### TECHNICAL SPECIFICATION

- **Nº:** I-ET-3010.00-1210-390-P4X-001
- **CLIENT:** SRGE
- **PROJECT:** REFERENCE BASIC DESIGN
- **UNIT:** BÚZIOS
- **TITLE:** HYDRAULIC POWER UNIT (HPU) FOR SUBSEA SYSTEM

Project Information:
- **PROJECT REFERENCE:** BASIC DESIGN 1001056398 0010
- **UNIT:** BÚZIOS
- **TITLE:** HYDRAULIC POWER UNIT (HPU) FOR SUBSEA SYSTEM

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1 INTRODUCTION

1.1 Object

1.1.1 This technical specification describes the minimum requirements and basic characteristics for a Hydraulic Power Unit for controlling subsea equipment and wells.

1.1.2 This HPU shall be used for driving all Christmas tree valves and other subsea valves. All scope in this specification, unless otherwise specified, is CONTRACTOR scope of supply.

1.2 Definitions

PURCHASER The Company designated as such in the Contract or the Purchase Order.

INTEGRATOR Third party responsible for integration of HPU external items among the FPU.

CONTRACTOR HPU supplier, responsible for all its scope.

1.3 Abbreviations

<table>
<thead>
<tr>
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<th>Definition</th>
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<tr>
<td>BDV</td>
<td>Blowdown Valve</td>
</tr>
<tr>
<td>CSS</td>
<td>Control and Safety System</td>
</tr>
<tr>
<td>DCV</td>
<td>Directional Control Valve</td>
</tr>
<tr>
<td>ESD</td>
<td>Emergency Shutdown</td>
</tr>
<tr>
<td>FPU</td>
<td>Floating Production Unit</td>
</tr>
<tr>
<td>HP</td>
<td>High Pressure</td>
</tr>
<tr>
<td>HPU</td>
<td>Hydraulic Power Unit</td>
</tr>
<tr>
<td>LP</td>
<td>Low Pressure</td>
</tr>
<tr>
<td>NPT</td>
<td>National Pipe Thread</td>
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<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
</tr>
<tr>
<td>PSV</td>
<td>Pressure Safety Valve</td>
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<tr>
<td>SCM</td>
<td>Subsea Control Module</td>
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<tr>
<td>SCSSV</td>
<td>Surface Controlled Subsurface Safety Valve</td>
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<tr>
<td>SDV</td>
<td>Shutdown Valve</td>
</tr>
<tr>
<td>SESDV</td>
<td>Subsea Emergency Shutdown Valve</td>
</tr>
<tr>
<td>WAG</td>
<td>Water Alternating Gas</td>
</tr>
<tr>
<td>WCR</td>
<td>Well Control Rack</td>
</tr>
<tr>
<td>WCT HD</td>
<td>Wet Christmas Tree Hydraulic Direct</td>
</tr>
<tr>
<td>WCT MUX</td>
<td>Wet Christmas Tree Multiplexed</td>
</tr>
</tbody>
</table>
2 REFERENCE DOCUMENTS, CODES AND STANDARDS

2.1 ISO – International Organization for Standardization

- ISO 2941: Filter elements - verification of collapse/burst pressure rating
- ISO 2942: Filter elements - verification of fabrication integrity and determination of the first bubble point
- ISO 2943: Filter elements - verification of material compatibility with fluids
- ISO 3968: Filters - Evaluation of differential pressure versus flow characteristics
- ISO 10949: Guidelines for achieving and controlling cleanliness of components from manufacture to installation
- ISO 11170: Filter Elements - sequence of tests for verifying performance characteristics
- ISO 4406: Hydraulic fluid power— Fluids — Method for coding the level of contamination by solid particles

2.2 IEC - International Electrotechnical Commission

- IEC 60079: Explosive Atmospheres
- IEC 60529: Degrees of Protection Provided by Enclosures (IP Code)

2.3 API – American Petroleum Institute

- API STD 520: Sizing, selection and installation of Pressure-relieving devices
- API STD 526: Flanged steel pressure relief valves

2.4 BSI – British Standards Institute

- BSI BS 1290: Wire Rope Slings and Sling Legs for General Lifting Purposes

2.5 ASTM International

- ASTM A269: Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
- ASTM A789: Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service

2.6 Project Documentation

2.6.1 Names below and respective document codes may vary according to each project but, in general, the following documents shall be considered along with this technical specification.

- HYDRAULIC POWER UNIT (HPU) FOR SUBSEA SYSTEM - HYDRAULIC DIAGRAM
- WATER INJECTION WELL CONTROL RACK
- PRODUCTION WELL CONTROL RACK
- SESDVS CONTROL RACK
- WATER INJECTION WELL CONTROL RACK - LAYOUT
3 HYDRAULIC SYSTEM REQUIREMENTS

3.1 General requirements

3.1.1 The HPU shall provide a pressurized hydraulic control fluid supply based on water-glycol with cleanliness class 17/15/12, according to ISO 4406. The HPU shall be able to operate with any of these fluids:

- MacDermid HW443;
- MacDermid HW525P;
- Castrol Transaqua DW;

3.1.2 The HPU shall supply the pressurized control fluid for all subsea equipment with Multiplexed Control, Direct Hydraulic Control and other subsea valves. The number of each equipment will be according to each project definitions.

3.1.3 The sizing of tanks, accumulator bank and pumps shall be also in accordance to each project definitions. All equations for calculations are in appendix of this document.

3.1.4 All HPU sizing shall be submitted to PETROBRAS approval. All premises and results shall be clearly defined, including:

- Basic formulae
- Hydraulic lines expansion at maximum pressure
- Flowrate (L/min) and chosen supplier of electrical pumps
- Flowrate (L/Min) and chosen supplier of pneumatic pumps
- Flowrate (L/Min) and chosen supplier of recirculation pumps
- Tanks volume
- Accumulator bank volume and quantity for each pressure class

3.1.5 The total T of subsea equipment and wells, T, is equal to Ta + Tb + Tc +Td + Te + Tf + Tg + Th + Ti + Tj + Tk, defined according to table 1, below:

<table>
<thead>
<tr>
<th>Wells and subsea equipment</th>
<th>TOTAL</th>
</tr>
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<tbody>
<tr>
<td>A. Production Satellite Well with WCT MUX (See note 1)</td>
<td>Ta</td>
</tr>
<tr>
<td>B. Water Injection Satellite Well with WCT MUX (See note 2)</td>
<td>Tb</td>
</tr>
<tr>
<td>C. Gas Injection Satellite Well with WCT MUX (See note 3)</td>
<td>Tc</td>
</tr>
<tr>
<td>D. Production Satellite Well with WCT MUX that might be relocated to subsea production manifold</td>
<td>Td</td>
</tr>
<tr>
<td>E. Water injection Satellite Well with WCT MUX that might be relocated to subsea water/WAG manifold</td>
<td>Te</td>
</tr>
<tr>
<td>F. Gas injection Satellite Well with WCT MUX that might be relocated to subsea</td>
<td>Tf</td>
</tr>
</tbody>
</table>
### HYDRAULIC POWER UNIT (HPU) FOR SUBSEA SYSTEM

#### Notes:
1. Satellite well is the one that WCT control umbilical is connected directly to FPU. The total shall be the sum of all production satellite wells with WCT-MUX.
2. Satellite well is the one that WCT control umbilical is connected directly to FPU. The total shall be the sum of all water injection satellite wells with WCT-MUX, excluding the ones that may be relocated to manifolds.
3. Satellite well is the one that WCT control umbilical is connected directly to FPU. The total shall be the sum of all gas injection satellite wells with WCT-MUX, excluding the ones that may be relocated to manifolds.
4. Sum of all manifolds of the respective type to directly connection to the FPU.
5. Sum of pairs of subsea WAG manifolds in "Piggypack". Each subsea WAG manifold shall be interconnected to the FPU through an independent umbilical.
6. Sum of pairs of wells in “Piggypack” interconnected to the FPU by the respective “master” WCT-MUX umbilical.
7. Maximum of 2 satellite wells with WCT-HD.

#### 3.1.6 The HPU shall have a total T of sets of 4 outlets of regulated hydraulic supply, for all subsea equipment and wells with multiplexed electro-hydraulic control, being:

- a) 2 outlets of manually adjustable pressure between 4000 and 5000 psi, defined as LP1 and LP2, or simply LP (low pressure)
- b) 2 outlets of manually adjustable pressure between 6500 and 7500 psi, defined as HP1 and HP2, or simply HP (high pressure)

#### 3.1.7 Up to 4 outlets of either LP1, LP2, HP1 and HP2 can share, respectively, the same pressure regulation. That is, 4 outlets of LP1 can share a LP1 pressure regulation, 4 outlets of LP2 can share a LP2 pressure regulation, 4 outlets of HP1 can share a HP1 pressure regulation and 4 outlets of HP2 can share a HP2 pressure regulation. The hydraulic circuit shall have 2 manual pressure regulator valves, in parallel, with blockage valves between them, such as one valve is spare of the other.

#### 3.1.8 In order to meet up to 2 wells with WCT-HD, the HPU shall have 3 outlets of regulated hydraulic supply to the Well Control Rack (WCR). Each outlet shall supply the three individual Well Control Hack headers, being:

- a) 1 outlet of manually adjustable pressure between 3000 and 5000 psi, for the WCR DCVs header that will actuate gate valves in the WCT.
- b) 1 outlet of manually adjustable pressure between 4000 and 5000 psi, for the WCR DCVs header that will actuate SCSSVs in the WCT 5k.
- c) 1 outlet of manually adjustable pressure between 6500 and 7500 psi, for the WCR DCVs header that will actuate SCSSVs in the WCT 10k.
3.1.9 The HPU shall receive the return of depressurized fluid through WCR. The WCR tubing and connections shall have a minimum internal diameter of \(\frac{1}{2}\)"

3.1.10 Each outlet to the WCR shall have its own manual pressure-regulating valve.

3.1.11 To supply up to 4 subsea SDVs from the FPU, the HPU shall have two redundant outlets of hydraulic supply, adjustable between 1350 and 3300 psi for the DCV rack of the subsea SDVs. The HPU shall not receive hydraulic fluid return from the subsea SDVs.

3.1.12 Each outlet to the DCV rack of the subsea SDVs shall have its own manual pressure-regulating valve.

3.1.13 The HPU shall have a header of non-regulated pressure upstream all manual LP regulating valves. The sizing of this pressure range shall allow that the pressure regulating valves can supply the regulated pressure within this range, that is, LP1 and LP2 outlets, 3000-5000 psi and 4000-5000 outlets for WCR and subsea SDVs outlets.

3.1.14 The HPU shall have a header of non-regulated pressure upstream all manual HP regulating valves. The sizing of this pressure range shall allow that the pressure regulating valves can supply the regulated pressure within this range, that is, HP1 and HP2 outlets and 6500-7500 outlets for WCR.

3.1.15 It shall be possible to convert maximum operating pressure from HP and WCR outlets from 7500 to 10000 psi. For such, it shall be considered easy-to-replace components, such as safety valves and pressure regulating valves. The conversion shall not include tubing, connections, pumps, accumulators, filters, instruments and DCVs. The HPU PLC shall already include operation with 10000 psi, such as means for its activation. All components to be replaced during this conversion shall be supplied with double blockage valves, upstream and downstream them, where applicable.

3.2 Constructive characteristics

3.2.1 The HPU shall be designed to operate in explosive atmospheres, with Zone 2 Group IIA temperature class T3, according to IEC 60079.

3.2.2 The HPU shall be made in stainless steel ASTM A269 Gr. TP 316L, with three sub-skids:
   - Skid 01: electrical and pneumatic pumps, DCV racks, pressure regulating valves rack, Motor Control Center and PLC.
   - Skid 02: tanks and recirculation pumps
   - Skid 03: accumulator bank.

3.2.3 As a whole, the HPU shall have the following equipment:
   a) 1 supply tank
b) 1 return tank

c) 1 non-regulated LP header

d) 1 non-regulated HP header

e) 2 electrical and 2 pneumatic pumps for HP header

f) 4 electrical and 2 pneumatic pumps for LP header

g) 2 recirculation pumps

h) Filters to keep the fluid cleanliness class

i) Accumulator bank for HP header

j) Accumulator bank for LP header

k) PLC

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 subsea SDVs

p) Double blockage valves for HP outlets and header

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

3.2.4 The skids shall be designed to protect the HPU and all its equipment during lifting and offshore transport. Each skids shall have 4 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.

3.2.5 The skids shall allow easy of access in their interior, with adequate space for maintenance and removal of its components. The piping routing shall allow this as well.

3.2.6 All electrical, hydraulic and pneumatic interconnections between HPU skids is INTEGRATOR scope of supply and execution.

3.2.7 The base of each skid shall have a slope such as any possible fluid leakage is drained to 2 lateral threaded outlets

3.2.8 Each skid shall be supplied ready for installation.

3.3 Operation and maintenance

3.3.1 The HPU shall have its own Local Control Panel, located in its external side. All instruments, visual indicators, valves and pushbuttons shall be located to provide ease of local HPU operation.

3.3.2 The Local Control Panel shall have at least the following equipment:

a) Pressure gauges for visualization of non-regulated hydraulic supply pressures of each header

b) Pressure gauges for visualization of regulated hydraulic supply pressures of each outlet LP1, LP2, HP1, HP2, WCR supply and subsea SDVs supply.
c) Pressure gauges for visualization of regulated and non-regulated air supply pressures
d) Status indicators (on, off, duty and standby) for each electrical and each pneumatic pump
e) Continuous visualization of supply and return tank levels
f) Continuous visualization of pump lubrication tank level

3.3.3 Sampling points for fluid cleanliness class shall be supplied in the main hydraulic circuits of the HPU. As a minimum, they shall be located:
a) In the recirculation pumps discharge
b) In supply and return tanks outlets
c) Between supply pumps discharge and accumulators of each header
d) Between each header accumulators and pressure regulating valves
e) Downstream pressure regulating valves for up to 4 outlets of the same supply

3.3.4 HPU shall allow each recirculation pump to be operated individually or together, even with low level in both supply and return tanks.

3.4 Hydraulic fluid conditioning

3.4.1 HPU shall have two tanks, for supply and return of hydraulic fluid. The supply tank volume shall be $V = 1.5 \times (A+B+C)$, where:

- $A =$ LP accumulators volume + HP accumulators volume (refer to item 3.6)
- $B =$ Umbilical hoses expansion volume (refer to appendix)
- $C =$ Actuators total volume (refer to appendix)

3.4.2 If $V$ is greater than 2000 liters, it shall be added a safety margin of 750 liters.

3.4.3 The return tank shall have a volume greater than or equal to $V$.

3.4.4 Both tanks shall have a drain piping in the upper part, in order to avoid possible overfill during a blowdown of the whole system or a level transmitter failure. This drain piping shall be directed to the bottom of the skid, in order to avoid wetting any HPU components.

3.4.5 Tanks vents shall have an air filter with minimal efficiency of $\beta_5 \geq 200$. Their air flowrate shall be calculated to meet the flowrates of both recirculation and supply pumps in parallel for supply tank and return fluid flowrate for return tank.

3.4.6 Supply and return tanks shall have reflex level gauges. They shall have drain and blockage valves.

3.4.7 Each tank shall have its bottom inclined in order to be drained individually, with drain lines diameters calculated to drain the whole tank in 6 hours maximum. The ends of the lines shall have a NPT thread, in order to eventually connect hoses.
3.4.8 Tanks shall be made out of stainless steel 316L.

3.4.9 HPU shall have circuits to fill, transfer between tanks and recirculation of return tank, always through a set of filters, with efficiency of $\beta_3 \geq 200$ or better, to meet cleanliness class requirements. These circuits shall have two electrical redundant recirculation pumps, capable of individually refill all reservoir tank in 60 minutes maximum.

3.4.10 All operations of filling, recirculation and fluid transfer between tanks shall be made without interfering in normal HPU operation.

3.4.11 All tanks shall have accessible manholes to inspection and complete clean operations.

3.4.12 HPU design shall not allow any other way of filling the tanks other than the filling inlet, with the pumps and the recirculation circuit, to guarantee the first filtering of the fluid.

3.4.13 It is also HPU scope to supply 1 portable equipment to verify the cleanliness class of the fluid by comparison method. The equipment shall have 4 standard “slides” for comparison, 2 for class 17/15/12 and 2 for class 19/17/14, according to ISO 4406.

3.5 Hydraulic circuits

3.5.1 The HPU shall be commissioned with all hydraulic circuits clean according to ISO 4406 class 17/15/12.

3.5.2 The HPU shall have pressure safety valves (PSVs) to protect against possible overpressures inside its hydraulic circuits and components. At least one of these PSVs shall be mounted downstream each pressure regulating valve of each HPU outlet. The PSV set shall be 1.1 times the maximum operating pressure of the respective outlet.

3.5.3 Each HPU outlets to multiplexed electro-hydraulic control (LP1, LP2, HP1, and HP2) shall have a locked open blockage valve.

3.5.4 The HPU shall have electrical solenoid-powered DCVs to depressurize hydraulic supplies of the multiplexed electro-hydraulic control system. This depressurization shall be commanded via CSS and shall not include the accumulator bank.

3.5.5 Each DCV shall be fail-safe, with spring return to closed position in case of electrical power loss. In such case, the DCV shall direct its outlet to the return tank.

3.5.6 One DCV shall be located downstream each supply pressure regulating valve. They shall be capable of depressurize simultaneously 4 supply outlets downstream these pressure regulating valves. The DCV shall not cause transient backpressures that interfere with normal HPU operation or with the equipment powered by the HPU.
3.5.7 The hydraulic circuits of each DCV shall meet the following requirements:
   a) Have an individual line or depressurization, from DCV to return tank
   b) Have a blockage and a needle valve upstream the DCV
   c) Have a locked open blockage valve downstream the DCV
   d) Be sized in order to not cause backpressure retarding simultaneous depressurization of 4 outlets from electro-hydraulic multiplexed system to return tank. In order to perform such sizing, it must be considered thermoplastic hoses. Steel tube umbilicals are not allowed to be considered in this sizing

3.5.8 All HP hydraulic circuits shall have double blockage valves.

3.5.9 All instruments shall have connections of block manifold type, in order to allow their easy replacement.

3.5.10 All hydraulic lines shall be made out of stainless steel ASTM A269 Gr. TP 316L or super-duplex steel ASTM A789 UNS S32750 or S32760. The lines of stainless steel shall have 2.5% of molybdenum in their composition.

3.5.11 All hydraulic connections shall use double ferrule connectors with double flare rings in stainless steel or super duplex steel. Coned-and-threaded connections can be accepted only to HP circuits, since all tubings and accessories are from the same manufacturer of the connections, and since the procedures for assembling and disassembling of the connections in each diameter are included in the HPU manual. The sealing of NPT threads shall be made with chemicals. Teflon duct tapes are not accepted.

3.5.12 Hydraulic lines shall be mounted next to each other and supported near connections. The maximum distance between supports shall be 1 meter. Curves shall have a radius 4 times the external diameter of the line, measured from the internal part of the curve. All hydraulic connections shall use double ferrule connectors with double flare rings in stainless steel or super duplex steel. Coned-and-threaded connections can be accepted only to HP circuits, since all tubings and accessories are from the same manufacturer of the connections, and since the procedures for assembling and disassembling of the connections in each diameter are included in the HPU manual. The sealing of NPT threads shall be made with chemicals. Teflon duct tapes are not accepted.

3.5.13 All HPU filters shall be redundant, without internal or external bypass, and equipped with differential pressure transmitters and a differential pressure gauges. The calibration of the differential pressure gauges shall be done locally.

3.5.14 The supply filters shall have the following characteristics:
   a) Stainless steel body with safety factor equal to 3
   b) Work pressure compatible with maximum pressure of the header in which the filter is
   c) Do not have bypass valves, except only to remove the differential pressure transmitter
d) Differential pressure gauge with 3 bar range

3.5.15 The recirculation filters shall have the following characteristics:

a) Stainless steel body with safety factor equal to 3
b) Work pressure of 10 bar
c) Do not have bypass valves
d) Differential pressure gauge with 3 bar range

d) Differential pressure gauge with 3 bar range

3.5.16 The filtering elements shall have the following characteristics:

a) Filtering medium: plissed inorganic microfibers with retaining capacity of 3 µm, β₃ > 200 (according to ISO 4572), plissed type internal profile and internal docking in stainless steel net
b) Collapse differential pressure greater than 160 bar
c) Machined cover, internal tube reinforcements in the welding process without material adding
d) Buna-N sealing
e) Total compatibility with subsea control fluid

3.5.17 Filters and filtering elements shall comply with the following standards:

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 cleanliness 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 cleanliness - Inspection document and principles related to contaminant collection, analysis and data reporting.

3.5.18 The pressure adjustment for up to 4 outlets of the same supply shall be made by any of the two manual pressure-regulating valves, connected in parallel by blockage and drain valves.

3.6 Accumulator bank sizing

3.6.1 There shall be independent accumulator banks for HP and LP headers, sized for maximum non-regulated pressure of each header.

3.6.2 LP accumulator bank shall be sized according to item 6.4.5.2 of ISO 13628-6 of 2016, below, considering the greater volume between V1 and V2, where:

a) V1: volume to allow a closed-open-closed cycle of all valves from 1 WCT MUX, without needing to pressure the accumulators, with electrical and pneumatic LP pumps turned off. It shall be considered V1 = 160 L
b) V2: volume to store enough energy to keep, without pumps, the subsea system pressure during a 12-hour period. For this calculation, it shall be considered a leakage of 20 mL/h for each LP DCV of the subsea system. The resulting volume shall be added by 20%.

3.6.3 HP accumulator bank shall be sized according to item 6.4.5.2 of ISO 13628-6 of 2016, below, considering the greater volume between V1 and V2, where:

a) V1: volume to allow a closed-open-closed cycle of all valves from 1 WCT MUX, without needing to pressure the accumulators, with electrical and pneumatic HP pumps turned off. It shall be considered V1 = 40 L

b) V2: volume to store enough energy to keep, without pumps, the subsea system pressure during a 12-hour period. For this calculation, it shall be considered a leakage of 20 mL/h for each HP DCV of the subsea system. The resulting volume shall be added by 20%.

3.6.4 The failure of 1 LP accumulator shall not compromise more than 25% of the LP accumulator bank capacity.

3.6.5 The failure of 1 HP accumulator shall not compromise more than 50% of the LP accumulator bank capacity.

3.6.6 Each accumulator bank shall be divided in two groups (of equal number each, or differing by 1 if the total number of accumulators is odd), by means of blockage ball valves. Each one of these groups shall have a maintenance connection, made of a blockage ball valve of ½” body and a connection JIC 37º of 3/8” with cover.

3.6.7 Each accumulator shall have a nitrogen pre-charge, pressure gauges to indicate both hydraulic fluid and nitrogen pressures, blockage and drain valves manifold, pressure safety valves and bursting disks.

3.6.8 Accumulators shall be of bladder type, made out of stainless steel. They shall be mounted vertically with dampers between them and the support skid.

3.6.9 The HPU shall be supplied with all documentation needed by Brazilian standards from Brazilian Ministry of Labor (Ministério do Trabalho).

3.7 Electrical and pneumatic pumps

3.7.1 The pumps of the whole HPU supply system shall have the following configuration:

a) 4 electrical pumps (E) and 2 pneumatic pumps (P) for non-regulated LP hydraulic circuit, being 2E+1P on duty and 2E+1P in standby.

b) 2 electrical pumps (E) and 2 pneumatic pumps (P) for non-regulated HP hydraulic circuit, being 1E+1P on duty and 1E+1P in standby.

3.7.2 The sizing of LP pumps shall meet the following requirements:
a) Each set of LP pumps 2E+1P shall be capable of pressurizing the subsea system up to maximum regulated pressure in a maximum of 120 minutes after complete umbilical depressurization (ESD-4). The pumps flowrate shall be calculated considering:
   - The volume from the expansion of 1 thermoplastic hose with ½” @5000 psi for each subsea equipment with electro-hydraulic multiplexed control system, plus:
   - The volume from the expansion of 4 thermoplastic hoses with 3/8” @5000 psi for each umbilical connected to a WCT HD
   All hose expansion coefficients are in appendix.

b) Each LP pump shall be sized for 50% of maximum flowrate of the whole LP system.

c) Each LP pneumatic pump shall be sized in order to keep non-regulated pressure of LP circuit without start-up of electrical pumps, not considering the eventual actuation of subsea valves. The pump shall be sized to repressurize the LP system non-regulated pressure goes below 90% of respective maximum pressure.

3.7.3 The sizing of HP pumps shall meet the following requirements:

a) Each set of HP pumps 1E+1P shall be capable of pressurizing the subsea system up to maximum regulated pressure in a maximum of 120 minutes after complete umbilical depressurization (ESD4). The pumps flowrate shall be calculated considering:
   - The volume from the expansion of 1 thermoplastic hose with ½” @10000 psi for each subsea equipment with electro-hydraulic multiplexed control system, plus:
   - The volume from the expansion of 2 thermoplastic hoses with 3/8” @10000 psi for each umbilical connected to a WCT HD
   Regardless of the umbilical that might be used, it shall be considered 10000 psi for this calculation. All hose expansion coefficients are in appendix.

b) Each HP pneumatic pump shall be sized in order to keep non-regulated pressure of HP circuit without start-up of electrical pumps, not considering the eventual actuation of subsea valves. The pump shall be sized to repressurize the HP system non-regulated pressure goes below 90% of respective maximum pressure.

c) Each pneumatic pump must have its suction side in order to allow an increase in 10% of design flowrate at maximum header work pressure with supply air at 7 bar, without cavitation.

3.7.4 The minimum supply air pressure from the FPU is 4.9 bar.

3.7.5 All electrical and pneumatic pumps shall have a selecting switch to designate them as “duty”, “stand-by” and “out of service”.

3.7.6 It shall be possible for the operator to manually command all HP pumps (electrical and pneumatic) to repressurize after an ESD-4.

3.7.7 The operating sequence of HP and LP pumps is described in table 2, below. P is the non-regulated pressure in each header and Pmax is the maximum non-regulated pressure in each header.
Table 2 – Operating sequence

<table>
<thead>
<tr>
<th>Header</th>
<th>Pump</th>
<th>P = 100% Pmax</th>
<th>P = 90% Pmax</th>
<th>P = 85% Pmax</th>
<th>P = 80% Pmax</th>
<th>P = 70% Pmax</th>
<th>P = 45% Pmax</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP</td>
<td>Pneumatic</td>
<td>Off</td>
<td>Start</td>
<td></td>
<td>Low pressure alarm</td>
<td>Stop pumps. HPU shutdown alarm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electrical</td>
<td>Off</td>
<td></td>
<td>Start</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LP</td>
<td>Pneumatic</td>
<td>Off</td>
<td>Start</td>
<td></td>
<td>Low pressure alarm</td>
<td>Stop pumps. HPU shutdown alarm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electrical</td>
<td>Off</td>
<td></td>
<td>Start 1st</td>
<td>Start 2nd</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.7.8 The pressures described in table 2 shall be adjustable manually through thumbwheel switches, with values in bar. These switches shall be located in a panel specific for this use, located inside the HPU, with restricted access.

3.7.9 The pneumatic pumps shall operate by balance of forces, having different inlets for supply air and pilot air from a pneumatic DCV. The supply air pressure shall be adjustable via a regulating pneumatic valve, up to the value needed to drive the pump to 105% of the maximum non-regulated header pressure (Pmax). The pump shall be commanded by the DCV upstream the pilot air inlet, according to the values of table 2. Pilot air pressure shall also be adjustable via a regulating pneumatic valve.

3.7.10 The electrical pumps shall be of triplex, or alternating pistons type with reduction gear, or rotary with axial pistons. Alternating pistons pumps must have pistons cladded with ceramic, internal wetted parts in stainless steel and valve seats in Nylon. Swashplate pumps are not acceptable.

3.7.11 The recirculation pumps shall be of positive displacement type or centrifugal type (with one or more stages). Pumps must have their internal parts in stainless steel or in a material compatible with the hydraulic fluid. They shall be able to overcome all pressure drops from lines, heights and filtering elements (which is 3 bar).

3.7.12 All pumps shall be installed horizontally, such as the tanks fluid level is always above their suction. Pumps must be lubricated by gravity, from a common header connected to a tank, with a level gauge and a level transmitter connected to the HPU, with a low level alarm.

3.7.13 Each pump shall have a 125 μm independent filter downstream them.

3.7.14 All pumps shall be adequate to the used hydraulic fluid.

3.7.15 Each recirculation pump shall have its suction line connected to supply tank and return tank. The hydraulic recirculation circuit shall have two sets of filters in parallel, isolated by blockage valves.
3.7.16 Each pump shall be protected by an individual PSV, sized according to API RP 520 and specified according to API STD 526. After each PSV, there shall be a check and a blockage ball valve. For HP pumps, the blockage valves shall be double block type.

3.7.17 Fluid velocity in suction lines shall not exceed 1.5 m/s.

3.7.18 Electrical pumps shall have pulsation dampers downstream them, connected to the HPU through flexible hoses, in order to minimize induced vibration in the HPU structure.

3.7.19 Each pump shall have an individual “on duty time” counter, to register accumulated hours on duty of each pump.

3.7.20 All pumps motors electrical requirements shall be in accordance with I-ET-3010.00-5140-712-P4X-001 - LOW-VOLTAGE INDUCTION MOTORS FOR OFFSHORE UNITS.

3.8 Instrumentation and control

3.8.1 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 PACKAGED UNITS.

3.8.2 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).

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

3.8.4 The panel shall be made out of stainless steel plates.

3.8.5 The panel shall be certified as Ex-pz, according to IEC-60079. In order to be certified as such, the HPU shall have a gas detector that, in case of confirmed gas in the HPU area while the PLC is opened, the power supply for the panel shall be interrupted.

3.9 Electrical system

3.9.1 All cables shall be identified and held through plastic clamps. Metallic clamps shall not be used.

3.9.2 All pump enclosures shall have ingress protection IP-56 according to IEC-60529.

3.9.3 The HPU shall have emergency lights powered by rechargeable battery.

3.9.4 The HPU shall have the following electrical interfaces:
4 IDENTIFICATION

4.1 General

4.1.1 All controls, connections and gauges assembled on the HPU shall be clearly identified. Numbers and codes alone are NOT acceptable for identifications.

4.1.2 The identification plates shall be made of stainless steel, with lettering in low relief and shall be attached with stainless steel bolts. The identification shall be in Brazilian Portuguese and all translations shall be submitted for verification and approval by PETROBRAS.

4.1.3 The front of the HPU shall be clearly and permanently identified by a nameplate sized 200 x 75 mm, bearing the following wording:

```
UH-1210001
UNIDADE HIDRÁULICA
```

4.1.4 The skid for the accumulator bank shall be identified on its front part with the following inscription:

```
BA-UH-1210001
BANCO DE ACUMULADORES DA UNIDADE HIDRÁULICA
```

4.1.5 The Hydraulic Fluid tanks skid shall also be identified on its front part with the inscription:

```
TQ-UH-1210001
RESERVATÓRIO
```

5 TESTS

5.1 Tests Requirements

5.1.1 HPU commissioning in the FPU shall be preceded by hydrostatic test at maximum allowable pressures in LP and HP circuits, without damaging the components. Except where it will cause such damage, it shall be considered a test pressure of at least 1.1 times the maximum allowable pressures applied by at least 15 minutes, after which no leakage shall occur (internal or external) and the pressure shall not fall more than 2% the test pressure.
5.1.2 It shall be verified the fluid cleanliness class in HPU hydraulic circuits, since final manufacturer phase until HPU commissioning end, using at least one of the two distinct methods:

a) Particle counting
b) Comparative method. At least 3 consecutive samples shall be made in the system outlets

5.1.3 The inspection, tests and warranty program shall be submitted for PETROBRAS approval.

6 SPARE PARTS AND CONSUMABLE ITEMS

6.1 General

6.1.1 Except for the first hydraulic fluid filling in the HPU, the HPU shall be supplied with all consumable parts.

6.1.2 At the end of the HPU manufacturing, it shall be delivered for PETROBRAS a list with estimated spare parts for a 2-year operation.

7 PREPARATION FOR DELIVERY

7.1 Requirements

7.1.1 HPU individual skids, including all their components, shall be supplied preserved for transportation. The preservation shall include protection of parts and components most exposed during handling.

8 WARRANTY

8.1 Requirements

8.1.1 HPU, including the accumulator bank, shall have total warranty for a period of 18 (eighteen) months operation counting from date of commissioning and acceptance by PETROBRAS.

9 TRAINING

9.1 Requirements

9.1.1 It shall be foreseen a training on HPU operation and maintenance. The training shall be made in shifts of 10 PETROBRAS professionals. All training material as well as the classes shall be in Brazilian Portuguese.
10 APPENDIX

10.1 Hose expansion calculations

10.1.1 This appendix describes the volume from expansion of the hoses connecting for each subsea equipment described in table 1 of this document. Each hose pressure class and diameter leads to different expansions. The values are described in table 3 and 4, below.

Table 3 – Hose expansion per meter for 3/8” diameter

<table>
<thead>
<tr>
<th>Pressure (psi/bar)</th>
<th>Expansion (cm³ / m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000 / 204</td>
<td>5.67</td>
</tr>
<tr>
<td>5000 / 340</td>
<td>7.56</td>
</tr>
<tr>
<td>7500 / 510</td>
<td>9.66</td>
</tr>
<tr>
<td>10000 / 680</td>
<td>11.76</td>
</tr>
</tbody>
</table>

10.1.2 Table 4 – Hose expansion per meter for 1/2” diameter

<table>
<thead>
<tr>
<th>Pressure (psi/bar)</th>
<th>Expansion (cm³ / m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3000 / 204</td>
<td>10.03</td>
</tr>
<tr>
<td>5000 / 340</td>
<td>13.45</td>
</tr>
<tr>
<td>7500 / 510</td>
<td>17.16</td>
</tr>
<tr>
<td>10000 / 680</td>
<td>20.90</td>
</tr>
</tbody>
</table>

10.1.3 It shall be considered:

- VHP = Expansion volume in 1 thermoplastic hose of ½” at 10000 psi. It should be considered 10000 psi for these calculations, regardless of the chosen umbilical, i.e., 20.90 cm³/meter of umbilical.
- VLP = Expansion volume in 1 thermoplastic hose of ½” at 5000 psi, i.e., 13.45 cm³/meter of umbilical.
- VHDHP = Expansion volume in 2 thermoplastic hoses of 3/8” at 10000 psi. It should be considered 10000 psi for these calculations, regardless of the chosen umbilical, i.e., 23.52 cm³/meter of umbilical.
- VHDLP = Expansion volume in 4 thermoplastic hoses of 3/8” at 5000 psi, i.e., 30.24 cm³/meter of umbilical.

10.1.4 The umbilical lengths to be used for preliminary calculation, based on typical distances between the FPU and each subsea equipment, is given in table 5, below. The actual value shall be confirmed during Detailing Engineering Design.
### TECHNICAL SPECIFICATION

**UNIT:** BÚZIOS  
**REV.:** 0  
**SHEET:** 20 of 23  
**NP:** NP-1  
**ESUP:**

**TITLE:** HYDRAULIC POWER UNIT (HPU) FOR SUBSEA SYSTEM

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**Table 5 – Distances from the FPU to the subsea equipment**

<table>
<thead>
<tr>
<th>Distance</th>
<th>Description</th>
<th>Value (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Distance from the FPU to a satellite well with WCT MUX</td>
<td>10</td>
</tr>
<tr>
<td>D2</td>
<td>In a piggyback configuration, distance from the FPU to the master WCT MUX</td>
<td>10</td>
</tr>
<tr>
<td>D3</td>
<td>In a piggyback configuration, distance from the master WCT MUX to the slave WCT MUX</td>
<td>10</td>
</tr>
<tr>
<td>D4</td>
<td>Distance from the FPU to a satellite well with WCT HD</td>
<td>10</td>
</tr>
<tr>
<td>D5</td>
<td>Distance from the FPU to subsea SDVs</td>
<td>6</td>
</tr>
<tr>
<td>D6</td>
<td>Distance from the FPU to WAG manifold</td>
<td>10</td>
</tr>
<tr>
<td>D7</td>
<td>Distance from subsea WAG manifold to WAG injection well #1</td>
<td>5</td>
</tr>
<tr>
<td>D8</td>
<td>Distance from subsea WAG manifold to WAG injection well #2</td>
<td>5</td>
</tr>
<tr>
<td>D9</td>
<td>In a piggyback configuration, distance from the FPU to the master WAG manifold</td>
<td>10</td>
</tr>
<tr>
<td>D10</td>
<td>In a piggyback configuration, distance from the master WAG manifold to the slave WAG manifold</td>
<td>5</td>
</tr>
<tr>
<td>D11</td>
<td>Distance from the FPU to water injection manifold</td>
<td>10</td>
</tr>
<tr>
<td>D12</td>
<td>Distance from the water injection manifold to water injection well #1</td>
<td>5</td>
</tr>
<tr>
<td>D13</td>
<td>Distance from the water injection manifold to water injection well #2</td>
<td>5</td>
</tr>
<tr>
<td>D14</td>
<td>Distance from the water injection manifold to water injection well #3</td>
<td>5</td>
</tr>
<tr>
<td>D15</td>
<td>Distance from the water injection manifold to water injection well #4</td>
<td>5</td>
</tr>
<tr>
<td>D16</td>
<td>Distance from the FPU to production manifold</td>
<td>10</td>
</tr>
<tr>
<td>D17</td>
<td>Distance from the production manifold to production well #1</td>
<td>5</td>
</tr>
<tr>
<td>D18</td>
<td>Distance from the production manifold to production well #2</td>
<td>5</td>
</tr>
<tr>
<td>D19</td>
<td>Distance from the production manifold to production well #3</td>
<td>5</td>
</tr>
<tr>
<td>D20</td>
<td>Distance from the production manifold to production well #4</td>
<td>5</td>
</tr>
</tbody>
</table>
10.1.5 Then, using the given values in tables 3, 4 and 5 and the volumes described in item 10.1.3, the total expansion volume (VR) for each group of subsea equipment described in table 1 will be given by equations below. 

The total hose expansion will be VRa + VRb + VRc + VRd + VRe + VRf + VRg + VRh + VRi + VRj + VRk + VRm.

- **Production Satellite Well with WCT MUX**
  
  \[ VRa = Ta \times [D1 \times (VHP + VLP)] \]

- **Water Injection Satellite Well with WCT MUX**
  
  \[ VRb = Tb \times [D1 \times (VHP + VLP)] \]

- **Gas Injection Satellite Well with WCT MUX**
  
  \[ VRc = Tc \times [D1 \times (VHP + VLP)] \]

- **Production Satellite Well with WCT MUX that might be relocated to subsea production manifold**
  
  \[ VRd = Td \times [(D11 + D12 + D13 + D14 + D15) \times (VHP + VLP)] \]

- **Water injection Satellite Well with WCT MUX that might be relocated to subsea water/WAG manifold**
  
  \[ VRe = Te \times [(D11 + D12 + D13 + D14 + D15) \times (VHP + VLP)] \]

- **Gas injection Satellite Well with WCT MUX that might be relocated to subsea WAG manifold**
  
  \[ VRf = Tf \times [(D11 + D12 + D13 + D14 + D15) \times (VHP + VLP)] \]

- **Subsea WAG manifold for 2 WAG injection wells with WCT MUX**
  
  \[ VRg = Tg \times [(D6 + D7 + D8) \times (VHP + VLP)] \]

- **Pairs of WAG manifolds in “Piggyback” for up to 4 WAG injection wells with WCT-MUX**
  
  \[ VRh = Th \times [(2 \times D7 + 2 \times D8 + D9 + D10) \times (VHP + VLP)] \]

- **Water injection manifold for 4 water injection wells with WCT-MUX**
  
  \[ VRi = Ti \times [(D11 + D12 + D13 + D14 + D15) \times (VHP + VLP)] \]

- **Subsea production manifold for 4 production wells with WCT-MUX**
  
  \[ VRj = Tj \times [(D11 + D12 + D13 + D14 + D15) \times (VHP + VLP)] \]

- **Pair of wells “Piggyback” (WCT-MUX) connected directly to FPU**
  
  \[ VRk = Tk \times [(D2 + D3) \times (VHDHP + VHDLP)] \]

- **Satellite well (any) with WCT-HD (n equals 1 or 2, the number of hydraulic-direct wells)**
  
  \[ VRl = n \times [(D4 \times (VHDHP + VHDLP)] \]

- **Satellite well (any) with WCT-HD (m equals the number of subsea SDVs)**
  
  \[ VRm = m \times (D5 \times VHDLP) \]
10.1.6 The figures 1 and 2, below, give more details about each distance.
10.2 Actuator volumes

10.2.1 The table 6, below, described the total actuators volume to be considered for each subsea equipment.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Total volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 WCT-MUX</td>
<td>LP: 23 L</td>
</tr>
<tr>
<td></td>
<td>HP: 1 L</td>
</tr>
<tr>
<td>1 WAG manifold connected to 2 WCT-MUX</td>
<td>LP: 16 L (manifold) + 46 L (2 WCT-MUX)</td>
</tr>
<tr>
<td></td>
<td>HP: 2 L</td>
</tr>
<tr>
<td>1 water injection or production manifold connected to 4 WCT-MUX</td>
<td>LP: 48 L (manifold) + 92 L (4 WCT-MUX)</td>
</tr>
<tr>
<td></td>
<td>HP: 4 L</td>
</tr>
<tr>
<td>1 WCT-HD</td>
<td>LP: 22 L</td>
</tr>
<tr>
<td></td>
<td>HP: 0.5 L</td>
</tr>
<tr>
<td>1 subsea SDV</td>
<td>LP: 8 L</td>
</tr>
</tbody>
</table>

Notes:
1) Totals for WCT-MUX and WCT-HD already include the volume corresponding to the SCSSV.
2) Totals for WCT and manifolds already include 1 L for internal SCM accumulator.
3) HP volumes include SCSSV and intelligent completion functions.