PETROBRAS	**TECHNICAL SPECIFICATION**	Nº: I-ET-3000.00-5139-800-PEK-004	
	CLIENT: **SANTOS BASIN PRE-SALT**		SHEET: **1** *OF* **41**
	PROGRAM: PETROBRAS-OWNED FLOATING PRODUCTION UNITS		
	AREA: UN-BS		
DENGE/SUB/ES /EESUB/ EMES	TITLE: HYDRAULIC POWER UNIT FOR SUBSEA EQUIPMENT WITH MULTIPLEXED ELECTROHYDRAULIC AND DIRECT HYDRAULIC CONTROL SYSTEM (OWNED FLOATING PRODUCTION UNIT)		**PUBLIC**

REVISION INDEX

REV.	DESCRIPTION AND/OR SHEETS REACHED
0	Original. This document is based on ET-3000.00-5139-800-PEK-004 Rev. C.
A	Adjust on HP range of HPU for new DHSVs

PREMISES FOR USING (PETROBRAS USERS)

This document is the generic Technical Specification for the Hydraulic Power Unit (HPU) to be installed in Petrobras-owned Floating Production Units (FPU) to control subsea equipment that have multiplexed electrohydraulic or direct hydraulic control systems. This document shall be complemented with the LIST OF HPU CONSUMERS, in accordance with the model and the criteria presented in Appendix I, which shall be part of the documentation in the contract of the production unit.
It is responsibility of the ENTERPRISE guarantee that the Well Control Rack and the SESDV actuation panel are compatible with the specific technical specification of the HPU.
(*) The definition of ENTERPRISE is on page 3.

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	21/09/2022	26/12/2024							
PROJECT	(Generic ET)	(Generic ET)							
EXECUTION	A. Menezes	A. Rabello							
VERIFICATION	A. Rabello	D. Natal							
APPROVAL	A. Bernardes	R. Miranda							

Contents

1) TERMS AND DEFINITIONS ADOPTED IN THIS DOCUMENT

a) ENTERPRISE: Manager responsible for the Basic Project, and/or construction, and/or conversion of the Petrobras-owned Maritime Production Unit in which the HPU will be installed.

b) CONTRACTOR: CONTRACTED company by PETROBRAS to provide the ENTERPRISE or part of it in which the HPU is included.

Note: in case of HPU acquired directly by PETROBRAS, the term ENTERPRISE shall be replaced by PETROBRAS in this document.

c) SUPPLIER: Company responsible for the design, manufacturing, and testing of the HPU destined to the ENTERPRISE. This term also applies in the technical proposal preparation phase for supplying the HPU to the ENTERPRISE.

d) GENERIC HPU: Hydraulic Power Unit according to specifications within the present document, complemented by the LIST OF HPU CONSUMERS (I-LI-3A36.12-5139-800-PEK-002_rev0) and respective umbilical's length for each subsea equipment connected to the FPU. Appendix VI presents the typical unifilar diagrams for each subsea equipment.

e) LIST OF HPU CONSUMERS: Table designed as the model in Appendix I to inform the number of wells and subsea equipment that will be connected to the FPU (including spares) for HPU sizing purposes.

f) THIRD PARTY: Company or entity subcontracted by the SUPPLIER.

g) CONTROL SYSTEM: Set represented by integrated software and hardware to control the subsea equipment connected to the FPU.

2) OBJECTIVE

2.1) This document specifies the minimum requirements for a GENERIC Hydraulic Power Unit (see 2.2 below) for a Floating Production Unity, whose gathering system uses subsea equipment that are standardized by PETROBRAS for the E&P Pre-Salt and equipped with a multiplexed electrohydraulic control system. The HPU shall also be used for up to two (2) wells equipped with Wet Christmas Tree (WCT) for direct hydraulic control from the FPU.

2.2) This ET shall be complemented by the LIST OF HPU CONSUMERS (I-LI-3A36.12-5139-800-PEK-002_rev0) provided by PETROBRAS and informing the quantity of each type of subsea equipment and its control mode that will be interconnected to the FPU. The list shall be in accordance with the model and criteria presented in Appendix I.

2.3) The CONTRACTOR shall also inform the supplier about the respective maximum lengths for the control umbilicals in accordance with the models presented in Appendix VI.

IMPORTANT: the lengths listed in the tables presented in Appendix VI can be used merely as a reference and cannot be used to determine the dimensions of the HPU, unless otherwise approved by PETROBRAS.

2.4) The HPU shall be able to supply hydraulic fluid to up to two (2) wells equipped with direct hydraulic WCT (Wet Christmas Tree) and four (4) SESDV (Subsea Emergency Shutdown Valves) in order to block

the gas pipelines at the base of their respective risers connected to the FPU. The SESDV will feature hydraulic direct control from the FPU. The CONTRACTOR will inform the amount of SESDV.

2.5) It is recommended that the CONTRACTOR chooses a SUPPLIER that can prove previous experience manufacturing HPU for electrohydraulic multiplexed control system of subsea production equipment (such as WCT, manifold or template-manifold) or with similar requirements for operation and maintenance of the control hydraulic fluid's cleanliness class. Appendix VIII contains criteria suggestions that the CONTRACTOR should evaluate.

3) REFERENCE DOCUMENTS, CODES AND STANDARDS

a) API STANDARD 17F: Standard for Subsea Production Control Systems, 4th Edition, 2017.

b) API RP 14C: Recommended practice for analysis, design, installation, and testing of safety systems for offshore production facilities.

c) API RP 14E: Recommended practice for design and installation of offshore production platform piping systems.

d) API RP 14F: Design, installation, and maintenance of electrical systems for floating offshore petroleum facilities.

e) API RP 500B: Recommended practice for classification of locations for electrical installations at production facilities on marine mobile platforms.

f) API STD 520: Sizing, Selection and Installation of Pressure-relieving Devices.

g) API STD 526: Flanged Steel Pressure Relief Valves.

h) ANSI B16.5: Flanged fittings, pipe flanges and steel piping.

i) IEC 60079: Explosive Atmospheres.

j) IEC 60529: Degrees of Protection Provided by Enclosures (IP Code).

k) I-ET-3010.00-1200-800-P4X-015: Requirements for Tubing and Fitting (Aligned to IOGP-JIP33 S-716).

l) I-ET-3010.00-1200-800-P4X-002: Automation, Control and Instrumentation on Package Units.

m) ISO 9001 and 9002: Requirements for the quality management systems.

n) ISO 2941: Hydraulic Fluid Power - Filter Elements - Verification of Collapse/Burst Pressure Rating.

o) ISO 2942: Hydraulic Fluid Power - Filter Elements - Verification of Fabrication Integrity and Determination of The First Bubble Point.

p) ISO 2943: Hydraulic Fluid Power - Filter Elements - Verification of Material Compatibility with Fluids.

q) ISO 3968: Hydraulic Fluid Power - Filters - Evaluation of Differential Pressure Versus Flow.

r) ISO 13628-6 Petroleum and natural gas industries – Design and operation of subsea production systems – Part 6: Subsea production control systems, 2nd Edition, 2006 (or more recent).

s) ISO/TR 10949: Hydraulic Fluid Power – Component Cleanliness - Guidelines for Achieving and Controlling Cleanliness of Components from Manufacture to Installation.

t) ISO 11170: Hydraulic Fluid Power - Sequence of Tests for Verifying Performance Characteristics.

u) ISO 16889: Hydraulic Fluid Power - Filter - Multi-Pass Method for Evaluating Filtration Performance of a Filter Element.

v) ISO 4406: Hydraulic Fluid Power - Fluids - Method for Coding the Level of Contamination by Solid Particles.

w) ISO 18413: Hydraulic Fluid Power.

x) NR-13: Caldeiras, Vasos de Pressão, Tubulações e Tanques Metálicos de Armazenamento.

y) I-LI-3A36.12-5139-800-PEK-002_rev0 - List of consumers for subsea HPU of the Buzios 12 Project

4) ACRONYMS

SMP	Subsea Multiphase Pump
CCR	Central System of Operation and Supervision of the FPSO
CI	Intelligent Completion (general reference)
CI-HD	Hydraulic Smart Completion (typical to wells with 2 zones and WCT in the Pre-Salt Standard)
CI-MUX	Multiplexed Intelligent Completion with 3 zones
CIS	Control System and Interlocking of the FPSO
CSS	Control and Safety Systema of the FPU
DCV	Directional Control Valve (also referenced as 3-way Solenoid Valve)
EH	Electrohydraulic
ESD	Emergency Shut-Down
ET	Technical Specification (*Especificação Técnica*)
FPSO	Floating Production Storage and Offloading Vessel.
FPU	Floating Production Unit
HMXO	Hydrate Mitigator Crossover
HP1	Hydraulic Supply of High Pressure (Primary) to SCEHM
HP2	Hydraulic Supply of High Pressure (Reserve) to SCEHM
HPU	Hydraulic Unity, Hydraulic Suplly Unity, Hydraulic Power Unity
ID	Inner Diameter
LP1	Hydraulic Supply of Low Pressure (Primary) to SCEHM
LP2	Hydraulic Supply of Low Pressure (Reserve) to SCEHM
MSIA	Subsea Water Injection Manifold (*Manifold submarino de injeção de água)*
MSIAG	Subsea Water Alternating Gas Injection Manifold (*Manifold Submarino de Injeção de Água e Gás)*
MSGL	Subsea Gas Lift Manifold (*Manifold Submarino de Gas Lift)*
MSP	Subsea Production Manifold (*Manifold Submarino de Produção)*
PCV	Pressure Control Valve
PSV	Pressure Relief and Safety Valve
SCEHM	Multiplexed Electrohydraulic Control System (*Sistema de controle eletrohidráulico multiplexado)*
DHCS	Direct Hydraulic Control System
SCM	Subsea Control Module, used in the SCEHM
SDU	Subsea Distribution Unit

SESDV Subsea Emergency Shut-Down Valve

STU Steel Tube Umbilical

TPU Thermoplastic hose umbilical

UPS Uninterrupted Font of Electrical Energy

WAG Water Alternating Gas injection

WCR Rack for Well Control used to DHCS

WCT Wet Christmas Tree

5) PROJECT PREMISES

5.1) Operating fluid, supplies, pressures and hydraulic dimensioning

5.1.1) Upon receiving this Technical Specification, the SUPPLIER shall immediately request that the CONTRACTOR presents the LIST OF HPU CONSUMERS provided by PETROBRAS, specifying the quantities for each type of subsea equipment regarding the ENTERPRISE for which the HPU is intended. The list shall be presented in a table according to the model in Appendix I.

5.1.2) The HPU shall meet the following requirements:

a) Provide 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 HPU shall be able to operate with any of the hydraulic fluids listed below, that the CONTRACTOR shall inform later on:

   i. MacDermid HW443;
   ii. MacDermid HW525P;
   iii. Castrol Transaqua DW.

b) Provide the pressurized control fluid to the subsea equipment equipped with MULTIPLEXED ELECTROHYDRAULIC CONTROL SYSTEM, according to the quantity and type of subsea equipment specified by PETROBRAS for the ENTERPRISE which HPU is intended.

c) Provide the pressurized control fluid for up to two (2) WCT operated via direct hydraulic control system (DHCS). The maximum quantity of two (2) will be confirmed by the CONTRACTOR.

d) Provide pressurized control fluid for up to four (4) Subsea Emergency Shutdown Valves (SESDV). The CONTRACTOR will inform the exact quantity of SESDV.

e) Provide pressurized control fluid for up to two (4) PLEM - Hydrate Mitigator Crossover HMXO. The CONTRACTOR will inform the exact quantity of PLEM-HMXO.

5.1.3) The HPU's hydraulic dimensioning shall include all subsea equipment informed in the respective LIST OF HPU CONSUMERS, considering the length of each umbilical, from the equipment to the FPU. The CONTRACTOR shall inform the SUPPLIER the lengths of the umbilicals of the ENTERPRISE, considering the typical unifilar diagram for each equipment shown in the Appendix VI.

IMPORTANT: The lengths in Appendix VI shall only be used as a reference and cannot be used to determine the dimensions of the HPU, unless otherwise approved by PETROBRAS.

5.1.4) In case the LIST OF HPU CONSUMERS specifies some type of subsea equipment that is not listed in the Appendix I of this ET, the SUPPLIER may request via the CONTRACTOR that PETROBRAS inform:

a) Whether the control system is either multiplexed electrohydraulic or direct hydraulic;
b) The configuration of the control umbilical;
c) The length of the control umbilical;
d) The number of regulated hydraulic supply outlets and their respective ranges of operating pressure for the multiplexed electrohydraulic control system, or;
e) The number of hydraulic supply outlets and their respective ranges of operating pressure for the equipment's hydraulic direct control rack.

5.1.5) The HPU's tanks, bank of accumulators, and capacity of the pumps shall be sized to meet requirements of the subsea equipment informed by PETROBRAS for the ENTERPRISE which the HPU is intended.

5.1.6) Data regarding the umbilicals (configuration, hose expansion coefficient) and equipment (actuators' volumes), in order to determine the dimensions of the HPU, can be found in Appendices II to V.

5.1.7) The hydraulic dimensioning of the HPU shall be submitted to a previous verification by the CONTRACTOR, and then forwarded for PETROBRAS' approval. The report shall clearly state all premises and results, including:

a) The LIST OF HPU CONSUMERS for the ENTERPRISE;
b) The lengths of the umbilicals from each equipment to the chosen FPU;
c) Basic formulas used in all calculations;
d) The calculated volume due to hose expansion for each umbilical at maximum pressure;
e) Capacity (flowrate in liters/min) of the electric pumps and expected manufacturer/model;
f) Capacity (flow rate in liters/min) of the pneumatic pumps and expected manufacturer/model;
g) Capacity (flow rate in liters/min) of the recirculation pumps and expected manufacturer/model;
h) Volumes of the tanks;
i) Volumes of the accumulators' banks and quantity for each expected pressure class;

5.1.8) The HPU shall have a total of T sets of four (4) regulated hydraulic supply outlets (see sub items *a* and *b* below) for the subsea equipment with multiplexed electrohydraulic control system connected to the FPU, being T = Ta + Tb + ... + Tk, in accordance with the HPU's list of consumers (table model in Appendix I). The four (4) outlets of each set are as follows:

a) Two (2) manually adjustable pressure outlets ranging between 4,000 and 5,000 psi, henceforth individually referred to as LP1 and LP2, or generically as "Low pressure" (LP).
b) Two (2) manually adjustable pressure outlets between 3,000 and 7,500 psi, henceforth referred to as HP1 and HP2, or generically as "High Pressure" (HP).

   IMPORTANT: The HPU shall be easily converted by the CONTRACTOR in order to provide up to 10,000 psi in the HP outlets whenever necessary (see further specifications in this document).

5.1.9) Considering the set of outlets (LP1, LP2, HP1 and HP2) connected to the SDU consumers (see Annex I and Annex VI), these hydraulic circuits shall have dedicated regulation valves for each SDU consumer connected to the HPU.

5.1.10) Once receiving the specification (or confirmation) of the quantity per type of subsea equipment for the ENTERPRISE for which the HPU is intended, the SUPPLIER shall determine the total number of LP1, LP2, HP1, HP2 supply outlets. The SUPPLIER shall then immediately request that the CONTRACTOR verify this dimensioning, with PETROBRAS' approval.

5.1.11) The HPU shall have three regulated hydraulic supply outlets for the "Well Control Rack" (WCR) intended to serve up to two (2) wells with WCT for Direct Hydraulic Control System. Each outlet shall supply the three individual headers of the WCR for each well, being:

a) One (1) manually adjustable pressure outlet between 3,000 and 5,000psi for the WCR directional control valve manifold that will operate standard WCT gate valves 5k (3,000 to 5,000psi) or 10k (6,500 to 10,000);

b) One (1) manually adjustable pressure outlet between 3,000 and 5,000psi for the WCR directional control valve manifold that will operate the DHSV from wells with 5k standard WCT;

c) One (1) manually adjustable pressure outlet between 3,000 and 7,500psi for the WCR directional control valve manifold that will operate the DHSV from wells with 10k standard WCT.

IMPORTANT: The manifold supply outlet of the WCR directional control valves that will operate the DHSV from wells with 10k standard WCT should be readily convertible to supply up to 10,000psi of pressure when necessary (see specifications later in this document).

5.1.12) HPU shall receive fluid return from up to two (2) wells with WCT for Direct Hydraulic control when it is depressurised through the Well Control Rack. The size of the return piping, including the WCR connection, shall be calculated so as not to cause backpressures that may delay the closure of the wells. It is recommended that the pipe and return fittings of the Well Control Rack have an internal diameter equal to or greater than ½ ".

5.1.13) Each supply outlet to the WCR shall have its own manual pressure regulator valve.

5.1.14) To serve up to four (4) SESDV hydraulically controlled directly from the FPU, the HPU shall have two adjustable hydraulic supply outlets (redundant) between 3,000 and 5,000 psi for the SESDV's directional control valve panel.

IMPORTANT: The HPU shall not receive the return of depressurized fluid from the SESDV.

5.1.15) Each of the SESDV's supply outlet for the directional control valve panel shall have its own manual pressure regulation valve.

5.1.16) The HPU shall have an unregulated pressure header that is common to every LP regulation manual valves. The dimensioning of the unregulated pressure range for the header shall allow the manual pressure regulation valves for each group of supply outlet to provide the regulated pressures in each operating range.

Note: Including each LP1, LP2 outlet group, the 3,000-5,000 psi and 4,000-5,000 psi outlets for the WCR, and those of each supply outlet for the SESDV control panel.

5.1.17) The HPU shall have an unregulated pressure header that is common to all HP regulation manual valves. The dimensioning of the unregulated pressure range for the header shall allow the manual pressure regulation valves for each group of supply outlet to provide the regulated pressures in each operation range. Note: Including each HP1, HP2 outlet group, and the highest-pressure outlet (3,000-7,500 psi) for the WCR.

5.1.18) The maximum operational pressure conversion for the HP outlets (from 7,500 to 10,000 psi) shall be possible with the exchange of just a few components in the HP header and the outlet themselves, if it is necessary. Components that are easily replaceable shall be taken under consideration, such as safety valves and manual pressure regulation valves. The pressure conversion shall not include tubing and theirs connections, pumps, accumulators, filters, instruments, and directional control valves (DCV). If Programmable Logic Controllers are used to control the HPU, its program shall already include the operation in 10,000 psi and the means for its activation. Whenever possible, all the components up for replacement in the conversion shall be provided with double block valves and upstream and downstream reliever, wherever applicable.

5.1.19) The HPU's hydraulic diagram (P&ID) shall identify and list the components that have to be replaced in the conversion of the HP and WCR outlets from 3,000 to 10,000 psi. Regarding the hydraulic diagram, a standard symbol may be used beside each component identified in the HP header, for a HP1 and HP2 outlet pair and the outlet to the WCR.

5.1.20) PETROBRAS shall approve the HPU's hydraulic diagram (P&ID).

5.1.21) The HPU's P&ID should be submitted for PETROBRAS' approval along with the Well Control Rack (WCR) and the SESDV's control panel.

5.2) Constructive characteristics

5.2.1) The HPU shall be designed and constructed to operate offshore in an area classified according to IEC 60079 as Zone 2, group IIA, temperature T3.

5.2.2) The service life of the HPU shall be 30 years in operation.

5.2.3) The HPU shall fully operate under the following environmental conditions:

a) Ambient temperature: 4°C to 45°C;

b) Relative air humidity: 100%;

c) Altitude above sea level: 5 m to 50 m;

d) Saline atmosphere: 1 mg of NaCl/m³.

5.2.4) The HPU shall be made in stainless steel ASTM A269 Gr. TP 316L or equivalent to be approved by PETROBRAS with two or three structures type "skid" open or close, suitable to be assembled side by side and on different floors. The SUPPLIER shall consider as dimensional reference two structures, each one with 8,300 mm (W) x 2,500 mm (D) x 4,100 mm (H) maximum.

IMPORTANT: the SUPPLIER shall request the CONTRACTOR to specify the maximum dimensions allowable to the HPU in one structure or divided in up to three structures. As a suggestion for the HPU divided in three structures, each structure could contain:

Skid 1: electric supply pumps, pneumatic pumps, panels with pressure regulating valves, directional

control valves (DCV), motor control center and operation logic.

Skid 2: tanks and recirculation pumps.

Skid 3: bank of accumulators.

5.2.5) As a whole, the HPU shall have the following main equipment and components:

a) 1(one) supply tank;

b) 1 (one) return tank;

c) 1(one) non-regulated LP header;

d) 1 (one) non-regulated HP header;

e) 2 (two) electrical and 2 (two) pneumatic pumps for HP header;

f) 4 (four) electrical and 2 (two) pneumatic pumps for LP header;

g) 2 (two) recirculation pumps;

h) Filters to keep the fluid cleanliness class;

i) Accumulator bank for HP header;

j) Accumulator bank for LP header;

k) Local control panel (or panels);

l) DCVs for depressurization of umbilicals interconnected to the HPU, keeping the accumulators pressurized;

m) Manual pressure regulating valves for each outlet group LP1, LP2, HP1 and HP2;

n) Manual pressure regulating valves for WCR;

o) Manual pressure regulating valves DCV rack of SESDVs;

p) Double blockage valves for HP outlets and header;

q) Pulsation damper for each pump, installed between pump discharge and its PSV.

5.2.6) The structures shall be designed to protect the HPU and all its components during lifting and transportation.

5.2.7) The skids shall be designed to protect the HPU and all its components during lifting and offshore transport. Each skid shall have at least 4 (four) lifting lugs capable of sustaining 200% the weight of the empty HPU (without hydraulic fluid). It shall be supplied all necessary accessories for lifting, according to BSI BS 1290 standard.

5.2.8) The HPU structure (or structures) shall allow easy access to its interior, providing suitable space and placement for its components to be properly maintained and removed. The pipes shall be distributed to allow the easy removal of all equipment.

5.2.9) If the HPU has two or three structures, the SUPPLIER shall provide all the electrical cables, hydraulic tubing, pneumatic tubing, and connections necessary to interconnect the structures. The assembly of the HPU and the flushing of the hydraulic interconnection between the HPU structures are also in the scope of the SUPPLIER.

5.2.10) The local control panels and the HPU outlets shall be in protected positions to guarantee their integrity during transportation and operation.

5.2.11) The base of each HPU structure shall have an inclination allowing the proper drainage of the spilled fluid in the HPU's interior, through two lateral outlets with NPT 1" thread or larger to avoid puddles or floods.

5.2.12) The HPU shall be supplied ready for installation.

5.2.13) HPU's access doors and tie in points shall be placed according to FPU arrangement design and 3D model, so that any interferences and/or improper access placements that may prohibit their usage are avoided. Examples of such interferences are pillars, lack of space due to proximity to module's edge, lack of space due to proximity to other equipment, doors facing a place with no access, among others.

5.3) Operation and maintenance

5.3.1) The HPU shall have its own local control panel to allow the unit's manual operation.

5.3.2) The local control panel shall be on the outside of the HPU. All the instruments, visual indicators, valves, and pushbuttons shall be located so as to facilitate local operation of the HPU.

5.3.3) The local control panel shall have all components required for manual operation of the HPU, including: block valves for the headers, pressure regulating valves (see item later), manometers, visual pumps operation indicators, and activation pushbuttons.

5.3.4) The pressure regulating valves and the corresponding manometer of each outlet (LP1, LP2, HP1, HP2) and supply for the WCR and SESDV panel can be grouped into dedicated panels, as long as they are located in the HPU itself. The manual pressure adjustment of the regulating valves shall be from the outside of the HPU.

5.3.5) The local control panel shall have a graphic diagram with the HPU's simplified P&ID.

5.3.6) Each electrical and pneumatic pump shall have an independent manual control, regulated by a key (automatic/manual), with triggering switch mounted on the control panel. The manual operation shall be able to occur independently from the HPU's logic.

5.3.7) The local control panel shall have at least the following resources to monitor the HPU:

a) Manometers to monitor the unregulated hydraulic supply pressure in each header;
b) Manometers to monitor the regulated hydraulic supply pressure for each outlet (LP1, LP2, HP1, HP2) and supplies for the WCR and SESDV panel;
c) Manometers to monitor pressures for both unregulated and regulated air supply in the HPU;
d) State indicators (on, off, on duty and stand-by) for each electrical and pneumatic HPU pump;
e) Continuous or discrete visualization of the levels in the supply and in the return tanks;
f) Continuous or discrete visualization of the levels in the lubrication tank's pump.

5.3.8) The design of the HPU shall consider the best practices regarding, safety, environment, health, and efficiency during commissioning, operation, and maintenance.

5.3.9) The project shall avoid or minimize inadequate or inadvertent handling by the technicians.

5.3.10) The HPU's internal layout shall allow easy access to replace filtering elements and other components in its interior that require regular replacement.

5.3.11) There shall be provided accessed to maintain equipment and components in the HPU's interior, whenever necessary, and without any impact to its operation. The project shall prioritize the removal and installation of manometers and other instruments, any valve substitution (blocking, relieving, safety, regulating), draining of accumulator, removal and installation of bottle of accumulator individually, removal and installation of pumps, tank decontamination of supply and return, and access to electronic devices of monitoring and control.

5.3.12) The HPU shall be equipped with load handling devices, such as hoist, suitable for the maintenance and replacement of pumps, motors, and accumulators. This device shall enable the removal of this equipment without harming the operation of the others.

5.3.13) Sampling points of cleanliness class of the hydraulic fluid shall be provided to the HPU's main hydraulic circuits. They shall be located at least:

a) In the discard of the recirculation pumps;
b) In the outlets of supply and return tanks;
c) Between the discard of the supply pumps and the accumulators of each header;
d) Between the accumulators of each header and the regulator valves (upstream to the regulating valves);
e) Downstream to the outlet of each set of two regulating valves for up to four outlets from the same supply.

Note: the fluid sampling points shall not be located in the main panel of the HPU.

5.3.14) The HPU shall allow each recirculation pump to be operated either individually or together, even if both tanks are at a low level.

5.4) Conditioning of the control fluid

5.4.1) The HPU shall have two hydraulic control fluid tanks:

a) Tank for clean fluid supply;
b) Return tank for the operating fluid.

5.4.2) Sizing of HPU control hydraulic fluid tanks:

a) Supply Tank: The volume of the supply tank shall be dimensioned by the following equation V = 1.5 x (A+B+C), where:
    - A = volume of the LP accumulators + volume of the HP accumulators (see item 5.6);
    - B = volume resulting from the expansion of the umbilical's hoses Type TPU (see Appendix II-A) and Type STU (see Appendix II-B);
    - C = total volume of the actuators (see Appendices I and IV);

    Note: If the volume evaluated is greater than 2,000 liters, additional 750 liters shall be included as safety margin.

b) Return tank: The volume of the return tank shall be greater than the volume of the supply tank.

5.4.3) The supply and return tanks shall have drainpipes, with a minimum diameter of 2" in the upper section to avoid possible fluid leakage in case of a flash depressurization of the entire system, or fault in the level

sensor. This drainpipe's outlet shall be directed to the bottom of the skid, so the HPU's components will not get wet.

5.4.4) The supply and return tanks shall be designed in order to avoid the accumulation of vapors from the evaporation of the control fluids. Air filters shall be planned, with minimum efficiency $\beta 5 \geq 200$, on the tanks' ventilation orifices. Their airflow shall be calculated to match the recirculation pump's flow and the supply pumps, turned on at the same time. Both for the supply tank and for the return fluid flow in case of depressurization in the return tank.

5.4.5) The supply and return tanks shall have a local level gauge (in the tank) and a remote level transmitter for graphic visualization on the HPU's local panel. The level gauges shall have both blocking and relief valves.

5.4.6) Each tank shall have its bottom inclined in order to be individually drained, and their drain line(s) diameter(s) shall allow the exhaustion all the fluid from the tank in (6) hours, at the most. The pipes' endpoints shall have HPT thread connections to allow the eventual coupling of hoses.

5.4.7) The tanks shall be in AISI316L stainless steel.

5.4.8) The HPU shall have circuits for filling, fluid transfer between tanks, and recirculation of the return tank's contents, always through a set of filters with $\beta 3 \geq 200$ efficiency (or better), to allow the fluid in the return tank to be framed in the operation's cleanliness class. These circuits shall have two redundant electrical pumps, capable to perform individually the filling and the recirculation of all fluid from the return tank in not more than 60 minutes. The outlet filter of the recirculation pumps shall have a greater filtration area than the other filters in the pressure lines, in order to increase the interval between replacements of the filter elements.

5.4.9) All operations of filling, recirculating and transferring fluid between tanks shall be done without any interfere with the HPU's regular operation.

5.4.10) The points of drainage, sampling and filling shall have protective caps with a small chain or steel cable to avoid a dirt build-up inside the connections and, therefore, the loss of protection.

5.4.11) All the fluid sampling points shall be easily accessed.

5.4.12) The tanks shall have manholes wide enough to allow its inspection and full cleaning. If they are positioned in the upper section of the tanks, access ladders shall be in the design.

5.4.13) In case of using a shared tank structure split in two, one for each tank, there can be NO communication between them, except via the hydraulic circuits for fluid transference and filtration, through the recirculation pumps.

5.4.14) The endpoints of both the return lines and the recirculation pump shall stay below of the tank's regular minimum level. The return lines and the recirculation pump shall have their entrances at the top of tank.

5.4.15) The HPU's design shall allow the tanks to be filled only through the filling nozzle, with the aid of the recirculation pump and circuit, in order to ensure the fluid's first filtration. An inox fisher shall be included, with a foot pump (if the pump is not self-priming), and an appropriate local to stow the fisher.

5.4.16) A warning sign with the alert type THE SESDV'S RETURN FLUID CANNOT BE REUSED IN THE HPU (and the respective translation to the language of the FPU crew) shall be affixed next to the filling point of the tanks.

5.4.17) The sampling points to verify the HPU's hydraulic control fluid's cleanliness class shall adhere to the following specifications:

a) Use verification equipment through Comparative Method.

b) Use particles electronic counter.

c) Provide easy access to connect and disconnect the equipment, as well as to the samples collecting process or the electronic counting (e.g. support base(s) for the sampling bottle used by the comparative method equipment).

d) Guarantee the safety of operations during the entire handling. The sampling operation shall be, at least in 2 (two) stages, in order to avoid that, over a single operation, the pressurized fluid may be communicated with the environment.

5.4.18) It is scope of supply of the HPU one (1) portable kit to verify the hydraulic fluid cleanliness, which can be one of the following types:

i) Electronic portable particles counter model PCM-500 or equivalent;

ii) Portable kit to verify the hydraulic fluid cleanliness by the Comparative Method, including consumables (slides/filters), necessary for two years of HPU operations considering two samples per day. The kit must be provided with four standard slides, respectively to for measures according ISO 4406 Class 17/15/12, and two for ISO 4406 Class 19/17/14.

Note: the portable kit shall be delivered directly from SUPPLIER to PETROBRAS, factory sealed (including the consumables), being prohibited previous usage of the kit by the SUPPLIER or the CONTRACTOR.

5.4.19) The control fluid sample points shall allow the usage of electronic particle counts model STAUFF LasPaC II for water-base hydraulic fluid, in options LasPaC II-P (portable), and LasPaC II-M (mobile). The electronic count is not part of the HPU scope of supply.

5.5) Hydraulic circuits

5.5.1) The HPU shall be commissioned with all the circuits cleaned in accordance with the Norm ISO 4406 CLASS 17/15/12 (equivalent to class 6 of old Norm NAS1638 "Cleaning requirements used in hydraulic systems").

5.5.2) The HPU shall have safety and relief valves to protect it against overpressures that may occur internally in its hydraulic circuits and components.

5.5.3) At least one safety and relief valve (PSV) shall be provided downstream to each of the HPU's supply manual outlet pressure control valve. The safety valves shall be configured to relief the pressure equivalent to 1.1x of the maximum operation pressure for the respective supply outlet.

Note: The safety valves for HP1, HP2 and WCR (3,000-7,500 psi) shall be replaced individually by similar ones adjusted to 11,000 psi if, in the future, PETROBRAS choses to convert the maximum operating pressure from 7,500 psi to 10,000 psi.

5.5.4) The supply circuits (LP1, LP2, HP1, HP2) shall comply with the followings the requirements:

a) Each supply outlet (LP1, LP2, HP1, HP2) shall have a Locked Open (LO) Valve, with a padlock, positioned downstream to its respective regulating valve;

b) It is not allowed the use of check valves downstream from the regulation valves.

5.5.5) The HPU shall have directional control valves (DCV) for electrical activation to depressurize the multiplexed electrohydraulic control system's hydraulic supply via CIS in case of an emergency. This depressurization shall not include the accumulator's banks.

5.5.6) The DCV, also referred as solenoid valve, shall be 'fail safe mode', with return by spring to the closed position, when there is interruption of electrical energization to the solenoid. When this interruption occurs, the DCV shall align its outlet to the draining position, communicating to the hydraulic circuit the downstream to the DCV to the HPU's return tank.

5.5.7) A DCV shall be downstream to each supply manual pressure control valve.

5.5.8) Each DCV shall be suitable for simultaneous depressurization of four supply outlets downstream to the manual pressure control valve. The DCV cannot cause backpressure or transients that hinder the performance of the HPU or any subsea equipment whose control systems are supplied by the HPU.

5.5.9) The hydraulic circuits of each DCV shall adhere to the following requirements:

a) Depressurization through individual piping, from the DCV to the return tank;

b) Have a block valve and a needle valve (in sequence) upstream of the DCV;

c) Have a block valve lockable ("lockable open") downstream to the DCV;

d) Be designed not to cause backpressure that delay the simultaneous depressurization of the four (4) shared supplies from the multiplexed electrohydraulic control system for the HPU's return tank. The comparison premise shall consider only umbilicals with thermoplastic hose. Umbilicals with steel pipes cannot be considered for this goal.

5.5.10) All of the HP hydraulic circuits shall have double block valves.

5.5.11) The drains of all instruments shall be directed to the bottom of the HPU, avoiding that the operating fluid spills over the adjacent components.

5.5.12) All instruments shall have connections in manifold blocks with block and relief valves to allow its easy replacement.

5.5.13) All hydraulic lines shall be in accordance with I-ET-3010.00-1200-800-P4X-015 – REQUIREMENTS FOR TUBING AND FITTING (ALIGNED TO IOGP-JIP33 S-716).

5.5.14) The hydraulic connections (pressure tubing fittings) shall use double ferrule connectors, with double flared rings, in either 316 stainless steel or super duplex. Autoclave and coned-and-threaded connectors may be accepted, as an exception, only for the HP circuits. It is mandatory to use tubing and accessories from the same manufacturer as the connectors and the inclusion of their respective assembly and disassembly connecting procedures for each pipe diameter used in the HPU's manual. The sealing of the NPT flanges shall be done with chemical flange sealer. Teflon tape shall not be used.

5.5.15) The hydraulic lines, in the inside of the HPU, shall be placed next to one another and preferably supported near the connections. The maximum distance between supports shall be one (1) meter. Radius

curves equivalent to four (4) times the outer diameter of the piping, measured from the inner wall of the curve, are preferable instead of knees.

5.5.16) Connections or points subjected to leakage directly over equipment or electrical terminals shall be avoided. Suitable protection shall be provided when this situation is inevitable.

5.5.17) The hydraulic lines subject to mechanical efforts during the removal of components shall be properly protected. The junctions and connections shall be installed allowing the verification of their tightness and leakage.

5.5.18) Every filter of the HPU shall be redundant, without any inner or outer by-pass, and equipped with a differential pressure transmitter (or one pressure transmitter upstream and another downstream to the filter), visual indicator of pressure drop, allowing the local calibration of all indicators.

5.5.19) The supply filters shall have the following features:

a) Casing in AISI 316 stainless steel with safety coefficient equal to 3.
b) Work pressure compatible with the maximum pressure of the header where it is located.
c) Cannot have a by-pass valve (except if it is used to remove the differential pressure transmitter).
d) It is desirable that all connections flanges have nickel-chemical treatment, in order to decrease flange wear and to allow sealing during maintenance.
e) Differential pressure gauge (replacement indicator) at 3 (three) bar.

5.5.20) The recirculation filters shall have the following features:

a) Casing in AISI 316 stainless steel with safety coefficient equal to 3.
b) Work pressure of 150 psi (10 bar).
c) Shall not have a by-pass valve.
d) It is desirable that all connection flanges have nickel-chemical treatment, in order to decrease flange wear and to allow sealing during maintenance.
e) Differential pressure gauge (replacement indicator) at 3 (three) bar.

5.5.21) The filter elements shall have the following features:

a) Filtering medium: pleated inorganic microfibers with retention capacity of 3 µm, beta ratio 3 > 200 (in accordance with ISO 4572), pleated inner profile and inner and outer anchoring in stainless screen.
b) Differential pressure of collapse > 160 bar, as ISO 2941.
c) Machined lids (cannot be printed), reinforcements in the inner tube by welding process without material addition.
d) Seals in Buna N;
e) Total compatibility with the subsea control fluid;

5.5.22) The filters and filter elements shall adhere to the following norms:

a) ISO 2941: Filter elements - verification of collapse/burst pressure rating;
b) ISO 2942: Filter elements - verification of fabrication integrity and determination of the first bubble point;
c) ISO 2943: Filter elements - verification of material compatibility with fluids;

d) ISO 3968: Filters - evaluation of differential pressure versus flow characteristics;
e) ISO 10949: Guidelines for achieving and controlling cleaning of components from manufacture to installation;
f) ISO 11170: Filter Elements - sequence of tests for verifying performance characteristics;
g) ISO 16889: Filter elements - multi-pass method for evaluating filtration performance of a filter element;
h) ISO 18413: Component cleaning - inspection document and principles related to contaminant collection, analysis and data reporting.

Note: Documentation proving that the filters are qualified according to these norms and essays shall be provided.

5.5.23) The setting of pressure to up four outlets for the same supply shall be done, for any manual pressure control valve connected in parallel by block and relief valves, facilitating the replacement of any one without hindering the HPU operation or the respective supply to the subsea equipment.

5.6) Accumulator bank sizing

5.6.1) There shall be independent accumulator banks for LP and HP headers, designed to withstand the maximum non-regulated pressure of each header.

5.6.2) The LP accumulator bank shall be designed in accordance with the criteria of items 6.4.5.2 of ISO 13628-6 (2006) below, considering the highest volume between V1 and V2, where:

a) V1: volume to allow an opening and closing cycle of all valves of one (1) WCT with multiplexed electrohydraulic control system without the need to pressurize the accumulators (LP's electrical and pneumatic pumps shall remain turned off). The necessary LP volume for this cycle of operations will be of 160 liters.
b) V2: volume to store enough energy to maintain the pressure of the subsea system for up to 12 hours, without the assistance of pumps. For this calculation, it shall be considered a leakage of 20 mL per hour for each LP DCV in the subsea system (see Appendices I and V). A 20% increase shall be applied to the resulting volume.

5.6.3) The HP accumulator bank shall be designed in accordance with the criteria of items 6.4.5.2 of ISO 13628-6 (2006) below, considering the highest volume between V1 and V2, where:

a) V1: volume to allow an opening and closing cycle of all valves of one (1) WCT with multiplexed electrohydraulic control system without the need to pressurize the accumulators (HP's electrical and pneumatic pumps shall remain turned off). The necessary HP volume for this cycle of operations will be of 40 liters.
b) V2: volume to store enough energy to maintain the pressure of the subsea system for up to 12 hours, without the assistance of pumps. For this calculation, it shall be considered a leakage of 20 mL per hour for each HP DCV in the subsea system (see Appendices I and V). A 20% increase shall be applied to the resulting volume.

5.6.4) The failure of one (1) LP accumulator shall not compromise more than 25% of the capacity of the LP accumulators' bank.

5.6.5) The failure of one (1) HP accumulator shall not compromise more than 25% of the capacity of the HP accumulators' bank.

5.6.6) Each accumulators' bank shall be divided into two (preferably equal) groups by means of blockage ball valves, and each of these groups shall have a maintenance connection, made of a blockage ball valve of 1/2" body and a connection JIC 37° 3/8" with buffer (see Appendix VII).

5.6.7) The accumulators shall be equipped with nitrogen preload circuits, fluid and nitrogen pressure indication manometers, shut and relief manifold valves, safety valves and rupture discs.

5.6.8) The accumulators shall be made of stainless steel and preferably of the "bladder" type.

5.6.9) The accumulators shall be mounted vertically and shall have dampers between the accumulators and the support structure.

5.6.10) The HPU shall be supplied with all the documentation required by NR-13 of the Ministry of Labor and NBR 12.274 and 13.243 standards.

NOTE: The SUPPLIER, if deems pertinent, shall request that the CONTRACTOR obtain from PETROBRAS the analyze and confirmation that, due to the type of contracting, it will not be necessary to provide the documentation for the accumulators according to normative instructions and Brazilian technical norms, especially NR-13, from the Ministry of Labor, and NBR 12.274 and 13.243 standards.

5.7) Electrical and pneumatic pump

5.7.1) The pressurization pumps for the entire HPU supply system shall have the following configuration:

a) Four (4) electrical pumps (E) and two (2) pneumatic pumps (P) for the LP's non-regulated hydraulic circuit, operating normally with a set composed by 2E+1P active (on duty) and other with 2E+1P as reserve (stand-by).

b) Two (2) electrical pumps (E) and two (2) pneumatic pumps (P) for the HP's non-regulated hydraulic circuit, operating normally with a set composed by 1E+1P active (on duty) and other with 1E+1P as reserve (stand-by).

5.7.2) The dimensioning of the LP pressurization pumps shall meet the following specifications:

a) Each set of two electric pumps and one pneumatic pump (2E+1P) shall be capable of pressurizing the subsea system up to the maximum set operating pressure within 120 minutes after the total depressurizing of the umbilicals (ESD4). Regardless of whether the type of control lines and chemical lines as being either TPU or STU, the pumps flow shall be calculated considering the volume resulting from the expansion of one (1) ½ "@ 5,000 psi thermoplastics hose for each umbilical from the subsea equipment with multiplexed electrical hydraulic control system directly connected to the FPU and four (4) 3/8"@ 5,000 psi hoses from each umbilical for wells with WCT for direct hydraulic control. The expansion coefficients for the umbilicals' thermoplastic hoses can be found in the tables in Appendix III.

b) Each LP electric pump shall be dimensioned to withstand 50% of the maximum flow required for

the entire LP system.

c) Each LP pneumatic pump shall be dimensioned to maintain the unregulated pressure circuit without turning on the electric pumps, disregarding the action of subsea valves. The pump shall be dimensioned to withstand the necessary flow to repressurize the LP system when the pressure of the unregulated circuit falls below 90% of its maximum operating pressure, causing the turning on of the pneumatic pump.

d) Each pneumatic pump shall have its suction line calculated in order to allow a 10% increase in the design flow rate, at the maximum working pressure of the header and with air pressure of around 7 bar, without cavitation.

5.7.3) The dimensioning of the HP pressure pumps shall meet the following specifications:

a) The HP electric pump and a pneumatic pump (1E+1P) set shall be capable of repressurizing the entire subsea system after the total depressurizing of the umbilicals (ESD4) within a maximum of 120 minutes. Regardless of whether the type of control lines and chemical lines as being either TPU or STU, the pump flow rate shall be calculated considering the volume resulting from the expansion of one (1) ½" @ 10,000 psi thermoplastic hose from each umbilical (see note below), for subsea equipment with multiplexed electrohydraulic control system connected directly to the FPU and two (2) 3/8" @ 10,000 psi hoses from each umbilical for wells with WCT for direct hydraulic control. The coefficients of expansion of the thermoplastic hoses of the umbilicals can be found in the tables in Appendix III.

   Note: Regardless of the umbilical that will be used, the 10,000 psi pressure shall be the dimensioning premise.

b) Each HP pneumatic pump shall be dimensioned to maintain the unregulated circuit pressure without turning on the electric pumps, disregarding the action of subsea valves. The pump shall be dimensioned for the necessary flow rate to repressurize the HP system when the pressure of the unregulated circuit drops below 90% of the respective maximum operating pressure, causing the pneumatic pump to turn on.

c) Each pneumatic pump shall have its suction line calculated in order to allow a 10% increase in the design flow rate, at the maximum working pressure of the header and with air pressure of around 7 bar, without cavitation.

5.7.4) The maximum and minimum supply air pressure from the FPU are 10 and 4.9 bar, respectively.

5.7.5) The HPU design shall avoid the occurrence of short stopping and restarting cycles of the pumps, that may have detrimental effects to its reliability.

5.7.6) All electric and pneumatic pumps shall have a selector switch for their designation as “on duty”, “stand-by” and “out of operation”, in a way that can be configured any combination between 2 and 4 electric pumps (LP) and one of two pneumatic pumps (LP) and one of two electric pumps (HP) and one of two pneumatic pumps (HP). The selector switch shall be on the HPU local control panel.

5.7.7) It shall be provided manual command by the operator to turn on every HP pumps (electrical and pneumatic) for the repressurization of the system after an ESD4.

5.7.8) It is suggested the following operating sequence for LP and HP pressurizing pumps in normal mode, considering P equal to the unregulated pressure measured in each header and P_{max} the maximum unregulated operating pressure in each header:

Header	Pump	P = 100% of Pmax	P = 90% of Pmax	P = 85% of Pmax	P = 80% of Pmax	P = 70% of Pmax	P = 45% of Pmax
HP	Pneumatic	Turned Off	Turns On			Alarm of pressure drop	Turn off pumps. HPU halt alarm
	Electric	Turned Off			Turns On		
LP	Pneumatic	Turned Off	Turns On			Alarm of pressure drop	Turn off pumps. HPU halt alarm
	Electric	Turned Off		Turns On 1st	Turns On 2nd		

(Suggestion for pumps operating sequence)

5.7.9) Halt and start pressures of the pumps shall have their set points manually set using thumbwheel switches (values in bar) located on a specific panel for this purpose, and easily accessible inside the HPU. The panel shall allow the keys to be seen with the set points and shall have restricted access with lid and padlock.

5.7.10) The **pneumatic pumps** shall work via balance of forces, having separate inputs for motor air, and for pilot air from a pneumatic DCV. The motor air pressure shall be adjustable by a regulating pneumatic valve up to the required value so that the maximum hydraulic pressure of the pump can reach 105% of the maximum unregulated operating pressure of the header (Pmax). The pump shall be turned on by the DCV upstream the pilot air outlet, according to the maximum and minimum unregulated operating pressure set points for each header. The pilot air pressure shall also be adjustable by a pneumatic regulating valve.

5.7.11) The **electric pressurization pumps** shall be from the "TRIPLEX" type or of alternate pistons with gear reduction box or rotating axial pistons. Alternate piston pumps shall have ceramic-coated pistons, internally in contact with the fluid in stainless steel and valve head in nylon. Swash plate axial thrust pumps will not be accepted.

5.7.12) The **recirculation pumps** shall be positive displacement (WING type or equivalent) or centrifugal type with one or more stages. The pumps shall be internally in stainless steel or material compatible with the hydraulic fluid and shall have sufficient discharge pressure to overcome the piping pressure drop, the settling height, and to achieve the exchange pressure of the filter elements of the recirculation filter, which is 3 bar.

5.7.13) All pumps shall be installed horizontally, so that the fluid level in the tank shall always be above the pumps' suction inlet. The pumps shall be lubricated by gravity, preferably from a header and a common lubrication tank with local level visual indicator and level transmitter for low-level alarm on the HPU's local panel. If each pump has its own lubrication tank, it shall have a local level visual indicator and level transmitter for low level alarm on the HPU's local panel.

5.7.14) All pumps shall have independent 125 µm filters upstream of them.

5.7.15) All pumps shall be appropriate to operate with the hydraulic fluid specified for the control system.

5.7.16) Each recirculation pump shall have its suction line connected to the supply tank and to the return tank. The recirculation hydraulic circuit shall have two sets of two filters each in parallel, isolated by blockage valves.

5.7.17) Each pump shall be protected by an individual safety and relief valve set according to API RP 520 Norm. After the relief valve downstream to each pump, there shall be a check valve and a ball-type block valve, in this order. The block valve shall have its highest-pressure holding capacity mounted downstream to the pump. As for the pumps of HP header, the blockage valves shall be double block type.

5.7.18) The fluid speed in the suction line of the pumps shall not exceed 1.5 m/s.

5.7.19) The electric pumps shall have pulsation dampers downstream to them.

5.7.20) The pumps shall have vibration dampers connected to the HPU piping through flexible hoses in order to reduce the vibration they induce into the HPU's structure.

5.7.21) Each pump shall have an individual hour counter to record the accumulated operating time.

5.7.22) The instruments air for pneumatic pumps shall be treated by a drying circuit equipped with filters, regulators, lubricators and block valves downstream to and upstream of them. This circuit shall be redundant and shall allow replacement of the filters without interrupting the HPU's air supply.

5.8) Instrumentation and control

5.8.1) The HPU shall have its own programmable logic controller (PLC) at least to monitor its instrumentation. This PLC shall be mounted properly in a panel inside the HPU.

5.8.2) The control logic may be fixed or executed by the HPU's resident PLC.

5.8.3) The HPU's PLC shall have a data communication network with the FPU.

5.8.4) The SUPPLIER shall submit to the CONTRACTOR the list of all data monitored by the HPU's PLC so that it can select which will be made available for remote monitoring in the FPU.

5.8.5) The communication protocol and the physical media to transmit data between the HPU's PLC and FPU shall be specified by the CONTRACTOR, considering preliminary one of the following options:

a) Protocol:

i. MODBUS under TCP/IP.

ii. OPC under TCP/IP.

b) Physical media: Ethernet with optic cable connection 100-BASE-T or 100-BASE-TX.

NOTE: upon receiving this document, the SUPPLIER shall immediately request the CONTRACTOR to specify the physical media and the protocol for communication between HPU and FPU.

5.8.6) The HPU shall have a pressure transmitter upstream of each individual umbilical supply outlet. The reading of each of these transmitters shall be available for interfacing with the FPU.

5.8.7) Independent pressure monitoring of each header: Each unregulated pressure header (LP and HP) shall be equipped with at least one pressure transmitter type 4-20 mA with two wires and HART protocol, powered by 24 VDC by the FPU, which will be monitored exclusively by the FPU. These transmitters shall be independent from one another and from the HPU's instrumentation itself. Its interface with the FPU's CIS shall be direct (feed and communication by the FPU) and both shall have readings in the CCR. This independent monitoring of the pressure in each header is specified in order to comply the requirement in the document PETROBRAS DR-ENGP-I-1.3 Safety Philosophy (ENGINEERING GUIDELINES), regarding the Emergency Shutdown Diagram: *Close the wing valves production and gas-lift wing in case of very low*

pressure of the hydraulic fluid in the subsea systems. The suggested pressure set-point value for each header will be the maximum between the HPU's emergency shutdown (trip) for this header and 80% (eighty percent) of the minimum value of the respective regulated pressure range. The operator shall be able to edit both set points in the CCR, while in 'administrator mode'.

NOTE: The CONTRACTOR may request from PETROBRAS the exclusion of this item 5.8.7 in case the pertinent documentation of the Emergency Shutdown Diagram does not form part of the ENTERPRISE contract.

5.8.8) The DCV for emergency depressurization of the supply outlets (LP1, LP2, HP1, HP2) to the umbilicals of the equipment with Multiplexed Electro Hydraulic Control System interconnected to the FPU shall be energized with 24 VDC through individual discrete outputs of the platform ESD system. The SUPPLIER shall request the CONTRACTOR the detailing of the energizing circuits.

5.8.9) All elements in contact with the fluid shall have a contact surface in 316 stainless steel and seals compatible with the HPU's work fluid.

5.8.10) All instruments shall have blocking valves (double block for the HP header and its branches).

5.8.11) Safety and relief valves shall be 'spring and seat' type. They shall be classified according to API RP 520 and 316L stainless steel.

5.8.12) Check valves shall ensure low leakage and fast action.

5.8.13) Manometers' housing for hydraulic lines shall have overpressure protection rupture discs and inlets to complete the display's internal fluid.

5.8.14) All filters shall have redundancy and shall have isolation and drain valves to enable replacement and maintenance without system shutdown.

5.8.15) The HPU shall be considered a P2 type package and shall meet with all such requirements described in I-ET-3010.00-1200-800-P4X-002 - AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS.

5.8.16) Despite the fact that the HPU is a P2 package, its panel shall be located near the HPU, instead of in the Automation and Electrical Panels Room (AEPR).

5.8.17) The panel shall have ingress protection IP-56 according to IEC-60529.

5.8.18) The panel shall be certified as Ex-pz, according to IEC-60079.

5.9) Electrical system

5.9.1) The electrical panels must be equipped with copper bars for grounding the enclosures, doors, instrument transformer secondary, cable frame, power cable protection conductor, and inside equipment in general.

5.9.2) Every metallic part in the lighting system's components, such as conduit boxes and luminaires, shall be grounded by a grounding conductor. All grounding cables and gears shall be dimensioned to adhere to the expected current requirements for fuses and associated equipment.

5.9.3) All equipment and skids must be equipped with segregated terminals for protective grounding and instrumentation grounding.

5.9.4) The cables must be identified and secured by plastic clamps. Metal clamps shall not be used.

5.9.5) The pump casings, transmitters and other electric instruments shall have a protection rating of IP-56.

5.9.6) The HPU shall be equipped with an emergency light powered by a rechargeable battery.

5.9.7) All instrumentation and data communication cables must have adequate shielding to prevent electrical interference by the electric pump motors.

5.10) Identification of components

5.10.1) Every electrical, hydraulic, or pneumatic instrument, as well as HPU's lines shall be identified with stainless steel plates, and these shall be embossed in low relief.

5.10.2) Instruments and equipment mounted on panels shall be identified behind the front of the panel.

5.11) Utilities and external interfaces

5.11.1) The HPU design shall have the following utilities as a PRELIMINARY premise:

a) 480 VAC @ 60 Hz, three phase, with floating neutral, for the electric motors.

b) 220 VAC @ 60 Hz ± 10% or 120 VDC from the UPS to the PLC and instrumentation.

c) 220 VAC @ 60 Hz for lighting and other electrical loads.

d) 24 VDC signals to the solenoids of the depressurization valves, coming from the ESD system of the FPU.

e) (to be defined) data communication network with FPU.

f) (to be defined) compressed air for the pneumatic pumps.

5.11.2) Upon receiving this document, the SUPPLIER shall immediately request that the CONTRACTOR inform which electrical and pneumatic utilities the HPU should use for the ENTERPRISE for which it is intended.

5.11.3) When starting the detailing of the project, the SUPPLIER must ask the CONTRACTOR to specify all the types of hydraulic and pneumatic connections that the HPU must use for the project for which it is intended. A preliminary list to be checked includes:

a) Outlet supplies LP1, LP2, HP1, and HP2;

b) Outlet supplies for the Well Control Rack;

c) Fluid return from the Well Control Rack;

d) Outlet supplies for the SESDV panel;

e) Skid drain;

f) Filling lance;

g) Compressed air intake.

5.11.4) The electrical and hydraulic interfaces shall be designed so that any exertion on the hydraulic lines or electrical cables, outside the HPU, is supported by the HPU's structure, and not transmitted to its internal lines.

5.11.5) The HPU shall be provided with its connections protected against contamination during transportation.

5.11.6) All external hydraulic and pneumatic connections must be located on "Bulkhead" type plates, with individual identification of each function.

5.12) Inspection and testing requirements

5.12.1) The HPU's commissioning in the FPU shall be preceded by a hydrostatic testing, at the maximum admitted LP and HP pressures, and without damaging the components. Unless it is not possible, the test shall consider pressures equivalent to at least 1,1 times the maximum admissible values, for at least 15 minutes, after which there shall be no external or internal leakage, or a pressure drop greater than 2% of the test's pressure.

5.12.2) The SUPPLIER shall verify the cleanliness class of the control hydraulic fluid according to norm ISO 4406, from the final manufacturing stage until the end of the HPU's commissioning, by using electronic particle counting and/or the comparative method. In order to verify using comparison, at least three consecutive samples from the system's outlets shall demonstrate compliance with the system's cleanliness class.

Note: The portable Cleanliness Class verification equipment (including consumables) that is part of HPU's scope of supply to Petrobras should not be used prior to this phase.

5.12.3) It is recommended that the results of the verification of the cleanliness class of the hydraulic control fluid are always reported according to ISO 4406.

5.12.4) The SUPPLIER must submit the HPU testing, inspection, and quality assurance plan for approval by the CONTRACTOR.

5.13) Consumables, spares, and documentation of the HPU

5.13.1) Except for the first filling of hydraulic fluid after installation of the HPU in the FPU, which will be the responsibility of the CONTRACTOR, all HPU consumables shall be provided by the SUPPLIER at no additional cost to the CONTRACTOR, until final acceptance of the commissioning of the HPU by the CONTRACTOR.

5.13.2) Upon completion of the HPU fabrication, the SUPPIER shall deliver to the CONTRACTOR a spare parts list for two (2) years of operation. The CONTRACTOR shall forward this list to the ENTERPRISE.

5.13.3) It shall be provided with the HPU two (2) copies and four (4) separate manuals for: Operation; Maintenance; Preservation; and Design, respectively. Except for the Project, all the others must be in Portuguese or bilingual Portuguese-English.

5.13.4) The manual of Preservation shall contain instructions for storage and preservation of the HPU with hydraulic fluid util the operation phase.

5.13.5) The manual of the Project shall include the requirements of the Classification Society and other certifications, the Data Sheet for each component, the acceptance tests, and the warranty terms.

5.13.6) Each component of the HPU shall be identified by its manufacturer's commercial "Part Number" and may additionally be assigned a reference number by the SUPPLIER.

6) PACKAGING, STORAGE AND TRANSPORTATION

6.1) The individual HPU structures, including the components for interconnection between them, should be supplied properly preserved for transportation. Preservation shall include protection of those parts and components most exposed to damage during handling.

7) TRAINING

7.1) The SUPPLIER must perform training in the operation and maintenance of the HPU. The training shall be done in Brazil for two classes of ten PETROBRAS professionals. All training material, as well as the classes, must be in Portuguese. The classes must be held in any of the three cities: Rio de Janeiro (RJ), Macaé (RJ) and Santos (SP), to be chosen by Petrobras.

8) APPENDICES

Appendix I - Model for the LIST OF HPU CONSUMERS

WELLS AND SUBSEA EQUIPMENT:	TOTAL
A. Satellite production well with WCT-MUX (see criterion n. 1 for definition and quantity)	**Ta**
B. Satellite water injection well with WCT-MUX (see criterion n. 2 for definition and quantity)	**Tb**
C. Satellite gas injection well with WCT-MUX (see criterion n. 3 for definition and quantity)	**Tc**
D. Satellite production well with WCT-MUX that can be relocated to the MSP, giving the its umbilical slot in the FPU to connect a manifold	**Td**
E. Satellite water injection well with WCT-MUX can be relocated to the MSIAG/MSIA giving its umbilical slot in the FPU to connect a manifold	**Te**
F. Satellite gas injection well with WCT-MUX that can be relocated to the MSIAG giving its umbilical slot in the FPU to connect a manifold	**Tf**
G. MSIAG for two (2) WAG injection wells with WCT-MUX (criterion n. 4)	**Tg**
H. Pair of MSIAG in piggyback for up to four (4) WAG wells with WCT-MUX (criterion n. 5)	**Th**
I. SWIM for four (4) water injection wells with WCT-MUX (criterion n. 4)	**Ti**
J. MSP or MSPG for four (4) production wells with WCT-MUX (criterion n. 4)	**Tj**
K. Pair of piggyback wells (WCT-MUX) connected directly to the FPU (criterion n. 6)	**Tk**
L. Satellite well (whatever the well) with WCT-HD (see criterion n. 7 for definition and quantity)	**Tl**
M. SDU for up to 5 wells with WCT-MUX (criterion n. 8)	**Tm**
N. SESDV (Subsea Emergency Shutdown Valves) (see criterion n. 9 for definition and quantity)	**Tn**
O. SDU for up to 4 wells + MSGL (Subsea Gas-Lift Manifold)	**To**
P. SDU for up to 5 wells + two PLEM-CHK-PO/IA/PG (Pipe Line End Manifold with Choke Valve) (see criterion n. 11 for definition and quantity)	**Tp**
Q. SDU + PLEM-HMXO (Pipe Line End Manifold with Hydrate Mitigator Crossover) (see criterion n. 10 for definition and quantity)	**Tq**
R. SDU cascaded with SDU for up to 5 wells with WCT-MUX (criterion n. 12)	**Tr**

Abbreviations:

- **WCT-MUX**: Wet Christmas tree with multiplexed electrohydraulic control system

- **WCT-HD**: Wet Christmas tree to direct hydraulic control
- **MSIAG**: Subsea manifold for water and gas injection
- **MSIA**: Subsea water injection manifold
- **MSP**: Subsea production manifold
- **MSPG**: Subsea production Gas Manifold
- **MSGL**: Subsea Gas Lift Manifold
- **PLEM-CHK**: Pipe Line End Manifold for two wells equipped with choke valve.
- **SDU**: Subsea electro-hydraulic distribution unit.
- **WAG**: Water alternating gas.
- **HMXO**: Hydrate Mitigator Crossover.

Criteria for the information of the quantities of equipment:

1) The satellite well is the one whose WCT control umbilical is directly connected to the FPU. The total shall be the sum of all satellite production wells equipped with WCT-MUX;
2) The satellite well is one whose WCT control umbilical is directly connected to the FPU. The total shall be the sum of all water injection wells equipped with WCT-MUX, EXCLUDING those that may be relocated to manifolds later on;
3) The satellite well is the one whose WCT control umbilical is directly connected in the FPU. The total shall be the sum of all satellite gas injection wells equipped with WCT-MUX, EXCLUDING those that may be relocated to manifolds later on;
4) Sum of all manifolds of the type provided for direct connection to the FPU;
5) Sum of MSIAG PAIRS in piggyback. Each MSIAG will be connected to the FPU by an independent umbilical;
6) Sum of the PAIRS of piggyback wells connected to the FPU by the umbilical of the respective Master WCT-MUX;
7) A maximum of two (2) FPU satellite wells equipped with WCT-HD;
8) Sum of all SDU, collecting only WTC-MUX, which are directly connected to the FPU;
9) A maximum of four (4) SESDV provided for direct connection to the FPU.
10) A maximum of three (4) PLEM-HMXO or SEDSV provided for direct connection to the FPU.
11) Sum of all SDU, collecting WTC-MUX and PLEM-CHK, which are directly connected to the FPU;
12) Sum of all system, collecting only WTC-MUX, which are directly connected to the FPU;

Appendix II – Volume estimation procedures

This section presents the procedure to find volumes resulting from the expansion of umbilical hoses considering the types of subsea equipment specified according to the model in presented in Appendix I.

The procedure for calculating the volume considers the total number of subsea wells and equipment presented in the HPU CONSUMERS LIST (completed according to the model in Appendix I above). Each type or set of subsea equipment(s) presented in HPU CONSUMERS LIST has its own single-line umbilical interconnection with the FPU. The respective single-line diagram with the length of each umbilical is presented in Appendix VI of this document.

For HPU sizing, the total volume corresponding to the volumetric expansion of all umbilical shall be the sum of all volumes calculated for the quantity of each type or set of subsea equipment(s) in the HPU CONSUMERS LIST (Ta, Tb, ... Tn).

The expansion volume for Tn shall be calculated as TPU umbilical according to the formulations herein presented:

Abbreviations and accronyms:

- **VHP** = Volume from the expansion of one (1) ½" thermoplastic hose @ 10,000 psi for umbilical length Dn according to the figure in Appendix VI. The pressure of 10,000 psi shall be a premise for the dimensioning, regardless of the umbilical to be used;
- **VLP** = Volume from the expansion of one (1) ½" thermoplastic hose @ 5,000 psi of umbilical Dn according to the figure in Appendix VI;
- **VHDHP** = Volume from the expansion of two (2) 3/8" thermoplastic hoses @ 10,000 psi of umbilical **Dn** according to the figure in Appendix VI. The pressure of 10,000 psi shall be a premise for the dimensioning, regardless of the umbilical to be used;
- **VHDLP** = Volume from the expansion of four (4) 3/8" thermoplastic hoses @ 5,000 psi of umbilical **Dn** according to the figure in Appendix VI.

A. Satellite production well with WCT-MUX
   VRa = **Ta** x (D1 x (VHP+VLP))

B. Satellite water injection well with WCT-MUX
   VRb = **Tb** x (D1 x (VHP + VLP))

C. Satellite gas injection well with WCT-MUX
   VRc = **Tc** x (D1 x (VHP + VLP))

D. Satellite production well with WCT-MUX that can be relocated to MSP or MSPG, giving its umbilical slot in the FPU to connect a manifold.
Note: This alternative shall consider the volumes for the manifold, which can be MSP or MSIA.
VRd = **Td** x (D16 x (VHP + VLP) + D17 x (VHP + VLP) + D18 x (VHP + VLP) + D19 x (VHP + VLP) + D20 x (VHP + VLP))

E. Satellite water injection well with WCT-MUX that may be relocated to MSIAG / MSIA, giving its umbilical slot in the FPU to connect a manifold.
Note: This alternative shall consider volumes for one (1) MSIA.
VRe = **Te** x (D11 x (VHP + VLP) + D12 x (VHP + VLP) + D13 x (VHP + VLP) + D14 x (VHP + VLP) + D15 x (VHP + VLP))

F. Satellite gas injection well with WCT-MUX that will may be relocated to MSIAG, giving its umbilical slot in the FPU to connect a manifold.
Note: This alternative shall consider volumes for one (1) MSIAG.
VRf = **Tf** x (D6 x (VHP + VLP) + D7 x (VHP + VLP) + D8 x (VHP + VLP))

G. MSIAG for two (2) WAG injection wells with WTC-MUX.
VRg = **Tg** x (D6 x (VHP + VLP) + D7 x (VHP + VLP) + D8 x (VHP + VLP))

H. Pair of MSIAG in piggyback for up to (4) WAG wells with WTC-MUX.
VRh = **Th** x (((D9 x (VHP + VLP) + D7 x (VHP + VLP) + D8 x (VHP + VLP)) + (D10 x (VHP + VLP) + D7 x (VHP + VLP) + D8 x (VHP + VLP)))

I. MSIA for four (4) water injection wells with WTC-MUX.
VRi = **Ti** x (D11 x (VHP + VLP) + D12 x (VHP + VLP) + D13 x (VHP + VLP) + D14 x (VHP + VLP) + D15 x (VHP + VLP))

J. MSP or MSPG for four (4) production wells with WCT-MUX.
VRj = **Tj** x (D16 x (VHP + VLP) + D17 x (VHP + VLP) + D18 x (VHP + VLP) + D19 x (VHP + VLP) + D20 x (VHP + VLP))

K. Pair of piggyback wells (WTC-MUX) connected directly to the FPU.
VRk = **Tk** x (D2 x (VHP + VLP) + D3 x (VHP + VLP))

L. Satellite well to the FPU with WTC-HD.
VRl = **Tl** x ((D4 x (VHDHP + VHDLP)), where Tl = 1 or 2.

M. SDU for five (5) WTC-MUX.

VRm = **Tm** x (D21 x (VHP + VLP) + D22 x (VHP + VLP) + D23 x (VHP + VLP) + D24 x (VHP + VLP) + D25 x (VHP + VLP) + D26 x (VHP + VLP))

N. SESDV

VRn = **Tn** x D5 x VLP x n, where 1 ≤ n ≤ 4 according to the number of SESDV lines to be informed by the CONTRACTOR.

O. SDU for five (5) WCT-MUX and two (2) PLEM-CHK-PO/IA/PG

VRo = **To** x (D27 x (VHP + VLP) + D28 x (VHP + VLP) + D29 x (VHP + VLP) + D30 x (VHP + VLP) + D31 x (VHP + VLP) + D32 x (VHP + VLP)) + D33 x (VHP + VLP)) + D34 x (VHP + VLP))

P. SDU for four (4) WTC-MUX and a MSGL

VRp = **Tp** x (D35 x (VHP + VLP) + D36 x (VHP + VLP) + D37 x (VHP + VLP) + D38 x (VHP + VLP) + D39 x (VHP + VLP) + D40 x (VHP + VLP))

Q. SDU + PLEM-HMXO or SDU + SESDV

VRq = **Tq** x (D48 x VLP x n + D49 x VLP x n + D50 x VLP x n + D51 x VLP x n + D52 x VLP x n) where 1 ≤ n ≤ 4 according to the number of HMXO lines to be informed by the CONTRACTOR.

R. SDU cascaded with SDU for five (5) WTC-MUX

VRr = **Tr** x (D41 x (VHP + VLP) + D42 x (VHP + VLP) + D43 x (VHP + VLP) + D44 x (VHP + VLP) + D45 x (VHP + VLP) + D46 x (VHP + VLP) + D47 x (VHP + VLP))

Appendix III – Expansion Coefficients for Umbilical

Expansion Coefficients for Hydraulic Umbilical Control Lines: When sizing the HPU, SUPPLIER shall consider a volumetric expansion according to data presented below.

a) **Umbilical TPU:**

Table 1: Volumetric expansion for 3/8" hose TPU	
Pressure (psi / bar)	Maximum permissible expansion (cc/m – cc/ft.)
3,000 / 204	5.67 – 1.72
5,000 / 340	7.56 – 2.30
7,500 / 510	9.66 – 2.94
10,000 / 680	11.76 – 3.58

Table 2: Volumetric expansion for 1/2" hose TPU	
Pressure (psi / bar)	Maximum permissible expansion (cc/m – cc/ft.)
3,000 / 204	10,03 – 3,06
5,000 / 340	13,45 – 4,10
7,500 / 510	17,16 – 5,23
10,000 / 680	20,90 – 6,37

b) **Umbilical STU:**

Table 3: Volumetric expansion for 1/2" Steel Tube	
Pressure (psi / bar)	Maximum permissible expansion (cc/m – cc/ft.)
5,000 / 340	0,030 – 0,009
10,000 / 680	0,13 – 0,034

Appendix IV – Actuator volumes

Table for equivalent swept volumes for the TOTAL hydraulic actuators for each type of subsea equipment referred to in this ET (except for the calculation of the accumulators' bank):

Equipment	Total equivalent volume of the actuators***
1x WCT-MUX	LP: 23 liters HP: 1 liter
1x MSIAG connected to 2x WCT-MUX	LP: 16 liters (MSIAG) + 46 liters (2x WCT) HP: 2 liters
1x MSP or MSIA or MSPG connected to 4x WCT-MUX	LP: 48 liters (MSP or MSPG) + 92 liters (4x WCT) HP: 4 liters
1x WCT-HD	LP: 22 liters HP: 0,5 liters
1x SESDV	LP: 8 liters
1x PLEM-HMXO	LP: 8 liters
1x MSGL	LP: 16 liters HP: 2 liters
1x PLEM-CHK-PO/IA/PG	LP: 23 liters HP: 1 liter

Table 4: Total equivalent volume of the actuators for each equipment

Notes:

1) The totals for WCT-MUX (SCEHM) and WCT-HD (SCHD) already include the well's DHSV;

2) The totals for WCT, MSGL, PLEM-CHK, MSIAG, MSPG and MSP (all with SCEHM) already include 1 liter for internal accumulator of the respective(s) SCM;

3) HP volumes include DHSV (typical 0.02 liter) and smart completion functions.

Appendix V – DCV's quantities

Table of quantity of DCV (subsea) for type of subsea equipment referred in this ET:

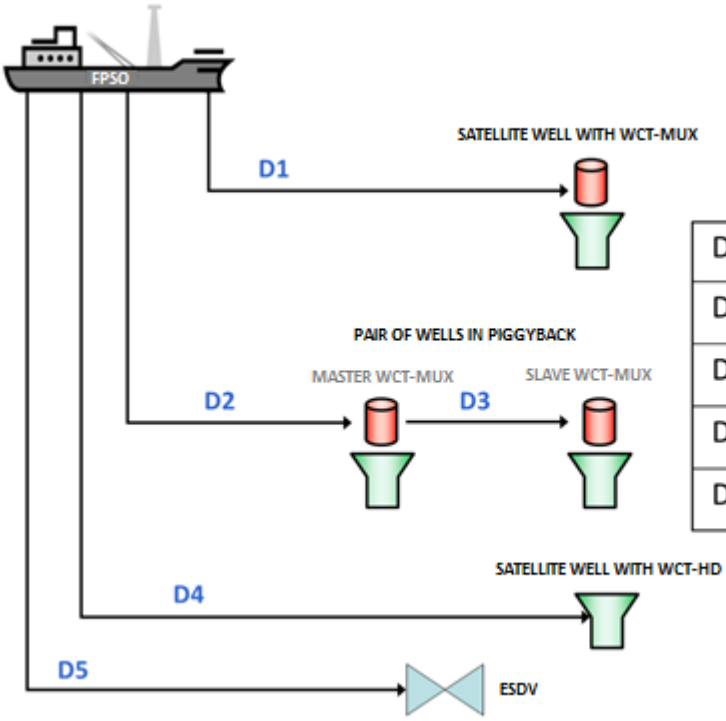
Equipment	Quantity of DCV for each type
1x WCT-MUX	LP: 20 HP: 4
1x MSIAG connected to 2x WCT-MUX	LP: 40 (MSIAG) + 40 (to 2x WCT) HP: 16 (to MSIAG + 2x WCT)
1x MSP or MSIA or MSPG connected a 4x WCT-MUX	LP: 40 (MSP or MSPG) + 80 (to 4x WCT) HP: 24 (to MSP + 4x WCT)
1 x MSGL	LP: 40 HP: 8
1 x PLEM-CHK	LP: 20 HP: 4

Notes:

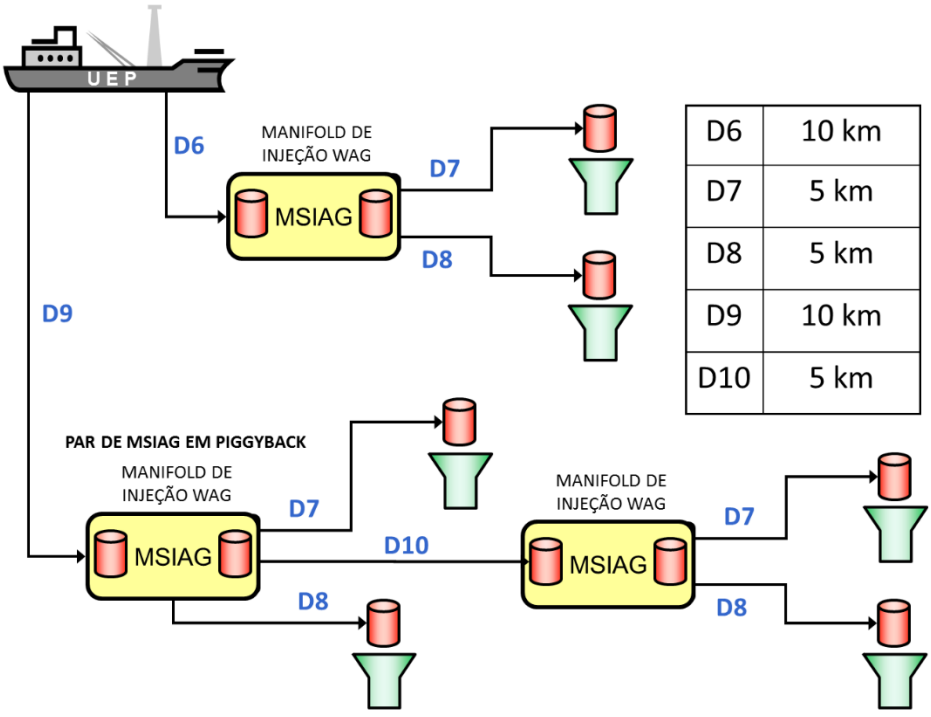
1) For the purpose of normalization, all SCM were considered to have 24 control functions, from which 20x are LP and 4x are HP. The amount of SCM per subsea equipment will be:
    a. 1x SCM for each WCT with SCEHM (WCT-MUX);
    b. 4 x SCM for each set: MSIAG (with SCEHM) and its 2 injection wells with WTC-MUX;
    c. 8 x SCM for each set: MSP or MSPG (with SCEHM) and its 4 production wells with WCT-MUX.
    d. 6 x SCM for each set: SDU connecting 4 WCT and 1 MSGL.
    e. 7 x SCM for each set: SDU connecting 5 WCT and 2 PLEM-CHK.

Appendix VI – Typical unifilar diagrams

Typical unifilar diagrams for subsea equipment connection

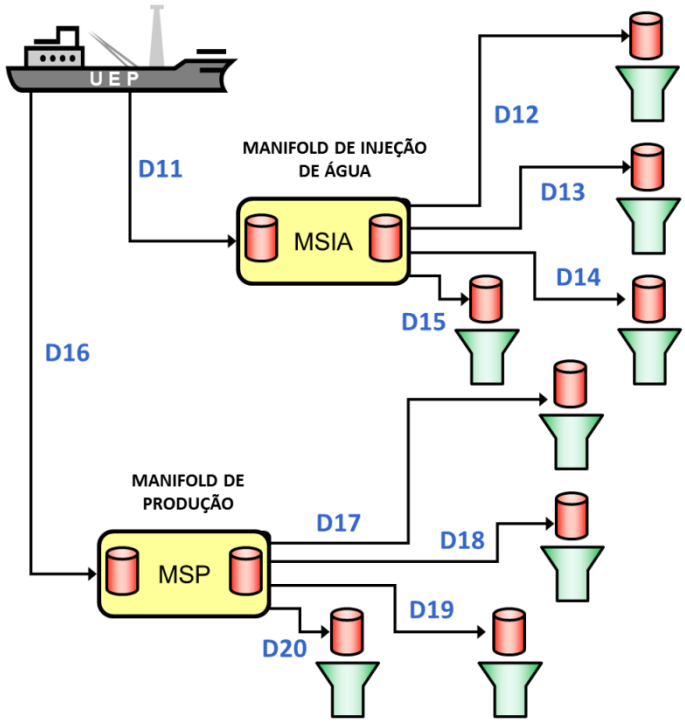


D1	10 km
D2	10 km
D3	10 km
D4	10 km
D5	6 km

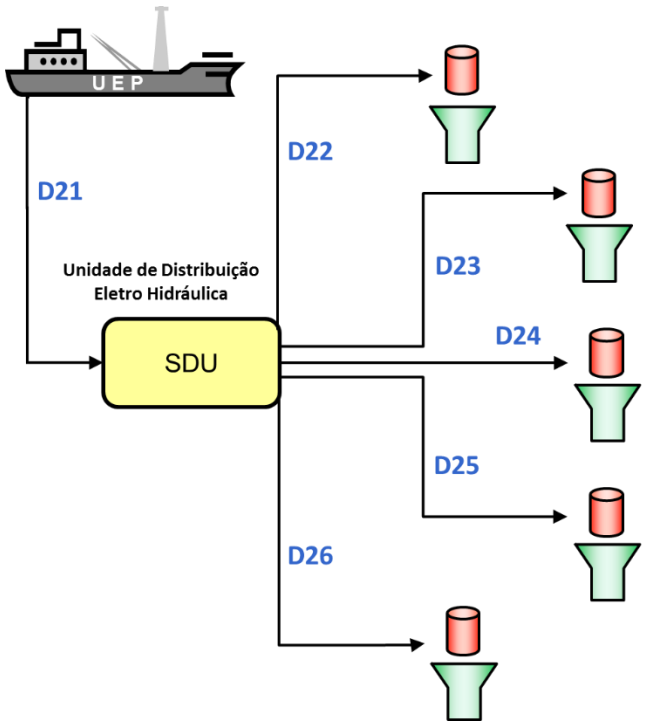


D6	10 km
D7	5 km
D8	5 km
D9	10 km
D10	5 km

NOTE: The umbilical lengths (Dn) are just a reference. The SUPPLIER shall request from the CONTRACTOR the lengths to be used for the HPU' s dimensioning.

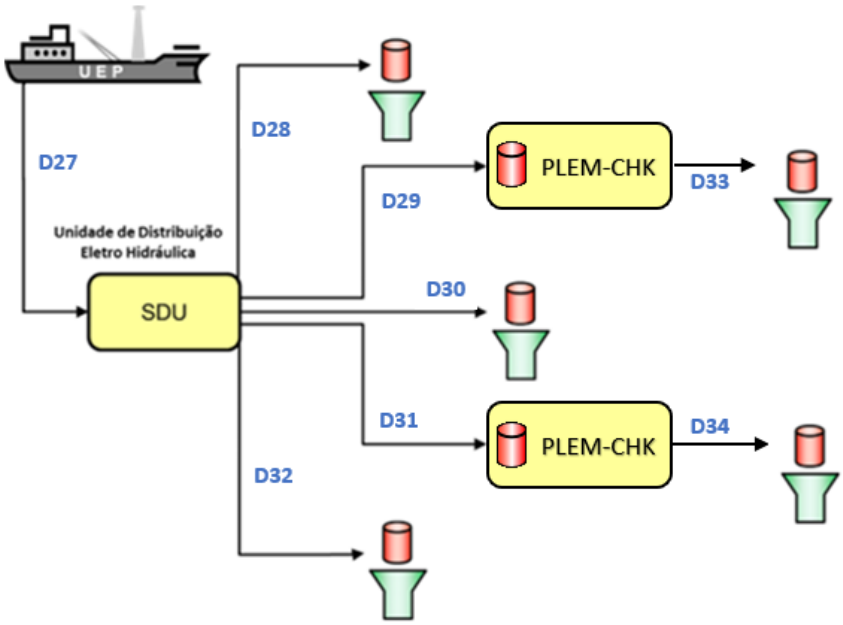


D11	10 km
D12	5 km
D13	5 km
D14	5 km
D15	5 km
D16	10 km
D17	5 km
D18	5 km
D19	5 km
D20	5 km

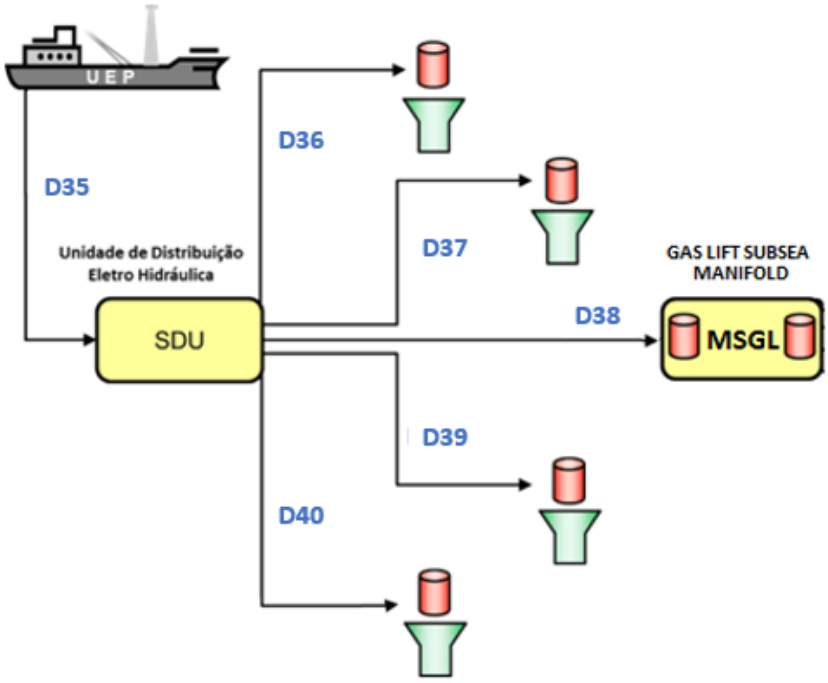


D21	7,5 km
D22	12,5 km
D23	5,0 km
D24	5,0 km
D25	5,0 km
D26	5,0 km

NOTE: The umbilical lengths (Dn) are just a reference. The SUPPLIER shall request from the CONTRACTOR the lengths to be used for the HPU' s dimensioning.

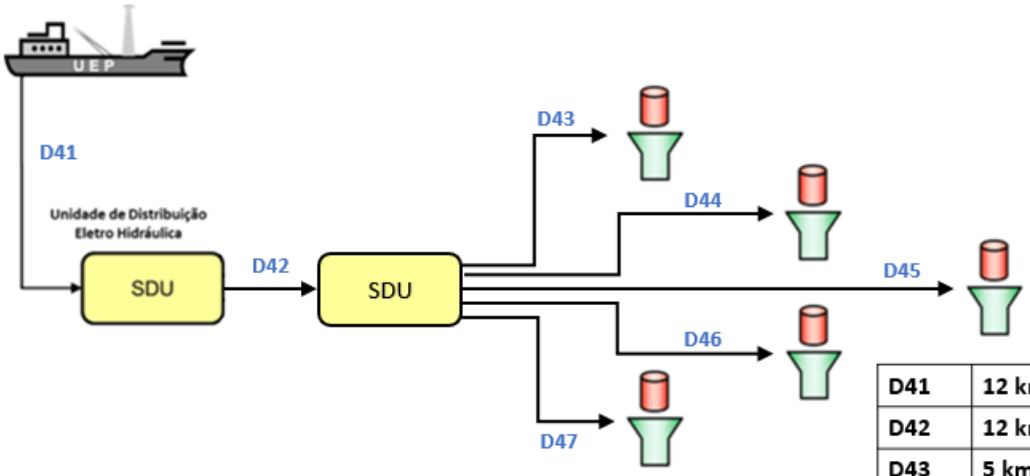


D27	12 km
D28	5 km
D29	7,5 km
D30	5 km
D31	5 km
D32	5 km
D33	50 mts
D34	50 mts

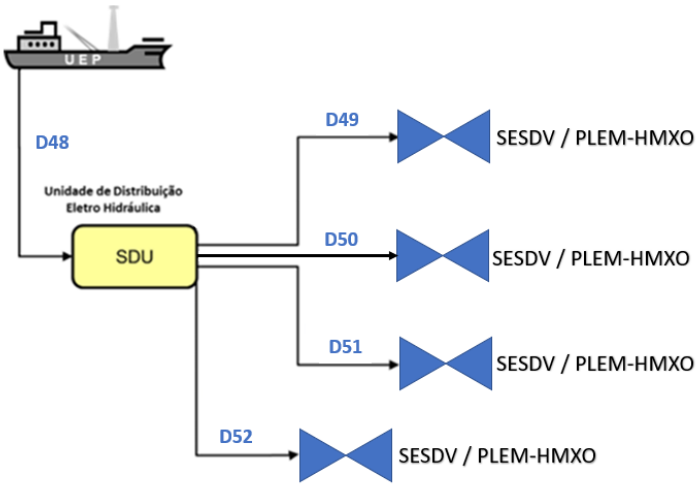


D35	12 km
D36	5 km
D37	7,5 km
D38	5 km
D39	5 km
D40	5 km

NOTE: The umbilical lengths (Dn) are just a reference. The SUPPLIER shall request from the CONTRACTOR the lengths to be used for the HPU' s dimensioning.



D41	12 km
D42	12 km
D43	5 km
D44	5 km
D45	5 km
D46	5 km
D47	5 km

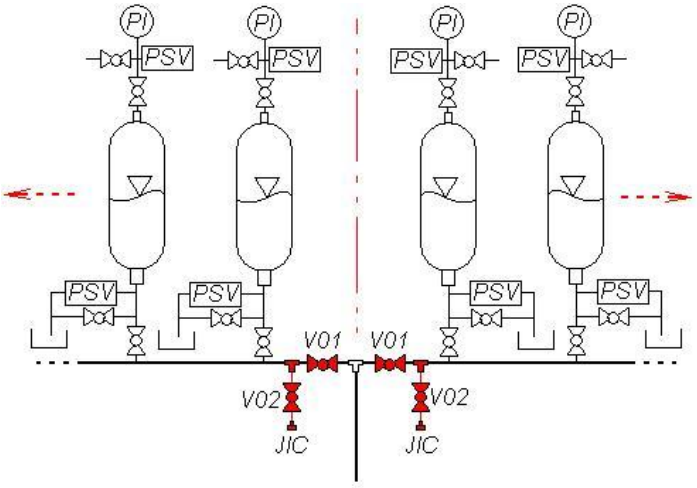


D48	6 km
D49	2 km
D50	2 km
D51	2 km
D52	2 km

NOTE: The umbilical lengths (Dn) are just a reference. The SUPPLIER shall request from the CONTRACTOR the lengths to be used for the HPU' s dimensioning.

Appendix VII – Typical diagram to divide accumulators

Typical diagram to divide each accumulators' bank into two groups by using sphere block valves and connector for maintenance, consisting of a 1/2" ball block valve and a buffered JIC 37° 3/8" connector.



Appendix VIII – HPU supply chain

Suggestions for technical criteria to evaluate potential candidates to supply the HPU:

1) The Hydraulic Power Unit (HPU) hereinafter referred to as “Multiplexed HPU” or HPU-MUX is a particular implementation of HPU for offshore use, specified to store and supply pressurized water-glycol based hydraulic fluid with Cleaning Class 17/15/12 by ISO 4406 required for the operation of Multiplexed Electro-hydraulic Control System(s) that are equipped with a Subsea Control Module (Subsea Control Module or SCM), according to items 4.1 (supplemented by A.3.3 in Appendix A), 4.4.1.a, and 4.4.1.h of the API 17F Standard for Subsea Production Control Systems, 3rd Edition, May 2014. Figure 1 of API 17F is for reference to visualize the typical architecture of Multiplexed Electro-hydraulic Control Systems equipped with SCM, used in different types of subsea production equipment such as Wet Christmas Tree (XT) and Manifold and over pressure control equipment (HIPPS).

2) In order to supply the Multiplexed HPU to Petrobras, the manufacturer shall have field proven track record for their products which shall be demonstrated by:

a) Option 1: Manufacturer shall prove at least 3 (three) supplies of HPU for supply of water-glycol based hydraulic fluid with Cleaning Class (minimum) 17/15/12 per ISO 4406 for operation of Multiplexed Electro-hydraulic Control System(s) equipped with Subsea Control Module (SCM) in subsea equipment such as Wet Christmas Tree, Template-Submarine, Manifold, or Submarine Manifold. In case of the most recent supply being more than 5 (five) years ago, the company will have to additionally prove it through 3rd Party certification by an internationally recognized entity that has qualified personnel, engineering, infrastructure and manufacturing process, component qualification, Testing Factory Acceptance (FAT), which meet items 5.4.6 (Design Requirements), 8 (Materials and Fabrication), 9.2.2 (Qualification of Hydraulic-Mechanical Components) and 9.3.2 (FAT) of the API 17F standard for application that requires Cleaning Class 17/15/12 defined by the ISO 4406 standard. The 3rd Party certification shall also prove that the Multiplexed HPU manufacturer has personnel qualified with previous experience in material compatibility tests with hydraulic control fluids, either with its own infrastructure or through contracting laboratories able to carry it out.

b) Option 2: Manufacturer shall prove at least 3 (three) supplies of HPU for flushing with water-glycol based hydraulic fluid with Cleaning Class (minimum) 17/15/12 per ISO 4406, supplied to equipment manufacturers of Multiplexed Electro-Hydraulic Control Systems equipped with Subsea Control Module (SCM) for Wet Christmas Tree, Submarine Template-Manifold, or Submarine Manifold.

3) The Multiplexed HPU manufacturer shall prove through a 3rd Party certification, provided by an internationally recognized entity, that has qualified personnel, engineering, infrastructure and manufacturing process, component qualification, Factory Acceptance Test (FAT), which meet items 5.4.6 (Design Requirements), 8 (Materials and Manufacturing), 9.2.2 (Qualification of Hydraulic-Mechanical Components) and 9.3.2 (FAT) of API 17F standard for application that requires Cleaning Class 17/15/12 defined by the standard ISO 4406. The 3rd Party certification shall prove that the Multiplexed HPU manufacturer has qualified personnel in material compatibility tests with hydraulic control fluids.

4) Have assembly facilities that avoid direct exposure to elements such as sand, earth, gravel, dust, and debris from cutting and reaming of metallic materials;

5) Have procedures for preservation and proper handling of components from receipt to assembly on the HPU, especially but not limited to tubing, filter elements, blocking valves, regulator and relief valves, and accumulators;

6) Have the infrastructure to analyze fluid samples for possible contamination;

7) Have flushing procedures for cleanliness class 15/13/10, according to ISO 4406 (Class 4 according to the old norm NAS 1638) and cleanliness class 17/15/12, according to the norm ISO 4406 (Class 6 according to the old norm NAS 1638);

8) Have HSE procedures for handling and exposing professionals to hydraulic control fluid during all phases of assembly, testing and commissioning of equipment;

9) Check HPU supplies for multiplexed electrohydraulic control systems of subsea production equipment installed in offshore units, or similar HPU supplies for hydraulic circuit cleaning and framework of cleanliness class of the fluid for the subsea and umbilical equipment (flushing) according to ISO 4406 classes 17/15/12 and 15/13/10.

10) Some verification items recommended:

a) Certificate for offshore operation with zone 2 classification, group IIa, temperature T3, according to IEC-60079-0;

b) Pressure class 5,000 psi or higher;

c) Operation with water-glycol based hydraulic fluid compatible with the following properties:

- Density @ 15.6C or 20C: between 1.02 and 1.08 g/ml;
- Viscosity @ 0C: between 3.0 and 9.2cSt;
- PH @ 20C: between 8.8 and 9.7;

d) Structure(s) in AISI-316L stainless steel;

e) Valves, instruments and their accessories (e.g.) shall be made of AISI-316L stainless steel;

f) All hydraulic and pneumatic lines (tubing) classified as ASTM A269 GR TP, in 316 or 316L stainless steel;

g) All hydraulic connectors shall be double ferrule, with double flared rings, made of 316L stainless steel;

h) Sealing of NPT flanges with chemical flange sealant, not allowing the use of Teflon tape;

i) Stainless steel accumulators, preferably bladder, equipped with nitrogen preload circuits, pressure and nitrogen pressure gauges, relief manifold and relief valves, relief and safety valves, and bursting discs;

j) Automation of the halt and start of the pumps by fixed logic or programmable logic controller (PLC);

k) Delivery (commissioning) with fluid in cleanliness class 15/13/10, according to norm ISO 4406 (class 4 according to the old norm NAS 1638);

l) Operation with fluid of cleanliness class 17/15/12, according to norm ISO 4406 (class 6 according

to the old standard NAS 1638);

---X---