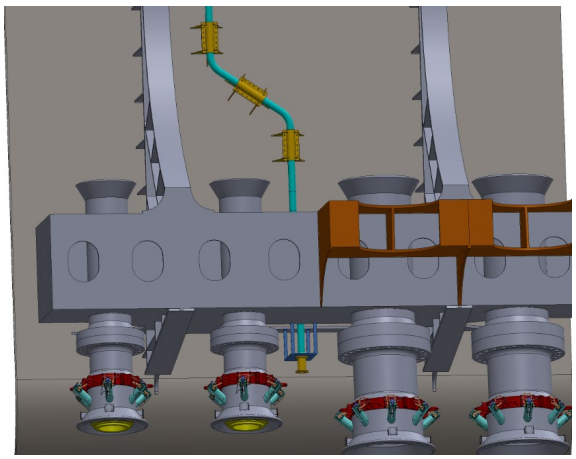

Figure 14 – Umbilical concept fixation

6.4.9.14 Umbilical and its supports design shall consider, at least, hydrodynamic loads (wave and current) acting on umbilical length over hullside.

6.4.9.15 A minimum number of 10 umbilical clamp supports over hullside shall be considered. The umbilical supports may be reduced if analysis of required on previous item along with stress analysis prove adequate results.

6.4.9.16 Umbilical supports shall be calculated to withstand the most stringent loads combination due to pipe, wave, currents, and hull movement. Hydrodynamic loads (wave and current) acting over the support shall be included in the stress analysis.

6.4.9.17 The installation positions for umbilical lines for BSDL-SI hydraulic actuation system shall not use any riser slot in balcony reserved to subsea riser arrangement. See example in Figure 15.

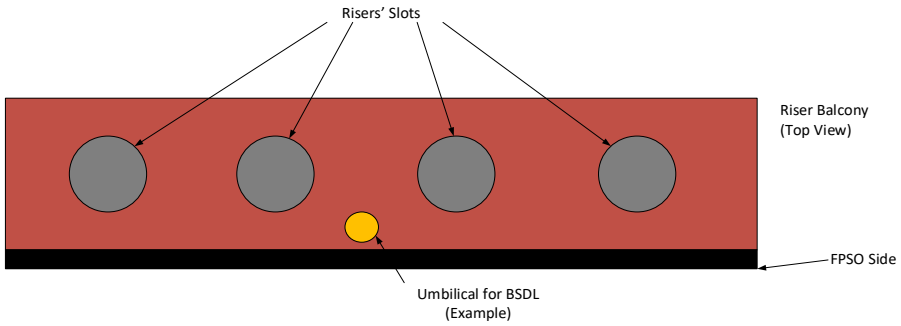

Figure 15 – Umbilical position

6.4.9.18 FPU CONTRACTOR shall guarantee that any thermoplastic hose will not be exposed to solar UV light to avoid upper balcony pigtails degradation.

6.4.9.19 The upper umbilical termination shall be fixed in upper riser balcony area with free access to terminal plate to allow future maintenance.

6.4.9.20 The lower umbilical termination shall be fixed in lower riser balcony area, with terminal plate sided to below area.

6.4.9.21 At the Lower Umbilical Termination, it shall be terminated the hydraulic pigtails with a medium pressure standard (ref. [21]) for interface with the lower balcony tubings.

6.4.9.22 At the Lower Umbilical Termination, it shall be terminated with electrical wet-mate connectors with the following requirements:

- Be diver-mateable;
- Have double-barrier protection
- Be housing made with stainless steel material (AISI 316L);
- Be qualified according to API-17F (shall present evidences);
- Have a design life of at least 25 years.

6.4.9.23 FPU CONTRACTOR shall evaluate in their detail design to have at least one hydraulic and one electrical spare connector at lower umbilical termination structure for each Hullside umbilical line.

6.5 Monitoring system

6.5.1 FPU CONTRACTOR shall provide a Monitoring System to show, verify the position of each actuator and cathodic protection of BSDL support.

6.5.2 Each quad cable of Hullside umbilical shall be dedicated to one BSDL. Four conductors' ways shall be designed in a CANBUS topology to gather all the BSDL hydraulic actuators positions and BSDL structure cathodic protection measurement.

6.5.3 All conductors related to each umbilical/local panel shall be terminated in an appropriated junction box with SAK connectors.

6.5.4 The Figure 16 presents a block diagram of control and monitoring system related to a single BSDL.

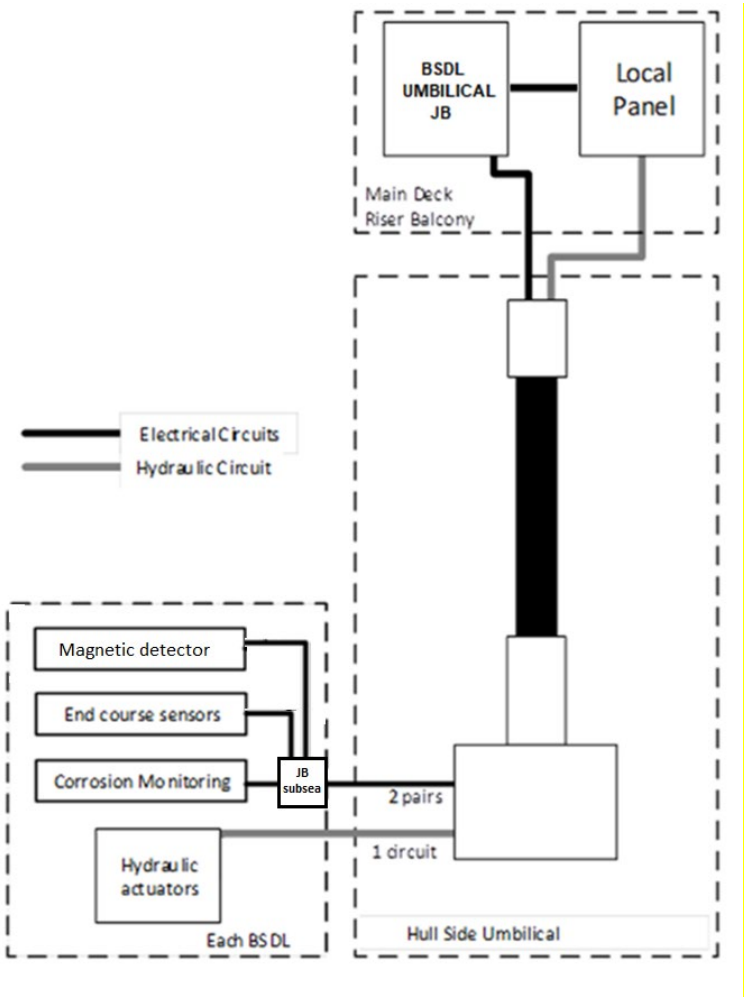

Figure 16 – BSDL Control and Monitoring system for a single support

6.5.5 To interface with the subsea cabling connected to the lower termination of Hullside Umbilical, the monitoring components shall be terminated with electrical wet-mate connectors with the following requirements:

- Be diver-mateable
- Have double-barrier protection
- Be housing made with stainless steel material (AISI 316L);
- Be qualified according to API-17F (shall present evidences);
- Have a design life of at least 25 years.

6.5.6 End course detector

6.5.6.1 FPU CONTRACTOR shall provide end course detector to monitor if after the hydraulic actuation system had all pistons worked.

6.5.6.2 These end course detectors work principle shall be a subsea inductive ultrasonic proximity sensor.

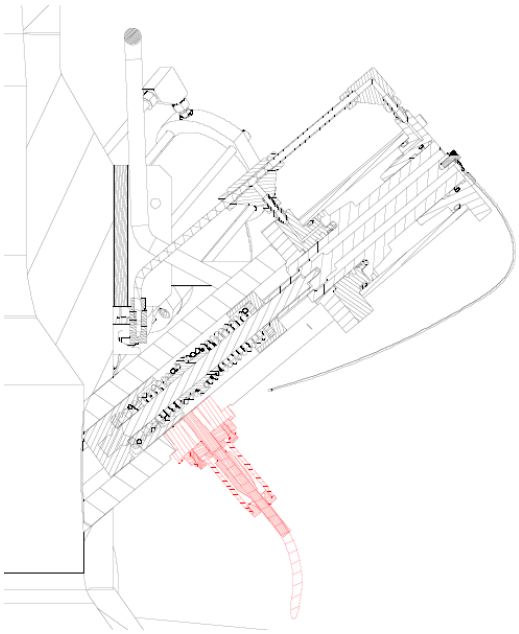

Figure 17 – End Course detector scheme at BSDL latch structure

6.5.6.3 All sensors shall be signal conditioned to communicate with the topside in a bus protocol by two electric pairs, available for this purpose.

6.5.6.4 FPU CONTRACTOR shall provide all electronics inside Monitoring RISER JBs to detect end course data and show it displayed at HMI screen inside the corresponding Local Panel and RISER Interface Cabinet.

6.5.6.5 The location of the end course sensors shall be designed by FPU CONTRACTOR and submitted to PETROBRAS approval. Its location shall not interfere the ROV's maneuverability.

6.5.7 Corrosion Monitoring

6.5.7.1 FPU CONTRACTOR shall provide an electrochemical potential monitoring solution of the support structure to verify an indication of corrosion process.

6.5.7.2 The electrochemical potential monitoring shall comprise one conductor connected to the support structure and other conductor connected to a Zinc reference electrode. Both connection points shall be close but not electrically connected. Both connection points shall be designed for easy access, maintenance and visualization by divers. The Zinc reference electrode shall be dimensioned for 25 years design life.

6.5.7.3 The corrosion monitoring shall be connected to a topside by two electrical conductors from one umbilical, available for this purpose. FPU CONTRACTOR shall provide terminal points in local panel in order to connect a multimeter to verify the electrochemical potential. FPU CONTRACTOR shall also provide all electronics inside local panel to measure the voltage differential between corrosion monitoring conductors' pairs and display at simple HMI screen.

6.5.7.4 The location of the corrosion sensors shall be designed by FPU CONTRACTOR and submitted to PETROBRAS approval. Its location shall not interfere the ROV's maneuverability.

6.5.8 Magnetic Detector Monitoring

6.5.8.1 FPU CONTRACTOR shall provide a magnetic detector to check if the bend stiffener adaptor cap, from the flexible riser, has been attached in the bellmouth structure.

6.5.8.2 These magnetic detectors work principle shall be a subsea sensor installed in the bellmouth structure body.

6.5.8.3 The sensor shall be signal conditioned to communicate with the topside in a bus protocol by two electric pairs, available for this purpose.

6.5.8.4 FPU CONTRACTOR shall provide all electronics inside Monitoring RISER JBs to detect the magnetic field signature change due to attachment of bend stiffener adaptor cap. It shall be displayed at HMI screen inside the corresponding Local Panel and RISER Interface Cabinet.

6.5.8.5 The location of the magnetic sensor shall be designed by FPU CONTRACTOR and submitted to PETROBRAS approval. Its location shall not interfere the ROV's maneuverability.

6.6 Technical requirements for TOPSIDE

6.6.1 Upper balcony infrastructure

6.6.1.1 FPU CONTRACTOR shall provide 1 (one) TUTU plate and 1 (one) umbilical JB for each hull side umbilical located in the upper balcony.

6.6.1.1.1 TUTU plate can be dismissed (agreed with Petrobras) if the upper umbilical termination is close to Local Panel (Maximum of 4 meters). In this case, Local Panel will have the function of TUTU plate.

6.6.1.2 TUTU plate shall have 1 (one) manual operated valve and 1 (one) pressure indicator for each hydraulic control line. The TUTU plate shall be connected in the topside with the corresponding Local panel.

6.6.1.3 FPU CONTRACTOR shall provide a seal tag for each hydraulic circuit at TUTU plate to certificate the correct assembly (avoid switching hydraulic lines during Construction and Assembly or operational phase). Each change during FPU Construction and Assembly shall be registered.

6.6.1.4 Umbilical JB shall aggregate all optical fibers (at splice trays) and electrical conductors (at SAK terminals) from umbilical pigtails. The Umbilical JB shall be connected in the topside with the corresponding Monitoring Riser JB.

6.6.2 Monitoring Riser JBs

6.6.2.1 FPU CONTRACTOR shall provide one junction box (named Monitoring Riser JB) for each hullside umbilical, and it shall be located in the main deck or a level without green water issue.

6.6.2.2 Monitoring Riser JB comprises the following main functions:

- Collect/process BSDL-SI Monitoring System electrical signals.
- Collect Local Panels Monitoring System electrical signals.
- Transmit data to SCADA Master Station (at RISER Interface Cabinet).

6.6.2.3 This JB shall be designed with a RTU automation solution. This RTU shall collect/process all analog signals and transmit using a TCP-IP standard protocol to the SCADA Master Station (at RISER Interface Cabinet).

6.6.2.4 RTU shall process/digitalize the following main variables:

- BSDL-SI locking module end strokes signals.
- BSDL-SI structure corrosion monitoring indication.
- BSDL-SI magnetic detector signals.
- Local Panels pressure transmitters.

6.6.2.5 Monitoring Riser JB shall be installed in places with easy access, in maximum height of 2 meters and where is dismiss the use of safety harness for high work.

6.6.2.6 Monitoring Riser JB shall be sealed against dust and powerful water jets (protection degree IP-66).

6.6.2.7 Monitoring Riser JB and cable glands specification/installation shall be in accordance with its corresponding area classification.

6.6.3 Local Panels

6.6.3.1 CONTRACTOR shall provide one Local Panel for each Hullside umbilical.

6.6.3.2 Local Panel comprises the following main functions:

- Terminate the hydraulic connections of each Hullside umbilical.

- Provide hydraulic interface (Hydraulic Connector and control valve) to PUPS.
- House HMI of monitoring system interface.

6.6.3.3 For each hydraulic circuit, FPU CONTRACTOR shall provide inside local panel two manual valves to interface with PUPS hydraulic supply header and return line.

6.6.3.4 The hydraulic circuit between Umbilical Upper Termination and Local Panel shall be made by steel tubing and follow requirement of Ref [15].

6.6.3.5 The hydraulic supply for Riser support control system shall be provided by PUPS system, that will be placed close and connected to all local panels for the pull-in/pull-out operations.

6.6.3.6 The Local panel shall be installed at main deck. The place shall consider the access and supply for PUPS hydraulic header and return line and for any maintenance of the internal components during FPU life.

6.6.3.7 The FPU CONTRACTOR shall provide hydraulic jumpers to connect PUPS unit to the hydraulic header and return line.

6.6.3.8 The hydraulic circuits routed in the same umbilical can share the same local panel, with individual circuits for each BSDL-SI. FPU CONTRACTOR shall guarantee the unmistakable correspondence solution between umbilical termination and Local panel outlets.

6.6.3.9 The Local Panel arrangement shall organize control valves the hydraulic outlets with clear identification, avoiding connection misunderstanding. Figure 18 shows an arrangement concept example.

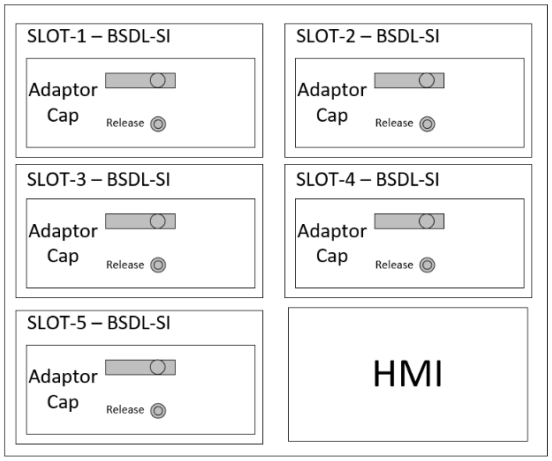

Figure 18 – Local Panel Arrangement example

6.6.3.10 The design of Local Panel shall include pressure transmitters for hydraulic supply and each hydraulic actuation lines to be data logged / showed in supervisory system (see item 6.5.4).

6.6.3.11 Local panels shall be supplied inside a closed cabinet to protect the internal items. It shall have front and rear access for any internal component maintenance during operational life.

6.6.3.12 Local panel shall have an HMI as described in section 6.5.4.4.

6.6.3.13 Each Local Panel shall have an internal solenoid valve aligned to the hydraulic supply header from PUPS Unit. This activation shall use electrical switches (ON / OFF) able to be locked in order to avoid activation by mistake. The control logic of solenoid actuation shall be controlled by the SCADA System inside RISER Interface Cabinet, allowing only one Local panel to be energized at a time.

6.6.3.14 The design of Local Panel shall include a signal indicator of solenoid activation.

6.6.3.15 The design of Local Panel shall include pressure indicators to verify pressure in hydraulic supply header and at all hydraulic outlets to BSDL.

6.6.3.16 Directional valves for BSDL actuation shall be manual operated.

6.6.3.17 FPU CONTRACTOR shall provide means to adjust BSDL hydraulic pressure actuation (for example, needle valves), if required by Pull-in Operational Team.

6.6.3.18 FPU CONTRACTOR shall supply a physical hydraulic jumper that guarantees uncoupling from BSDL Hydraulic Circuit, avoiding actuation of unwanted support by mistake.

6.6.4 Portable Umbilical Pressurization System (PUPS)

6.6.4.1 PUPS is a topside portable device to allow the FPU CONTRACTOR to safety pressurize control line of a hull side umbilical.

6.6.4.2 FPU CONTRACTOR shall provide one PUPS unit according to ref. [22], and it shall be located in the same deck level from Local panels.

6.6.4.3 PUPS operation location shall be with easy access for operators and with all air supply facilities required to operate.

6.6.4.4 PUPS shall be designed in accordance with its corresponding area classification where it will be operated.

6.6.4.5 FPU CONTRACTOR shall provide a main hydraulic supply header and return line for all local panels connected to the PUPS unit.

6.6.5 RISER Interface Cabinet

6.6.5.1 Supervisory System

6.6.5.1.1 A Supervisory System shall communicate with the RTUs and act as an interface to human operators and external systems of the monitoring system.

6.6.5.1.2 FPU CONTRACTOR shall provide a supervisory system to:

- Allow operator in local panel check the status of each sensor installed in BSDL-SI.
- Manage the entire system and to data log at RISER Interface Cabinet.

6.6.5.1.3 Supervisory system shall observe the topology of Figure 19.

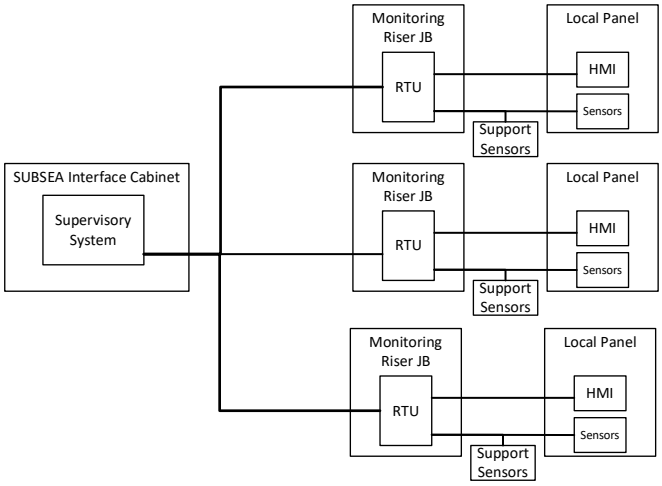

Figure 19 – Supervisory System topology

6.6.5.1.4 FPU CONTRACTOR shall provide an HMI integrated to Local Panel to check all supports related to respective panel. The supervisory screen shall show graphically all supports and the data sensors related to each one.

6.6.5.1.5 Riser Support Supervisory System shall be connected to FPU automation network and shall have a server installed in RISER Interface cabinet to allow manage all system and register data log of all sensors.

6.6.5.1.6 RSMS Processing equipment shall be installed in Cabinet named RISER Interface Cabinet that can be shared with SESDV Monitoring System (if in FPU scope).

6.6.5.1.7 Riser Support Supervisory System shall not be part of the FPU cause and effect matrix (i.e. shall not be used to trigger emergency shutdowns).

6.6.5.1.8 In the case of power loss, the main processing equipment shall be able to restart automatically without the need for operator intervention.

6.6.5.1.9 CONTRACTOR shall inform, during the commissioning, all administrator passwords needed to operate and manage all equipment.

6.6.6 Supervisory and Data Server

6.6.6.1.1 The use of a well-established integrated supervisory solution able to provide all required functionalities is strongly advised.

6.6.6.1.2 Dedicated supervisory screens shall report the value of every monitored variable as they are acquired, along with the status of communication channels and each monitoring unit, including the Local Panels, RTU and Cabinet housekeeping data.

6.6.6.1.3 CONTRACTOR shall design supervisory to receive data from all risers supports position in FPU.

6.6.6.1.4 The FPU position provided by on-board GPS and AHRS (Attitude and Heading Reference System) shall be retrieved by the supervisory system from the POS system (*Positioning and Navigation Systems for Floating Production Unit (FPU)*) as it is broadcast by means of three (3) TIA/EIA-485 connections and/or TIA/EIA-422 connections:

- **GPS NMEA 0183 link:** GSA, GSV, GGA and ZDA messages.
- **AHRS TSS1 link:** FPU attitude in TSS1 protocol.
- **AHRS NMEA 0183 link:** HDT message.
- **CUSTOMIZED INPUT:** ASCII message.

6.6.6.1.5 Supervisory system shall be able to receive a customized input of FPU Positioning System. This input will receive ASCII data by serial RS-485/422 and can trigger some settable alarms in supervisory.

6.6.6.1.6 The GPS UTC time provided by the FPU Positioning System shall be used as reference for the timestamps of all acquired data.

6.6.6.1.7 Data shall be continuously retrieved from the instrumentation installed on risers. The sampling period shall be 1 second and a timeout event shall be understood as the unsuccessful retrieval of 3 consecutive samples.

6.6.6.1.8 A database system for storage of generated data points shall be included in a OPC server.

6.6.6.1.9 The database shall operate on a circular buffer pattern, whereby older records shall gradually be overwritten by newer samples once the database reaches its capacity. Storage space shall be provided as a dedicated RAID 1 array, sized for at least 24 months of logging at the highest possible data sampling rate.

6.6.6.1.10 Data shall be provided to external systems and users via standardized OPC UA (Unified Architecture) interfaces as follows:

- OPC UA Data Access (DA) for real-time data.
- OPC UA Historical Access (HA) for historical data.

6.6.6.1.11 Real-time data shall be made available for external access through a standardized OPC UA Data Access interface.

6.6.6.1.12 Historical data stored on the local database shall be accessible through an OPC UA Historical Access interface.

6.6.6.1.13 Alarms shall be made available for external clients through an OPC UA Alarms & Conditions interface.

6.6.6.1.14 The provided interfaces shall be ready for use by external systems from the PETROBRAS corporate network which are allowed through FPU network firewalls.

7 TESTS, INSTALLATION AND COMMISSIONING REQUIREMENTS

7.1 The requirements presented in this section shall be met regarding commissioning activities. Planning of installation and commissioning activities shall be developed and submitted for PETROBRAS approval.

7.2 Commissioning is understood, in this context, as the process of placing the system (or parts thereof related to a particular monitored structure) in a fully functional state, without any pending issues.

7.3 All equipment (BSDLs, umbilical lines and local panels) shall be tested onshore before deployment at FPSO.

7.4 FPU CONTRACTOR shall perform Factory Acceptance Test (FAT) of the Hydraulic Actuator System with bell mouth FAT itself. For this test, shall be used a BSDL-SI dummy cap to simulate pull-in and pull-out operations. See bellow an example of setup for this test. A detailing of required FAT for BSDL-SI is specified in Ref [15].

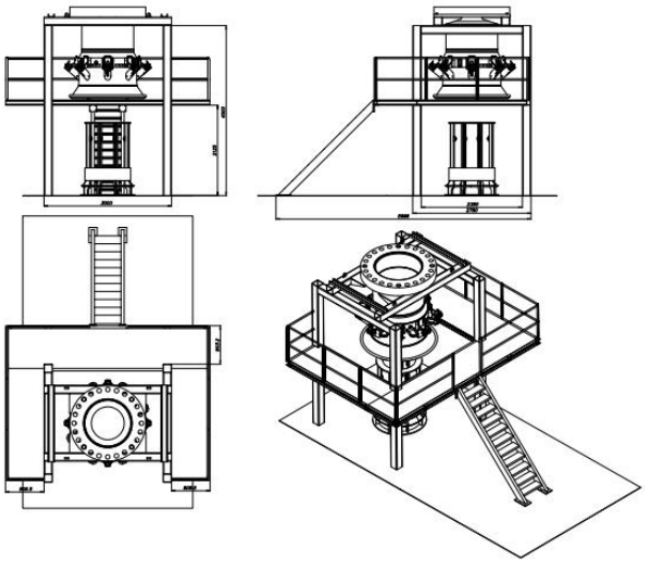

Figure 20 – Example of FAT set-up

7.5 After installation at FPSO, during the commissioning of hydraulic actuator system, the FPU CONTRACTOR shall perform integrated tests to certificated that:

- All system is correctly installed and operational (following design).
- Each local panel is activating the correct BSDL.
- All hydraulic actuators are operational (visual check)
- All end courses (section 6.4.4) are operational (electrical check)
- All corrosion monitoring (section 6.4.5) is operational (electrical check)
- All magnetic sensors (section 6.5.7) are operational (electrical check).
- There is no leak and no bubbles at hydraulic circuit.

7.6 The tests from item 8.1.5 shall be done in dry dock, to perform possible corrections.

8 DOCUMENTATION REQUIREMENTS

8.1 Documentation shall be issued in compliance with agreed standards and formal processes.

8.2 The documentation shall include at least the following:

- Block diagram;
- Piping and Instrumentation Diagram (P&ID);
- General arrangement of BSDL-SI system with hydraulic actuator and monitoring system;
- General arrangement with routing of hydraulic circuit;
- General arrangement with routing of monitoring system;
- General arrangement of local panels;
- Factory Acceptance Test Procedure/Reports;
- Factory Integration Test Procedure/Reports;
- Acceptance and Performance test (TAP) Procedure/Reports;
- Operational procedure for BSDL-SI in pull-in and pull-out operations.

8.3 During de executive design shall be issued to PETROBRAS approval a Technical Proposal of the Hydraulic Actuator System for BSDL, including the following information:

- Datasheet of each component of the system;
- Detail of each material used in the system;
- Evidence of SUBCONTRACTOR experience (items 11.1.1 and 11.1.2).

9 SCOPE OF SUPPLY

9.1 Hydraulic Actuator and Monitoring System for BSDL

9.1.1 FPU CONTRACTOR shall provide all BSDLs to flexible risers and subsea umbilical slots with a Hydraulic Actuator system and monitoring system for each.

9.2 Lower Riser Balcony infrastructure

9.2.1 FPU CONTRACTOR shall provide all hydraulic tubings with all connections to BSDL-SI hydraulic actuators and lower umbilical termination plates and fixing supports.

9.2.2 FPU CONTRACTOR shall provide all subsea electrical cabling with all connections to BSDL-SI monitoring system and lower umbilical termination plates and fixing supports.

9.2.3 All subsea cabling shall be supplied with a protection system designed and developed to protect the electrical conductors against any abrasions and dynamical effects.

9.2.4 FPU CONTRACTOR shall supply all lower umbilical termination plates and umbilical line mechanical fixations at lower balcony structure.

9.3 Hull side Umbilical

9.3.1 FPU CONTRACTOR shall supply all hull side umbilical lines required for the hydraulic actuation and monitoring system for all BSDL.

9.3.2 FPU CONTRACTOR shall supply all the hull side fixation supports welded required to protect the umbilical body.

9.4 Topside Structure

9.4.1 FPU CONTRACTOR shall supply all upper umbilical termination plates and umbilical line mechanical fixations at upper balcony structure.

9.4.2 FPU CONTRACTOR shall provide all hydraulic tubing's with all connections to upper umbilical termination plates and local panel hydraulic circuits with all fixing supports.

9.4.3 FPU CONTRACTOR shall provide all electrical cabling with all connections to upper umbilical termination plates, TUTU Plates, topside JBs, local panels with all fixing supports and cable trays.

9.4.4 FPU CONTRACTOR shall provide a local panel for each hull side umbilical to manual act each corresponding BSDL.

9.4.5 FPU CONTRACTOR shall supply PUPS with topside air supply able to be used as a hydraulic supply of BSDL-SI actuation system.

9.4.6 FPU CONTRACTOR shall supply RISER supervisory system at RISER Interface Cabinet.

10 SCOPE OF WORK

10.1 Executive Design

10.1.1 FPU CONTRACTOR shall design and detail a Hydraulic Actuator system for BSDLs locking/unlocking mechanism.

10.1.2 FPU CONTRACTOR shall design and detail a local panel system for BSDLs locking/unlocking mechanism.

10.1.3 FPU CONTRACTOR shall design and detail umbilical line system including accessories for BSDLs locking/unlocking mechanism.

10.1.4 FPU CONTRACTOR shall design and detail the complete hydraulic system for BSDLs locking/unlocking mechanism.

10.2 Factory acceptance tests

10.2.1 FPU CONTRACTOR shall perform factory tests to confirm acceptance for all BSDLs with Hydraulic Actuator and Monitoring system.

10.2.2 FPU CONTRACTOR shall perform factory tests to confirm acceptance for all umbilical lines and accessories.

10.2.3 FPU CONTRACTOR shall perform factory tests to confirm acceptance for all local panels and JBs.

10.3 Factory integration tests

10.3.1 FPU CONTRACTOR shall perform factory integration tests to confirm acceptance for all sets that are going to be installed at dry dock of BSDLs with Hydraulic Actuator and Monitoring system and corresponding local panel. In order to perform this test, is not mandatory using the umbilical lines.

10.4 Installation/Commissioning at dry dock

10.4.1 FPU CONTRACTOR shall install at dry dock all BSDLs with Hydraulic Actuator and Monitoring system.

10.4.2 FPU CONTRACTOR shall install at dry dock all umbilical lines with installation accessories.

10.4.3 FPU CONTRACTOR shall install at dry dock all hydraulic tubing's connecting all BSDLs with Hydraulic Actuator system to umbilical lines.

10.4.4 FPU CONTRACTOR shall install at dry dock all electrical cabling connecting all BSDLs with Monitoring system to umbilical lines.

10.4.5 FPU CONTRACTOR shall install at dry dock all local panels.

10.4.6 FPU CONTRACTOR shall install at dry dock all hydraulic tubing's connecting Local Panels to umbilical lines.

10.4.7 FPU CONTRACTOR shall install at dry dock all electrical cabling connecting Local Panels and JBs.

10.4.8 FPU CONTRACTOR shall fill and flush all hydraulic circuit with PUPS water-glycol based hydraulic control fluid with cleanliness class according to Norm ISO 4406 CLASS 17/15/12. (Equivalent to class 6 from the old Norm NAS1638 Cleanliness Requirements used in Hydraulic Systems) and ensure no air bubbles inside. PUPS shall include inside components to guarantee control fluid cleanliness (i.e. hydraulic filters).

10.4.9 FPU CONTRACTOR shall perform commissioning of the complete system at dry dock.

10.4.10 Commissioning of umbilical lines for risers' systems shall be witnessed by PETROBRAS representative.

10.4.11 Commissioning of umbilical lines for risers' systems report shall be issued and shall contain at least:

- The following information for each BSDL-SI: Pictures of each BSDL-SI tag number and umbilical hydraulic hoses identification on lower balcony and connected upper balcony connected hydraulic functions.
- The torque evidence of each JIC connection using a torque tool.

10.4.12 Commissioning report of umbilical lines for riser systems shall provide enough information to assure that no failure in connection of BSDL on lower balcony and its corresponding Local Panel actuation line on topside has occurred.

Note: PAY SPECIAL ATTENTION IN ORDER TO PREVENT CONNECTING WRONG TO THE CORRESPONDING LOCAL PANEL AND BSDL UNIT SINCE IT RESULTS IN FUTURE ACCIDENTS OFFSHORE LIKE BEND STIFFENER DROP.

10.4.13 Commissioning tests for each control function: Each BSDL-SI shall be tested, at least, 3 times for each hydraulic function and 3 times for manual actuation.

10.4.14 If during dry dock period, the installation items of topside structure (items 11.4.4 to 11.4.7) cannot be performed, FPU CONTRACTOR shall present to PETROBRAS an alternative plan to do the installation/commissioning by phases for formal approval.

10.4.15 During the installation FPU Contractor shall define TAGs and procedures to guarantee the correct correspondence between hydraulic circuit (at Local Panel), Umbilical hose and BSDL.

11 SUBCONTRACTOR REQUIREMENTS

11.1 To design and supply the umbilical lines and accessories for the project of the Hydraulic Actuator System for BSDL, FPU CONTRACTOR shall chose umbilical manufacturer with experience (track record) with PETROBRAS.

11.2 To design, supply, test and commission the Hydraulic Actuator System for BSDL-SI (subsea and topside scopes), FPU CONTRACTOR shall chose a BSDL-SI INTEGRATOR (SUBCONTRACTOR) with experience (track record) in:

- Subsea systems;
- Hydraulic systems;
- Instrumentation systems.

11.3 During de executive design FPU CONTRACTOR shall submit to PETROBRAS approval a Technical Proposal of the Hydraulic Actuator System for BSDL, including the evidence of attending items 12.1.1 and 12.1.2.

ANNEX A: HYDRAULIC PRESSURE TESTS

A.1 Integrity Test

The purpose of this test is to verify the assembly of the actuator cylinder-piston. According to API 6A (21st edition), item 14.16.4.1, this test must be performed with the entire actuator assembly mounted on the valve.

FPU CONTRATOR shall follow the steps below:

1) Pressure monitoring equipment and device must be isolated from the pressure source.
2) It must be ensured that the external surfaces of the system parts are dry.
3) Integrity pressure (1.5x operating pressure, i.e. 7500 psi) must be applied to the system. After reaching and stabilizing the pressure, FPU CONTRACTOR must wait for at least 3 minutes.
4) The applied pressure must be reduced to 0 (zero).
5) Integrity pressure (1.5x operating pressure, i.e. 7500 psi) must be applied to the system again. After the pressure is reached and stabilized, FPU CONTRACTOR must wait for at least 3 minutes.

Note: If any part of the system cannot be submitted to this test, it shall be submitted to PETROBRAS approval.

A.2 Actuator Sealing Test

According to item 14.16.4.2 (a) of API 6A, this test basically consists of a sealing test at low (20%) and high pressure (100%). This test can be performed with the entire actuator system coupled.

FPU CONTRATOR shall follow the steps below:

1) Pressure monitoring equipment and device must be isolated from the pressure source.
2) It must be ensured that the external surfaces of the system parts are dry.
3) A pressure of up to 20% operating pressure, i.e., up to 1000 psi, must be applied for at least 3 minutes after reaching and stabilizing the set pressure.
4) A pressure of at least 100% operating pressure must be applied, i.e., 5000 psi or more for at least 3 minutes after reaching and stabilizing the set pressure.

Acceptance Criteria: There must be no leaks in the system at any of the stages.

Note: Pressure, start time and end time of steps 3 and 4 must be recorded.

A.3 Operational Test

As the nominal actuation pressure is 5000 psi, the actuator must be capable to function with a maximum of 4500 psi. Then, in this case, it will have 10%, or 500 psi of clearance to accommodate any increases in friction that may arise over time.

FPU CONTRATOR shall follow the steps below:

1) Pressure monitoring equipment and device must be isolated from the pressure source.
2) It must be ensured that the external surfaces of the system parts are dry.
3) A pressure of up to 90% operating pressure must be applied (up to 4500 psi) and the actuator must reach the fully open position.
4) Step 3 must be repeated at least 3 times.

Note: It is important that the entire actuation, opening and return pressure curve be mapped.