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|---|---|---|---|---|---|---|---|
| DATE | 30/07/2020 | 07/01/2020 | | | | | |
| DESIGN | SUB/ES | SUB/ES | | | | | |
| EXECUTION | Vinicius Prado | Vinicius Prado | | | | | |
| VERIFICATION | | | | | | | |
| APPROVAL | | | | | | | |

## INDEX

# 1. INTRODUCTION

## 1.1. SCOPE

This document establishes the minimum mandatory technical requirements to be complied with for the FPSO spread mooring, riser and towing systems. Refer to the GTD for the required design life.

In case of conflict between this document, the GTD, CS or other third-part requirements, PETROBRAS must be formally consulted for clarification.

## 1.2. REFERENCE STANDARDS

[1] ISO19901-7 (2013): Stationkeeping Systems for Floating Offshore Structures and Mobile Offshore Units

[2] ISO18692 (2018, 2019): Fiber Ropes for Offshore Stationkeeping, Pts 1 and 2

[3] IACS W22 (2016): Offshore Mooring Chains

[4] DNV 2.22 (2013): Lifting Appliances

## 1.3. ACRONYMS

| | |
|---|---|
| FPSO | Floating Production Storage Offloading Unit (also Unit) |
| KOM | Kick-off Meeting |
| LOI | Letter of Intent |
| CS | Classification Society |
| GTD | General Technical Description |
| METOCEAN | Meteorological and Oceanographic Data |
| OLB | One Line Broken |
| MLP | Mud-line Penetration Point |
| MPM | Most Probable Maximum |
| FAT | Factory Acceptance Test |
| RAO | Response Amplitude Operator |
| QTF | Quadratic Transfer Function |
| SF | Safety Factor |
| SWL | Safe Work Load |
| MBL | Minimum Break Load |
| WD | Water Depth |
| SLWR | Steel Lazy Wave Riser |
| PLR | Pig Launcher / Receiver |
| TSA | Thermal Spray Aluminum |
| AHV | Anchor Handling Vessel |
| ROV | Remotely Operated Vehicle |
| PLSV | Pipe Laying Support Vessel (also Installation Vessel) |
| PLC | Programmable Logic Controller |
| TBD | To Be Defined |
| OCIMF | Oil Companies International Maritime Forum |
| TBD | To Be Defined |

## 2. DESIGN DATA

### 2.1. GENERAL REQUIREMENTS

All Brazilian Administration, Flag Administration and CS requirements for the FPSO are to be fulfilled considering that the Unit cannot be dry-docked during the contract period.

Analytical techniques and model test data are required to establish a sufficient database for the complete design of the system and its associated structural components (e.g., RAOs, QTFs, wind and current drag coefficients, damping coefficients, calibration of numerical models, etc.).

### 2.2. ACCEPTABLE SYSTEM

The FPSO shall be provided with a non-disconnectable, passive spread mooring system. The mooring lines shall be arranged in four clusters, located at the corners of the Unit (bow and stern, portside and starboard).

The riser system shall be installed along a balcony located on the portside of the Unit.

### 2.3. LOCATION

The FPSO will be installed offshore, in the TBD field off Brazil. The Unit heading is TBD deg relative to true North and WD at location is TBD m. This information will be confirmed in DE-SUBSEA LAYOUT provided at the KOM.

### 2.4. SOIL DATA

The spread mooring system shall be designed in accordance with the soil data at the installation site. The detailed data (fine bathymetry chart, geohazard map, etc.) will be provided by PETROBRAS during the execution phase.

### 2.5. METOCEAN DATA

The spread mooring and riser system shall be designed in accordance with the data contained in I-ET-METOCEAN and the applicable CS requirements.

The environmental conditions shall be considered in the several directions informed in I-ET-METOCEAN in order to cover all possible critical situations that the spread mooring and riser system may have to withstand during operational life.

The analyses shall be performed combining surface currents, wind and waves according to a collinear approach, with all coming from the same direction, and a non-collinear approach, with currents up to 45 deg apart of wind and waves. Wind and waves shall always be collinear.

JONSWAP wave spectrum shall be used according to the formulation presented in I-ET-METOCEAN. Only unimodal extreme sea-states shall be considered. For fatigue analyses, refer to I-RL-CLUSTERS OF SIMULTANEOUS CONDITIONS.

NPD wind spectra shall be used if no other data is available. If necessary, current profiles shall be truncated to the project WD.

## 3. FPSO INTERFACE

### 3.1. STRUCTURAL DESIGN

All structural elements of the spread mooring and risers system (hull appendages and foundations) shall be designed as non-inspectable for the Unit design life according to GTD and CS requirements.

The calculation reports of the spread mooring and risers system structural components shall be submitted for PETROBRAS evaluation.

### 3.2. PAINTING AND CATHODIC PROTECTION

Structural elements shall be painted in accordance with the GTD.

The inner surface of I-tubes shall be protected with an anti-fouling painting scheme to avoid marine growth. CONTRACTOR shall not paint the bellmouths after their FATs.

Receptacles shall be TSA-coated on internal surfaces.

CONTRACTOR shall provide adequate cathodic protection for the structural elements of the spread mooring and risers system, preferably via galvanic anodes.

## 4. CONTROL AND MONITORING

The control systems of the mooring hook-up and risers pull-in systems shall be provided with dedicated PLCs. The control panels shall include readings from the machinery monitoring sensors with data and event logs.

## 5. TOWING SYSTEM

CONTRACTOR shall provide at least four smit-brackets and four chocks on the FPSO stern and bow (two each). The position of these devices shall be defined considering:

(i) Simultaneous operations of support vessels during the hook-up campaign

(ii) Interference between towing / stationkeeping lines and surrounding structures onboard the FPSO

Smit-brackets, chocks and support structures shall have a minimum SWL of 250 mT.

CONTRACTOR shall supply all necessary handling facilities and gears for connection between the tugs and the FPSO during towing and stationkeeping operations. Interface with PETROBRAS fleet shall be compatible with a connection shackle of minimum SWL 120 mT (to be confirmed during execution phase).

Ropes for stationkeeping shall be at least 400 m long and made of synthetic fiber with MBL 600 mT. These ropes shall be stored onboard the FPSO for pull-back operations, if ever required.

The Unit shall be able to operate with up to four stationkeeping boats simultaneously. The towing and stationkeeping arrangements shall be submitted for PETROBRAS evaluation.

# 6. MOORING SYSTEM

## 6.1. GENERAL

CONTRACTOR shall design, supply and install a safe and suitable mooring facility for the FPSO.

CONTRACTOR shall also design and supply all mooring lines. See APPENDIX B – MOORING MATERIALS SCOPE OF SUPPLY. The mooring lines shall be designed as non-inspectable for the contract period according to CS requirements.

Mooring lines installation is PETROBRAS' responsibility.

## 6.2. MOORING ANALYSIS

Fully coupled time-domain analyses shall be carried out for the mooring system assessment. All relevant effects to the FPSO dynamic behavior, such as the stiffness of mooring lines and the influence of risers (horizontal restoring forces and moments, low-frequency damping, etc.), shall be taken into account. PETROBRAS accepts the following softwares for mooring analysis: ARIANE, MIMOSA, ANYSIM, ORCAFLEX and SIMO.

Current and wind coefficients shall be calculated in accordance with test results and CS rules. The provisions of OCIMF – Prediction of Wind and Current Loads on VLCCs (1994) may also be used. Windage areas shall be determined from plan and profile layouts of the FPSO projections with topsides equipment, cranes, flare tower and accommodations block. The calculations shall be submitted for CS approval and for PETROBRAS information.

CONTRACTOR shall design the system to have the minimum number of mooring lines as possible. The mooring lines shall be arranged in four clusters, located at the bow and stern, portside and starboard of the Unit. The minimum spacing between mooring lines shall be TBD deg due to installation issues.

The design shall ensure FPSO connection adequacy and that safe clearances are maintained between mooring lines, hull, risers and umbilicals under operational and survival conditions, including damaged stability cases. Additionally, it shall be assured that polyester ropes will not touch the seabed in intact mooring conditions.

The system shall be able to withstand, at all operational drafts, the loads imposed by a shuttle tanker moored in tandem to the FPSO, either bow to bow or bow to stern, under the specified operational environmental conditions. Reference tankers are described in I-ET-OFFLOADING SYSTEM.

The mooring pattern is presented below. The pattern is symmetric in relation to the FPSO midship. The preliminary riser configurations for the mooring analysis are informed in APPENDIX A – RISER CONFIGURATION DATA.

**Table 1 – Mooring pattern**

| Cluster | FPSO Corner | Max Anchoring Radius / WD [m] | WD @ Anchoring Devices [m] | Mooring Pattern [deg] |
|---|---|---|---|---|
| NW | FWD-PS | TBD | TBD | TBD |
| SW | AFT-PS | TBD | TBD | |
| SE | AFT-SB | TBD | TBD | TBD |
| NE | FWD-SB | TBD | TBD | |

All SF calculations at chain segments shall take the corrosion allowances into account. See ISO 19901-7 for reference.

The stiffness curves of fiber ropes shall be properly justified and related references shall be presented. Sensitivity analyses for this parameter shall also be presented in order to demonstrate the robustness of the design.

The design conditions defined in Table 2 and applicable CS requirements shall be evaluated. The FPSO shall be considered at least at ballast, intermediate and fully-loaded drafts for the operational conditions and at ballast draft for the temporary conditions.

In addition to ISO and CS requirements, CONTRACTOR shall design the mooring system to ensure the FPSO will not exceed the maximum offsets herein outlined, given with respect to the FPSO nominal position, for the intact and OLB cases. The offsets shall include the mean offset plus appropriately combined wave-frequency and low-frequency FPSO displacements and also positioning errors.

The FPSO nominal position is established as the design coordinates given in DE-SUBSEA LAYOUT. CONTRACTOR is free to define the FPSO neutral equilibrium position, i.e., the vessel coordinates when subject to the forces imposed by the mooring and risers system but no environmental loads acting.

**Table 2 – Mooring design conditions**

| Design Case | Mooring System | Offset Limit [% WD] | Risers Connected | Environmental Condition (1) | | |
|---|---|---|---|---|---|---|
| | | | | Wave | Wind | Current |
| Storm Safe | Intact | - | No risers | 1-year | 1-year | 1-year |
| Pull-in | Intact | 9.5 | No risers | 1-year | 1-year | 1-year |
| 1st Oil | Intact | 9.0 | 1 production bundle | 10-year | 10-year | 1-year |
| | | | | 1-year | 1-year | 10-year |
| | OLB | 9.5 | 1 production bundle | 10-year | 10-year | 1-year |
| | | | | 1-year | 1-year | 10-year |
| Operational | Intact | 7.0 | Phase 1 (2) / All risers | 1-year | 1-year | 1-year |
| | OLB | 7.5 | Phase 1 (2) / All risers | 1-year | 1-year | 1-year |
| Extreme Environment | Intact | 9.0 | Phase 1 (2) / All risers | 100-year | 100-year | 10-year |
| | | | | 10-year | 10-year | 100-year |
| | OLB | 9.5 | Phase 1 (2) / All risers | 100-year | 100-year | 10-year |
| | | | | 10-year | 10-year | 100-year |
| Offloading | Intact | 9.0 | 1 production bundle | Refer to I-ET-OFFLOADING SYSTEM. | | |
| | | | All risers | | | |

Note 1: if available in the METOCEAN, extreme dominant and its associated environmental conditions may be used instead of the given recurrence period extremes.

Note 2: for the tender process, the following loads imposed by the risers system on the FPSO (vessel ballasted at nominal position, static loads) may be adopted. This information is preliminary and will be confirmed at the KOM.

**Table 3 – Static riser loads**

| Vessel Axis | Phase 1 [kN] | All Risers [kN] |
|---|---|---|
| Fx (to FWD) | TBD | TBD |
| Fy (to SB) | TBD | TBD |
| Fz (to UP) | TBD | TBD |

For the assessment of OLB cases, at least the two scenarios below shall be considered:

- Breaking of the most loaded line for each environmental direction in order to maximize the FPSO offsets
- Breaking of the second most loaded line for each environmental direction in order to maximize tensions on the most loaded line and avoid sequential line breakings

CONTRACTOR shall also calculate the offsets for the set of fatigue sea-states given in I-RL-CLUSTERS OF SIMULTANEOUS CONDITIONS. The mooring system shall be considered intact in this case.

The maximum tension on the mooring lines at the MLP shall not exceed TBD kN for the intact condition and TBD kN for the damaged condition.

CONTRACTOR shall inform the maximum tensions and uplift angles at the MLP of each mooring line. PETROBRAS will calculate the profile of the chain buried in the soil (between the pile and the MLP) based on the information provided. The final mooring analysis shall consider the buried lengths into account.

CONTRACTOR shall inform the minimum number of mooring lines, considering all lines slacked or all lines with a minimum pre-tension value, for which:

- Tugboats can be disconnected and released (storm-safe condition)
- The FPSO is ready for pull-in operation (pull-in condition)
- The FPSO is ready to start production (1st oil condition, to be certified by the CS)

CONTRACTOR shall comply with the hook-up strategy defined by PETROBRAS based on the results obtained by such evaluations.

CONTRACTOR shall deliver the Mooring Analysis Report within 9 months after issuance of the LOI. The report shall detail the design basis, screening procedures, applicable rules and CS requirements, calculations performed and also:

- MPM tensions at fairlead and mud-line levels of each mooring line
- MPM offsets in all directions
- Critical load cases (FPSO draft and environmental conditions) for each result presented
- Added mass and potential damping coefficients for all drafts assessed in the report

- Wave exciting forces for all drafts assessed in the report
- Surge, sway and yaw QTFs (Newman's approximation) for all drafts assessed in the report
- Dimensional wind and current drag coefficients (given from 0 to 360 deg, each 15 deg) for all drafts assessed in the report
- Gyration radii and CGs for all drafts assessed in the report
- Roll viscous damping for all drafts assessed in the report

## 6.3. MOORING BALCONY

CONTRACTOR shall design, fabricate and install mooring balconies of sufficient size to accommodate the hook-up and tensioning system.

CONTRACTOR shall consider the minimum longitudinal distances of 35 m between the aftmost and forwardmost riser slots and the respective nearest fairleads in order to avoid interference between mooring lines and risers. This information is preliminary and will be confirmed at the KOM.

## 6.4. MOORING SYSTEM COMPONENTS

### 6.4.1. GENERAL

Mooring hook-up operations onboard the FPSO and any diver-assisted related operations are CONTRACTOR's responsibility.

The package shall consist of all required equipment, materials, handling devices and spare parts in order to enable the installation / de-installation of mooring lines onboard the FPSO.

All equipment and instruments shall be compatible with the area classification (hazardous / non-hazardous) and a marine / salty / aggressive environment with water splashes.

All mooring line components shall be supplied with certificates verifying:

- Grade and strength
- Quality in compliance with the appropriate standards
- CS requirements

All mooring lines shall have the same sizing in terms of diameters of chains and polyester segments. The mooring lines of each cluster shall have the same configuration in terms of length of chain and polyester segments.

CONTRACTOR shall not specify the use of non-torque-balanced segments (such as six strand wire rope) in series with synthetic rope segments unless a specific torsional fatigue calculation is presented to PETROBRAS.

CONTRACTOR shall perform trial fittings for all mooring materials prior to delivery to PETROBRAS.

CONTRACTOR shall supply one additional mooring line, complete with all its accessories and the same specification as that of the longest mooring line, and store it in a own site in Brazil, from the offshore installation campaign until the end of the contract.

### 6.4.2. FIXED POINTS

PETROBRAS will be responsible for the design, fabrication, CS approval and site installation of the anchoring devices.

CONTRACTOR shall consider the mooring chain pig-tails supplied by PETROBRAS with a 200 m length.

### 6.4.3. CHAINS

Offshore studless mooring chains grades R3, R4, R4S or R5 shall be supplied. In case bottom chains are provided with nominal diameter larger than 120 mm, the connection accessories provided by PETROBRAS (KS hook, KS shackle, anchor shackle, etc) shall be verified in terms of maximum loads, fatigue life and assembly on the chains by the CONTRACTOR.

The upper chain segments shall have a minimum length of 110 m outside the fairleads after hook-up and tensioning in order to prevent marine growth on the top synthetic rope segments. This minimum length applies for the FPSO at ballast draft and nominal position.

INSTALLATION AND TOP CHAIN SEGMENTS

CONTRACTOR, considering a maximum allowable load of 150 mT on the AHV deck during hook-up operations, shall define the length of installation and top chain segments. Fabrication tolerances of polyester ropes (informed by the vendors) and mooring chains (specified in the applicable standards), anchoring device installation errors (15 m radius) and bathymetry measurement errors (0.5% WD) shall be taken into account.

CONTRACTOR shall assure the FPSO will have installation chains permanently stored inside the chain-lockers of each cluster in order to enable in-service maintenance of the mooring lines during the Unit operational life. Other arrangements may be proposed.

### 6.4.4. POLYESTER ROPES

Polyester ropes shall be supplied according to the applicable standards. All ropes shall be provided with sand barrier, braided jacket and polyurethane coating, including on the rope terminations.

The ropes shall be supplied with spool thimbles or shackles (or thimble-shackles) with grade and diameter adequate for the polyester break load. The polyester ropes shall be provided with chafing chains at least 10 m long, to enable the use of shark jaws to TBD the mooring lines during installation.

Polyester ropes shall be adequate for pre-abandonment on the seabed during the period between mooring lines installation and the FPSO hook-up. CS shall consider this requirement for certification. The necessary soil information will be provided by PETROBRAS upon request.

Polyester rope segments shall have a nominal maximum of 1000 m (length @ 2% MBL) for 215 mm diameter ropes (MBL 1340 mT) or volumetric equivalent. PETROBRAS will install these ropes as supplied by the CONTRACTOR, i.e., no pre-stretching will be performed.

The polyester ropes shall be delivered in steel reels with dimensions as follow:

- Width between flanges: maximum 6.5 m
- Flange diameter: maximum 6 m
- Hole diameter: 300 to 310 mm

### 6.4.5. CHAIN CONNECTOR DEVICES

Only standard chain-connecting shackles, in which an external nut and nut-locking device restrains the pin, shall be used in the mooring lines. Other types of connectors (Kenter links, Baldt links, etc.) are not acceptable.

CONTRACTOR shall supply four installation links (one per cluster), compatible with the upper chain segments, for connection of this chain with the pre-deployed mooring lines. These links shall be adequate for passage through the fairleads.

### 6.4.6. FAIRLEADS

Fairleads adequate for the top chain segments shall be supplied and installed on the FPSO sides. The fairleads and incoming mooring lines shall not constitute navigation hazards to other vessels.

Deck-mounted, azimuthal sheaves or chain-pipe types are acceptable.

### 6.4.7. CHAIN STOPPERS

The mooring chains shall be fastened to the FPSO using positive locking, hydraulically operated, flapper-type chain stoppers that permit chain length adjustment.

The chain stoppers shall be installed at the mooring balcony level. The flappers shall be designed to operate easily, with no manual assistance. Technical or operational failures shall not lead to uncontrolled chain pay-out.

The chain stoppers shall be identified in bas-relief. The correlation between chain stoppers and mooring lines shall be clearly represented in the hook-up procedure.

### 6.4.8. CHAIN TENSION INDICATION

CONTRACTOR shall provide the chain stoppers with load cells (or similar) and datalog for the continuous monitoring of line tensions and indicate if any has failed. The chain tension signal shall be transmitted to the Unit Central Control Room.

Chain tension calibration shall be verified regularly, considering the polyester behavior and the FPSO draft variation in the calculations of the expected mooring line tension levels.

### 6.4.9. HOOK-UP WINCHES (CHAIN-JACKS)

CONTRACTOR shall supply and install four electro-hydraulic chain-jacks (one per cluster). A suitable arrangement for tensioning every mooring line in each cluster shall be provided.

The pull speed shall be at least 1.5 m/min @ maximum load. The pull capacity shall be defined according to the pre-tension levels estimated in the Mooring Analysis with a minimum dynamic amplification factor of 1.5 to cover the environmental conditions for hook-up operations, friction losses, etc.

Means to enable easy handling and connection of the installation chain to the top chain shall be provided, so that the mooring lines can be paid-in / paid-out individually in order to perform their inspection by ROVs.

## 7. RISERS SYSTEM

### 7.1. GENERAL

The riser system will be a coupled system, with flexible risers and umbilicals connected to the FPSO through bellmouths and rigid risers connected to the FPSO through receptacles.

CONTRACTOR shall design, fabricate and install the riser balcony structures and facilities, including bellmouths, receptacles, I-tubes, hang-offs, hard-pipes and the pull-in system.

All relevant information regarding the riser configurations is available in APPENDIX A – RISER CONFIGURATION DATA.

Refer to the GTD for the risers' details. The FPSO shall be prepared for all alternatives and diameters there informed. Refer to the DE-RISER BALCONY ARRANGEMENT for wells identification, functions, diameters, positions, bundles composition, etc.

Refer also to I-ET-RIGID RISER MONITORING SYSTEM (RRMS), I-ET-MODA RISER MONITORING SYSTEM (MODA) and I-ET-ANNULUS PRESSURE MONITORING AND RELIEF SYSTEM.

### 7.2. RISER BALCONY AND PULL-IN STRUCTURE

CONTRACTOR shall design, fabricate and install a balcony of sufficient size to accommodate the number of I-tubes for flexible risers and receptacles for rigid risers defined in the DE-RISER BALCONY ARRANGEMENT.

The riser balcony shall be composed of two parts: a Lower Riser Balcony (LRB), where bellmouths and receptacles will be located, and an Upper Riser Balcony (URB), vertically above the LRB, for the flexible risers hang-off. See Figure 1.

CONTRACTOR shall also design, fabricate and install a platform over the URB to support the riser pull-in system. The vertical clearance between the bottom of the last sheave in the main pull-in wire rope path and the top flange of the upper I-tubes at URB level shall be at least 8 m. Refer to item 7.5.

The bellmouths sustain the bend-stiffeners of flexible risers at the LRB and the I-tubes guide the risers for connection with the FPSO piping at the URB. The flexible risers shall be arranged in one layer, parallel to the FPSO side.

Rigid risers shall be installed on underwater receptacles in a layer positioned outwards the lower I-tubes. The receptacles shall be aligned with their respective riser azimuths. Receptacles for keel-hauling positions may be located in a layer closer to the FPSO side-shell in order to reduce the pull-in system structure.

The Unit side-shell shall be provided with hard-pipes near the rigid riser positions for underwater connection after the pull-in and pre-commissioning of the risers. See item 7.4.6 for further requirements.

The LRB position shall guarantee that no clashing between risers and FPSO structures will occur considering extreme (100-yr offsets and motions) and accidental cases (1-yr offsets and motions combined with MODU damage heeling or minimum 15 deg). The vertical position of receptacles shall be such as to avoid the stress / flexible joints to be continuously emerged at any operational condition.

The URB shall be designed with walkways around the upper I-tubes to assist flexible riser hang-off installation, pipe spool and umbilical connections, etc. The design shall minimize assembly / disassembly of riser SDVs (shutdown valves) during pull-in / pull-out operations. Handling facilities shall be provided to enable easy and safe operations.

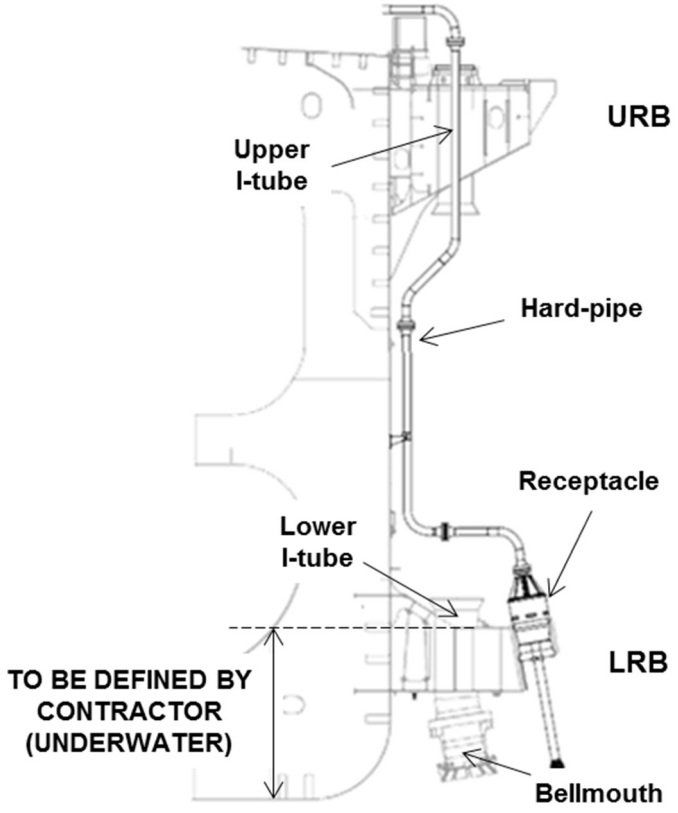



**Figure 1 – Riser balcony arrangement**

The position and clearances between riser slots shall be defined by the CONTRACTOR based on interference studies during pull-in / pull-out operations and considering the FPSO heel, trim and dynamic motions. No interference between pull-in cables, sheaves and adjacent pre-installed risers shall occur.

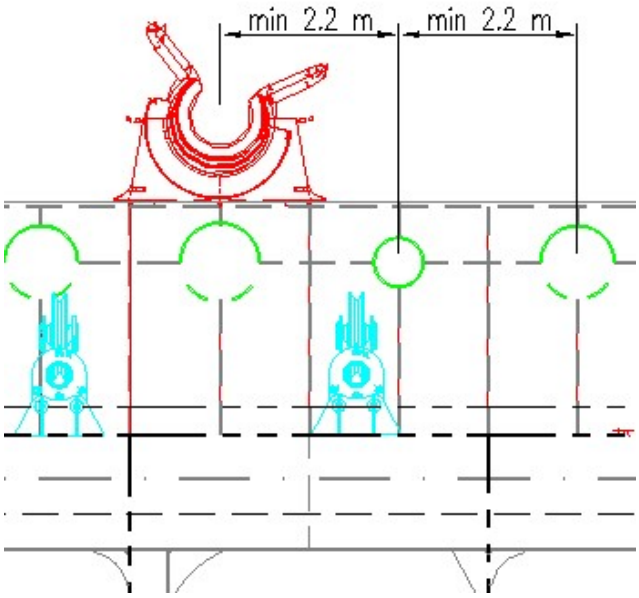



**Figure 2 – Riser balcony conceptual structural arrangement**

In order to enable proper riser connection / disconnection, PETROBRAS recommends a minimum face-to-face clearance between adjacent I-tubes of 600 mm for the BSN900E (conventional bellmouth – for operating the bellmouth locking tool) or 200 mm for the BSDL (diverless bellmouth – for engaging / disengaging handles).

The distance between adjacent supports (receptacles and / or I-tubes) shall provide a spacing of 1600 mm face-to-face between the outer diameters of the risers in order to allow for inspections by ROVs. Additionally, the distance between center of adjacent supports shall be 2200 mm at least to help mitigate interference between the top section of the risers. Figure 2 presents a schematic of the riser balcony supports as devised by PETROBRAS.

CONTRACTOR shall inform the as-built coordinates, top angle and azimuth angle for all riser supports at URB level (hang-off) and LRB level (bellmouths / receptacles). The maximum construction tolerances shall be ± 0.5 deg for the top angles and azimuths.

## 7.3. RISER LOADS

CONTRACTOR shall supply the interface loads for the risers vendors within 9 months after issuance of the LOI.

CONTRACTOR shall evaluate the riser configurations informed in APPENDIX A – RISER CONFIGURATION DATA, in order to ensure proper dimensioning of the riser balcony and the pull-in system.

The acceptable methodology is described in I-ET-RISER TOP INTERFACE LOADS ANALYSIS. CONTRACTOR shall consider that:

- For flexible risers: bending moments, shear forces and 10% of tension are applied on the LRB (due to friction) while 100% of tension is applied on the URB
- For rigid risers: bending moments, shear forces and tension are applied on the LRB

## 7.4. RISER INTERFACES

### 7.4.1. TOP FLANGES

CONTRACTOR shall provide the flanges with ring gaskets, stud bolts and nuts for the risers interfaces according to API 6A and API 17D. The datasheets, including dimensional drawings, shall be submitted for PETROBRAS.

The interface flange materials shall be defined in accordance with the GTD. The materials selection report shall be submitted for PETROBRAS.

All flanges shall be provided with 3 mm nickel alloy UNS6625 overlaid on the ring-groove. In addition, flanges for gas injection positions shall be overlaid on the face and bore due to the Joule-Thomson effect in case of gas leakage. If applicable, the requirements of DNVGL-RP-F112 should also be observed.

Stud bolts and nuts of underwater flanges shall be made in alloy UNS7718. Special care shall be taken with operational issues related to the cathodic protection system (e.g., lack of protection or hydrogen embrittlement).

Ring-grooves shall have minimum hardness of 220 HB and iron content less than 5% at 0.5 mm from the overlay surface. The ring gaskets shall be compatible with the flanges and with maximum hardness 190 HB. SBX gaskets are not acceptable.

CONTRACTOR shall provide hard-pipes / spool pieces, ending in swivel flanges with the specs given in the tables below to interconnect the riser end-flanges to the FPSO piping. All alternatives defined in the GTD and DE-RISER BALCONY ARRANGEMENT shall be taken into account.

**Table 4 – Flexible riser and umbilical interfaces**

| Riser Top Flange | | FPSO Spool Flange | | |
|---|---|---|---|---|
| **ID [in]** | **Spec** | **ID [mm]** | **Spec** | **Flange Height [mm]** |
| 4 or 6 | 7 1/16" API 6BX 10000 psi BX-156 | 152.40 | 7 1/16" API 17SV 10000 psi BX-156 | 810 ± 2.5 |
| 8 | 9" API 6BX 10000 psi BX-157 | 203.20 | 9" API 17SV 10000 psi BX-157 | 960 ± 2.5 |
| 9.125 | 11" API 17SS 5000 psi BX-158 | 231.78 | 11" API 17SV 5000 psi BX-158 | 960 ± 2.5 |
| 11 | 13 5/8" API 17SS 5000 psi BX-160 | 282.58 | 13 5/8" API 17SV 5000 psi BX-160 | 1000 ± 2.5 |
| UEH | 9" API 6B 2000 psi flat face | - | - | 600 ± 2.5 |

**Table 5 – Rigid riser interfaces**

| Riser Top Flange | | FPSO Spool Flange | |
|---|---|---|---|
| **ID [in]** | **Spec** | **ID [mm]** | **Spec** |
| 6 | 7 1/16” API 6BX 15000 psi BX-156 | 152.40 | 7 1/16” API 17SV 15000 psi BX-156 (1) |
| 6.5 | 7 1/16” API 6BX 15000 psi BX-156 | 165.10 | 7 1/16” API 17SV 15000 psi BX-156 (1) |
| 8 | 9” API 6BX 10000 psi BX-157 | 203.20 | 9” API 17SV 10000 psi BX-157 |

Note 1: these flanges shall be designed by the CONTRACTOR according to API 6BX dimensions and ID compatible with the rigid risers.

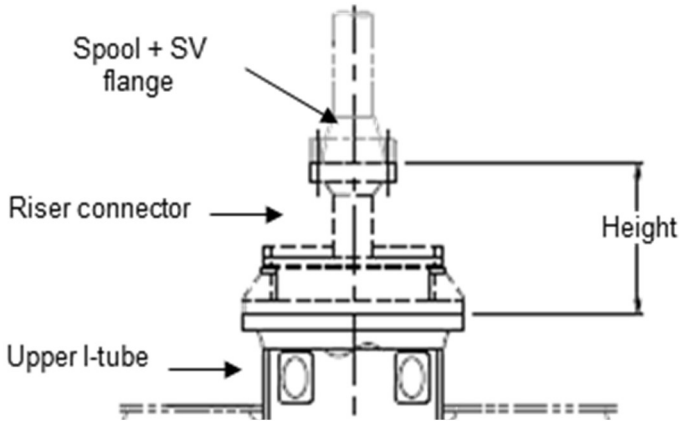



**Figure 3 – Hang-off detail**

The flexible riser end-fittings will be provided with $N_2$ test ports and a gas bleed-off connection for depressurization in case of gas leakages. CONTRACTOR shall design the venting system in accordance with I-ET-ANNULUS PRESSURE MONITORING AND RELIEF SYSTEM.

Underwater flanged connections shall also be provided with leak test ports and means to drain any trapped fluids (see API 17D for reference). For stress / flexible joints, their $N_2$ leak test port may be used to drain water from the ring grooves.

### 7.4.2. HANG-OFFS

The hang-off systems (split-collar + pull-in head) for flexible risers and umbilicals will be supplied by PETROBRAS. Detailed schematic drawings of the flexible riser end-fittings and hang-off fittings (split-collars) will be provided during execution phase.

Proper means to move the riser hang-off systems to the connection deck and position them in place shall be provided.

### 7.4.3. I-TUBES

Continuous guide tubes are not acceptable. The guide tubes shall be split into upper and lower parts in order to allow risers inspection.

CONTRACTOR shall define the required wall thickness for the upper and lower I-tubes.

The upper I-tubes shall end in MSS SP-44-2010 FFWN #300 seat flanges matching the respective riser hang-off split collars. These flanges shall be 500 mm above the URB level to allow the provision of three evenly spaced windows (150 mm height x 150 mm width), in order to enable inspection of the flexible riser end-fittings. Removable caps shall be installed on the upper I-tubes flanges and inspection windows.

The lower I-tubes shall also end in flanges, with the respective nominal top angles and azimuths as defined in the DE-RISER BALCONY ARRANGEMENT, and matching the respective bellmouth flange.

The nominal diameters for the I-tubes and bellmouths are given in Table 6. Details of the pull-in / pull-out rigging will be provided by PETROBRAS during execution phase upon request.

**Table 6 – Nominal diameter of I-tubes and bellmouths**

| Riser | Nominal Diameter [in] | |
|---|---|---|
| | Lower I-tube + Bellmouth | Upper I-tube |
| Flexibles | 48 | 40 for WD ≤ 1500 m<br>48 for WD > 1500 m |
| Umbilicals | 32 | 32 |

The intermediate ends of the upper and lower I-tubes shall be flared to a conical shape with smooth internal edges. Protection for the exposed parts of the risers shall be designed if indicated by the required safety studies.

The I-tubes shall be identified in three points, evenly spaced, in bas-relief and painted in a white color. The correlation between I-tubes and subsea wells shall be clearly represented in the installation procedures.

CONTRACTOR shall fabricate machined mockups to enable proper fit-up test at shipyard in order to guarantee the correct dimensioning of spool pieces connecting the FPSO piping and flexible risers top connector flanges at the URB level. The mockup drawings shall be submitted for comments.

The mockups shall be fabricated including blind flanges at the top end with the same specification of the risers top flanges in order to enable fit-up tests and positive isolation during operational phase.

### 7.4.4. BELLMOUTHS

Refer to the GTD for the bellmouths specification. The bellmouth concept will be defined by PETROBRAS at the KOM. CONTRACTOR shall supply all bellmouths already bolted in their positions and with safety locking devices.

CONTRACTOR shall design the bellmouths in such a way that offshore replacement by divers is possible. All materials and operations will be CONTRACTOR’s responsibility. The operational procedure shall be submitted for PETROBRAS.

During execution phase, CONTRACTOR shall endorse the bellmouth design for the expected loads at the FPSO location. If any design revision is required, PETROBRAS shall receive the technical modification proposal for analysis. The final engineering verification, manufacturing drawings and manufacturing processes are CONTRACTOR’s responsibility.

All weld surfaces inside the bellmouths shall be grinded down to an even and smooth profile, to avoid interference with the bend-stiffener locking devices. Care shall be taken regarding electrical connections between the bellmouth flanges and moving parts (dogs) in order to guarantee continuous cathodic protection from the FPSO.

CONTRACTOR shall provide as-built drawings together with all inspection reports performed during fabrication. The as-built drawings shall inform top angles, dimensions and tolerances. These tolerances shall take the paint thickness into account.

All bellmouths shall be identified in three points, evenly spaced, in bas-relief and painted in white color. The correlation between bellmouths and subsea wells shall be clearly represented in the installation procedures.

CONTRACTOR shall fabricate dummy caps to perform interference checking after bellmouths are bolted and tightened to the lower I-tubes, according to the bellmouth documentation.

### 7.4.5. RECEPTACLES

CONTRACTOR shall design, fabricate and install the receptacles. The internal profile of the receptacles shall comply with DE-STANDARD CONIC RECEPTACLE informed in the GTD.

In order to optimize pull-in operations, the design of receptacles shall include auxiliary devices such as lateral guides and / or guide cones.

CONTRACTOR shall provide as-built drawings together with all inspection reports performed during fabrication. The drawings shall inform top angles, dimensions and tolerances. These tolerances shall take the paint thickness into account.

The receptacles shall be identified in three points, evenly spaced, in bas-relief and painted in white color. The correlation between receptacles and subsea wells shall be clearly represented in the installation procedures.

CONTRACTOR shall fabricate machined mockups to enable proper fit-up test at shipyard in order to guarantee the correct dimensioning of spool pieces connecting the FPSO piping and stress / flexible joint top flanges at the LRB level. See Figure 4 (L = to be defined during execution phase). Refer also to DE-RISER TOP CONNECTOR MOCKUP GEOMETRY. The final mockup drawings shall be submitted for comments.

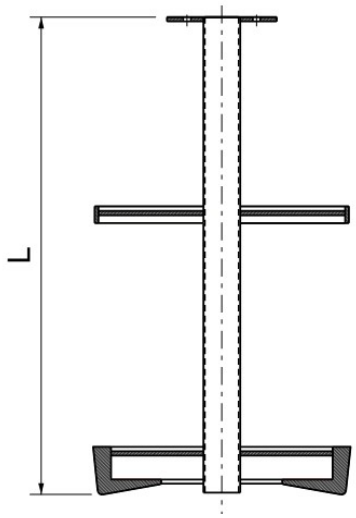



**Figure 4 – Mockup schematic**

The mockups shall be fabricated including blind flanges at the top end with the same specification of the risers top flanges in order to enable fit-up and $N_2$ leak tests of the FPSO piping. Such tests shall be performed at the shipyard before final sail-away.

### 7.4.6. HARD-PIPES

The spool pieces / hard-pipes will interconnect the rigid risers to the FPSO production and injection manifolds. CONTRACTOR may adopt any of the concepts listed below:

- Hard-pipes connected to the risers through L-shaped spool pieces installed by divers after pull-in
- Hard-pipes connected to the risers through a rotation of the pipe (either the whole hard-pipe or just its bottom end by means of underwater swivel flanges) from a sea-fastened pre-pull-in position (rotary hard-pipes)

The hard-pipe supports shall provide enough degree of freedom to enable fine tuning during underwater fit-up operations. Allowable misalignments between the rigid risers top flanges and the hard-pipe interface flanges shall be taken from the flanges design standards.

CONTRACTOR shall provide a pipe stress analysis of the hard-pipe in operational conditions. The assessment shall include construction and assembly tolerances, hull sagging and hogging, hydrodynamic loads acting on the pipe, deflections of the pipe during transit and displacements of the riser balcony structure due to the riser loads. The pipe stress analysis results shall include pipe stress, flange leakage (refer to API 6AF) and the loads acting on the pipe support. The calculations shall be issued for PETROBRAS approval.

The design shall speed up the assembly, minimizing diving activities, offshore construction, loads lifting, etc. The hard-pipes in their pre-pull-in position shall not interfere with nor impose restrictions to the pull-in / pull-out operations of adjacent risers.

The lower flanges of the pipes shall be identified in three points, evenly spaced, in bas-relief and painted in white color. The correlation between hard-pipes and subsea wells shall be clearly represented in the installation procedures.

CONTRACTOR may propose alternative solutions to be evaluated by PETROBRAS during the tender process.

## 7.5. PULL-IN SYSTEM

Pull-in / pull-out operations onboard the FPSO and any diver-assisted related operations are CONTRACTOR's responsibility.

The package shall consist of all required equipment, materials, handling devices and spare parts in order to enable the installation / de-installation of risers onboard the FPSO.

All equipment and instruments shall be compatible with the area classification (hazardous / non-hazardous) and a marine / salty / aggressive environment with water splashes.

The system shall be able to access every riser position and shall not interfere with installed risers.

The pull-in system facilities shall enable the realization of pre- and / or post-pull-in activities (e.g., positioning of auxiliary sheaves, closing of interface flanges, pre-commissioning activities, etc.) in different positions simultaneously with main winch operations. The final system design shall be submitted for PETROBRAS.

### 7.5.1. PULL-IN WINCHES

The pull-in rig shall be composed of at least one main winch and two auxiliary winches. All winches shall be electro-hydraulic.

The main winch minimum pull capacity shall be 550 mT and minimum rated speed shall be 2 m/min @ maximum load (top layer).

The main winch shall be provided with means to guarantee that the wire rope will always reach the flexible riser supports in a vertical and centralized configuration and the rigid riser supports with the required clearance for a safe operation, as per item 7.5.8.

The two auxiliary winches shall be used for the hauling-in of the stress / flexible joints of rigid risers into the receptacles. See also item 7.5.8. The auxiliary winches shall be provided with a tension release control mode to enable easy and safe rigid risers pull-in operations.

The main winch shall be able to pay-out at least 600 m of wire rope hanging below LRB level. The auxiliary winches shall be able to pay-out at least 100 m of wire rope hanging below LRB level. The winches shall be capable of paying-in / out small lengths of wire rope, to allow accurate positioning of the risers into their slots.

All winches and storage drums shall be provided with an automatic braking system, to be engaged when paying-in/out operations have stopped, at power failure, control failure or at emergency stop. Technical or operational failures shall not lead to uncontrolled cable pay-out. An emergency brake release system (e.g. hand pumps) shall also be provided.

Storage drums of linear pull-in winches shall be automatically synchronized with the speed and the required back-tension of the wire rope coming from the winch, even in manual operation mode. Alternative arrangements may be proposed.

Multi-layer drums shall be Lebus grooved. The maximum number of rope layers shall be 7.

CONTRACTOR is responsible for the verification of the minimum pull capacity required for all winches during execution phase, in accordance with I-ET-RISER TOP INTERFACE LOADS ANALYSIS. For the main winch assessment, an extra load of 50 mT shall be added to the design loads of flexible risers and umbilicals in order to account for the shearing of cables during the bend-stiffener connection to the associated bellmouth.

CONTRACTOR shall demonstrate that all winches were designed and tested to operate safely at minimum and maximum loads. The stall load shall be settable so that it is possible to use the winches to lift lower loads in safe conditions. CONTRACTOR shall inform the lowest stall load setting possible and associated accuracy.

The riser configurations informed in APPENDIX A – RISER CONFIGURATION DATA are preliminary and intentionally conservative. During execution phase, PETROBRAS will inform the final riser loads for the CONTRACTOR to evaluate the true environmental limits for the risers hand-over and pull-in operations.

### 7.5.2. PULL-IN ROPES

The pull-in wire ropes shall be dimensioned considering the smallest diameter that meets the required SWL with a SF = 2.5 on the respective winch nominal pull capacity.

The wire ropes shall be specified according to the following characteristics (or similar): EIPS steel (1960 MPa), galvanized, rotation-resistant, right hand Lang’s lay, compacted strands, heavy duty lubrication, crushing and bending fatigue resistant, ending in:

- Main winch: Closed Spelter sockets
- Auxiliary winches: Open or Closed Spelter Sockets (to be confirmed by PETROBRAS during execution phase).

Fiber ropes are also acceptable for the auxiliary system. In this case, the specification shall be informed to PETROBRAS for prior evaluation.

The ropes shall be furnished in the winch drums and already tensioned, according to the required back-tension specified by the wire rope manufacturers.

CONTRACTOR shall present evidence compliance with the technical requirements of wire rope manufacturers. The ropes shall be supplied with certificates verifying:

- Grade and strength
- Quality in compliance with the appropriate standards
- CS requirements

### 7.5.3. DEVIATION SHEAVES

Effective devices shall be provided to prevent the wire ropes from escaping the sheaves.

Minimum sheave diameter shall be 16 times the respective wire rope nominal diameter.

Sheaves efficiency shall not be less than 98%.

### 7.5.4. SERVICE FACILITIES

CONTRACTOR shall provide facilities to assist pull-in / pull-out operations, e.g., for the assembly / disassembly of flexible riser hang-off systems, assembly / disassembly of spool pieces at URB and LRB, connection / disconnection of pull-in riggings, deployment / retrieval of messenger ropes to / from installation vessels (specially for keel-hauling operations), main pull-in wire rope handling and routing through deviation sheaves, connection / disconnection of PLRs and riser top valves, etc.

CONTRACTOR shall provide a davit or crane with minimum SWL 10 mT @ 5 m capable of operating independently of the main winch system in order to, for example, support diving operations in different positions simultaneously with main winch operations. Other arrangements may be proposed.

### 7.5.6. DIVING FACILITIES

Diving activities required for pull-in / pull-out operations are CONTRACTOR's scope. The diving team shall be sized to operate 1 front x 24 hours/day uninterruptedly during the risers installation campaign.

CONTRACTOR shall also provide all other resources required to enable the diving activities described below. Refer to the contract for the detailed scope.

- Pull-in / pull-out preparation (messenger lines installation, handling of cables, connection / disconnection of transfer riggings, bellmouths and receptacles inspection, etc.)
- Bend-stiffener connection / disconnection to bellmouths (contingency cases)

- Bellmouths replacement
- Support of rigid risers pre-commissioning operations (PLR and riser top valves assembly / disassembly and operation, etc.)
- Connection / disconnection of spool pieces / hard-pipes to the top flanges of rigid risers (handling, bolts tensioning, seal test, etc.)
- Installation and hook-up of the rigid risers monitoring system (top motion measurement devices on all risers and strain measurement devices on half of them). See I-ET-RRMS. The detailed procedure will be provided during the execution phase.

### 7.5.7. LOOSE ITEMS

CONTRACTOR shall provide heaving lines, messenger wire ropes with 150 m length, four polypropylene ropes with 220 m length and all other materials necessary to enable pull-in / pull-out operations on the FPSO side.

CONTRACTOR shall deliver one spare rope for each winch. Means for spooling the spare ropes onto the winches and meet the required pre-tension with the FPSO at the final location shall be provided. CONTRACTOR shall issue a detailed procedure and provide all necessary equipment and accessories.

CONTRACTOR shall also supply spare sockets for the offshore re-termination of the pull-in ropes (minimum one spare socket per cable).

The use of snatch blocks for installation and de-installation procedures is not acceptable. Sheave blocks, fairleads, swiveling blocks, etc., shall be used instead.

### 7.5.8. ADDITIONAL PROVISIONS FOR RIGID RISERS

Pull-in operations of rigid risers include the preparation and pre-comissioning activities listed below. Refer to the contract for detailed information.

- Handling of main and auxiliary cables, assembly of riggings, positioning of auxiliary sheaves, inspection of receptacles, etc.
- PLR valves operations, PLR and pull-in head recovery and transfer to installation vessel, interface flanges connection and seal test, etc.

Figure 5 illustrates the rigid riser pull-in sequence devised by PETROBRAS.

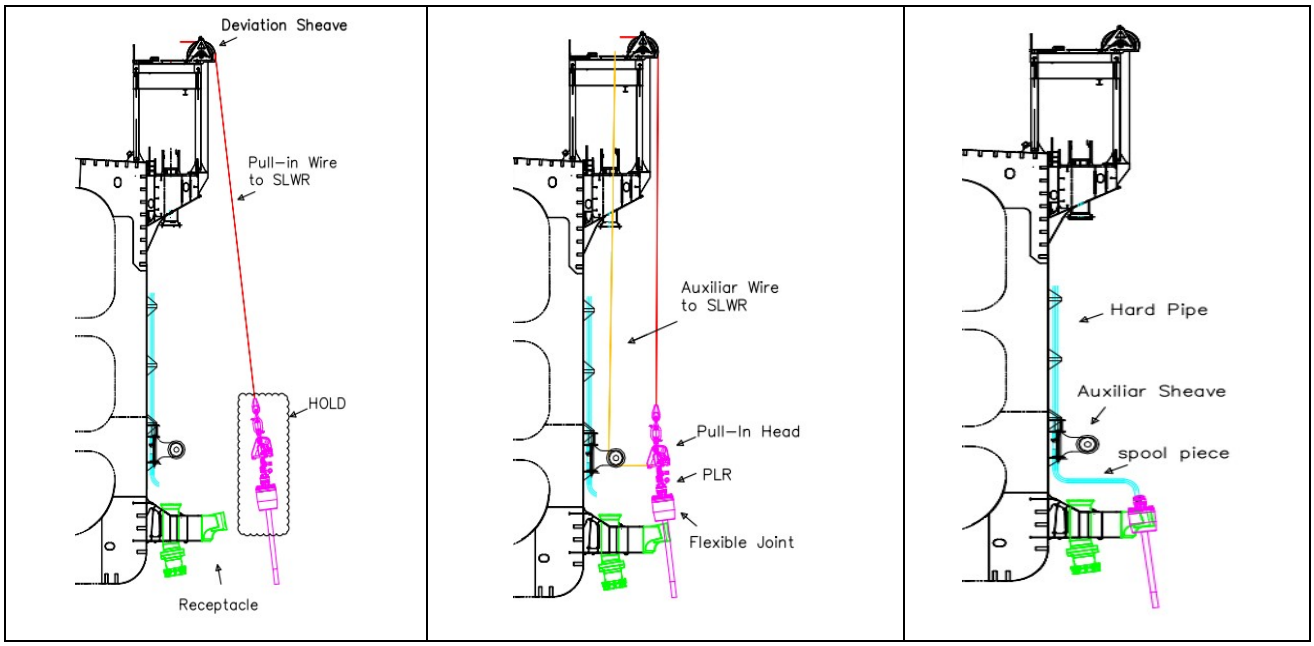



**Figure 5 – Rigid riser pull-in operation**

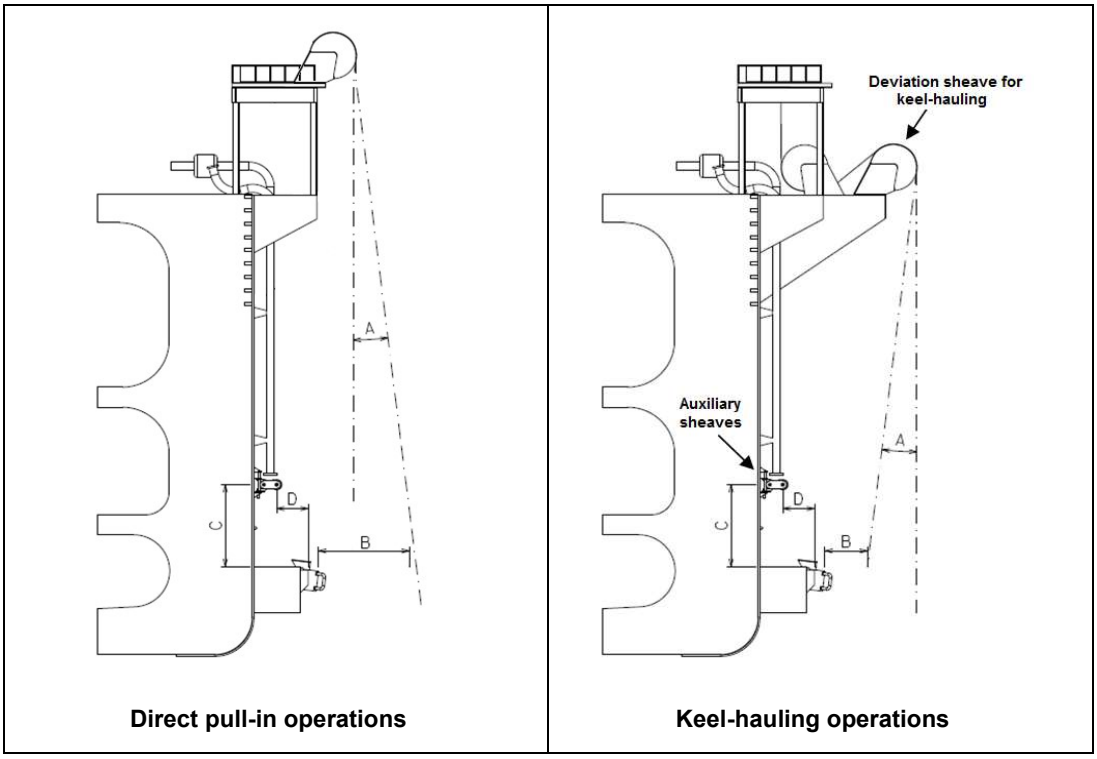
The maximum dimensions of the main pull-in rigging shall be considered as below. Detailed information will be provided by PETROBRAS during execution phase.

- Length: 17 m (from the main winch socket to the stress / flexible joint bottom)
- Pull-in head diameter: same as the receptacle diameter

The connection of the auxiliary system to the main rigging during the final steps of the pull-in operation is CONTRACTOR's scope. CONTRACTOR must take into account the weight and flexibility requirements applicable for the auxiliary ropes, in order to enable easy handling by divers and / or climbers (base case) or ROVs supplied by the Installation Vessel (contingency cases due to environmental conditions).

For pull-in / pull-out operations of rigid risers coming from the FPSO side opposite the riser balcony (keel-hauling operations), PETROBRAS suggests the location of deviation sheaves for the main winch cable at URB level, aligned with each riser azimuth as per Figure 6.

CONTRACTOR shall design the system to enable the safe execution of operations considering the criteria defined in Table 7. Clashing between the pull-in cable, riggings or rigid riser and the FPSO structures during pull-in / pull-out operations is not acceptable.




**Direct pull-in operations** | **Keel-hauling operations**

**Figure 6 – Rigid risers pull-in system design criteria**

**Table 7 – Rigid risers pull-in system design criteria**

| Description | Dimension (Figure 6) | Value |
|---|---|---|
| Riser installation top angle after total load transfer (keel-hauling operations) | A | 7 deg |
| Riser installation top angle after total load transfer (direct pull-in operations) | A | 6 deg |
| Maximum pull-in cable top angle (direct pull-in operations) | A | 30 deg |
| Minimum static clearance between FPSO structures and stress / flexible joint face | B | 2.5 m |
| Minimum clearance between top of support and auxiliary sheaves | C | 8.0 m |
| Minimum clearance between receptacle centers and auxiliary sheaves | D | 2.0 m |

The vertical position of the pull-in auxiliary sheaves shall be defined by CONTRACTOR, ensuring a minimum 1 m vertical clearance between the bottom of stress / flexible joint and the FPSO structures.

KEEL-HAULING OF RIGID RISERS

The outline of the riser transfer procedure is presented in Figure 7. CONTRACTOR shall consider a maximum distance of 160 m between the installation vessel and the FPSO side (opposite the balcony) during this operation.

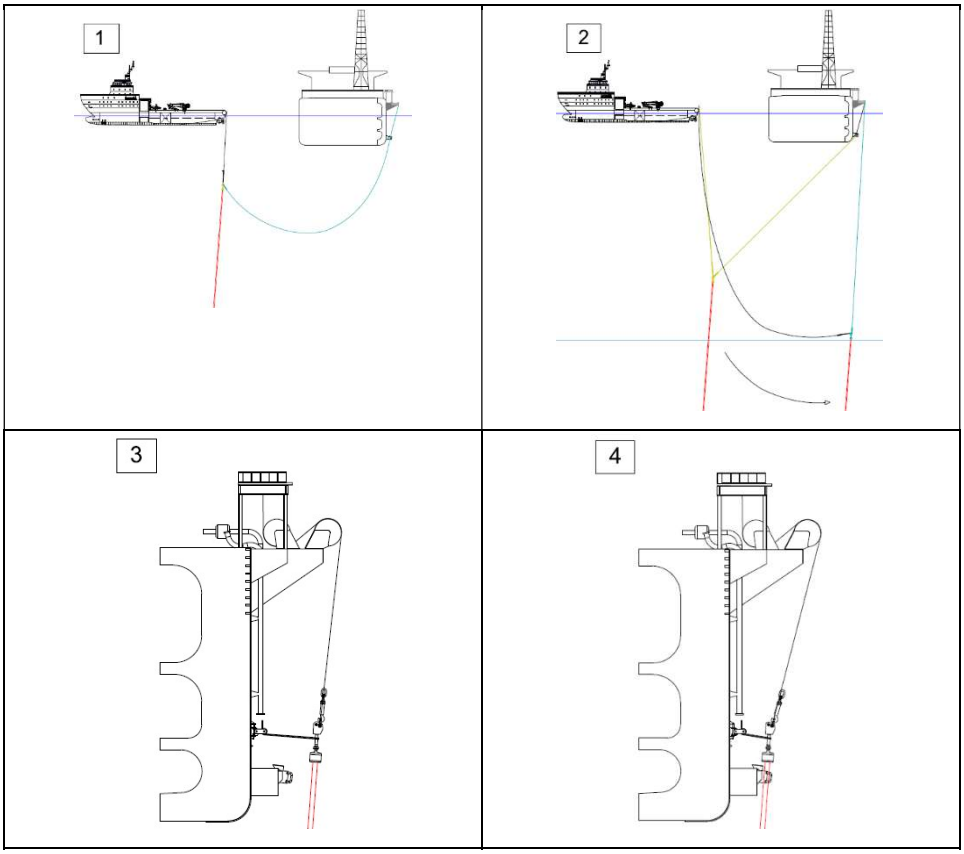



**Figure 7 – Outline of the rigid riser keel-hauling procedure**

As per Figure 8, the maximum deviation angle of the pull-in cable inside the receptacle can be assumed as 45 deg @ 35% maximum pull-in load. During the riser transfer, when inside the receptacle, the FPSO pull-in cable length paid will remain fixed and only the Installation Vessel cable will be paid-in / out.

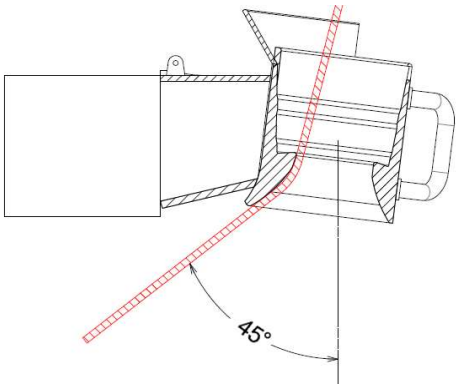



**Figure 8 – Maximum wire rope deflection during load transfer**

## 8. HYDRAULIC POWER UNITS

Hydraulic Power Units (HPUs) shall be supplied and installed in suitable locations near the mooring hook-up and risers pull-in system.

The HPUs shall be dimensioned to supply enough power to simultaneously operate all the equipment necessary as defined in the operational procedures. A minimum of 2 x 100% or 3 x 50% hydraulic pumps shall be provided for redundancy.

## 9. OPERATIONAL PROCEDURES

### 9.1. GENERAL

The mooring hook-up and risers pull-in packages shall be provided with descriptive manuals, operating manuals and maintenance manuals.

All operational procedures for the towing, and also mooring lines installation / de-installation and risers pull-in / pull-out operations on the FPSO side shall be designed by the CONTRACTOR and issued for PETROBRAS at least 12 months before the Unit Provisional Acceptance date. These procedures shall cover, as a minimum, the following:

- Maximum allowable environmental condition
- Required preparation works at shipyard and offshore
- Personnel to be mobilized
- Special assemblies, required materials and installation aids, equipment setup, etc.
- Check-lists for starting the operations
- Step-by-step procedures, with sketches and all necessary information (calculations, standards, etc.) for its correct understanding

### 9.2. TOWING

Refer to the contract.

### 9.3. MOORING LINES INSTALLATION AND HOOK-UP

Mooring lines installation/ de-installation will be performed by PETROBRAS (AHV side). CS surveillance onboard the AHVs will also be provided by PETROBRAS. CONTRACTOR will be notified 30 days in advance and shall witness the operation onboard PETROBRAS' vessels.

CONTRACTOR shall be responsible for the final certification of the as-laid system.

The mooring lines installation and de-installation procedures (FPSO side) shall be issued by the CONTRACTOR considering the following requirements:

- Use of messenger lines to transfer the installation chains
- Quick-release of mooring lines after the LLLC link is connected between the top and installation chains (base case)
- Operations shall not interfere with any pre-installed adjacent mooring lines
- Mooring lines hook-up sequence either from midship to bow / stern or from bow / stern to midship

## 9.4. RISERS INSTALLATION AND DE-INSTALLATION

Risers installation / de-installation will be performed by PETROBRAS (Installation Vessel side).

The procedures shall consider that pull-in / pull-out operations can be performed either first-end connection (before flowlines have been connected to the X-mas trees or PLETs) or second-end connection (flowlines connected to the X-mas trees or PLETs and then laid down towards the FPSO).

The riser installation and de-installation procedures shall be issued by the CONTRACTOR considering the following requirements:

- Thermal radiation emitted by the FPSO flare shall not compromise the operations
- Hot work onboard the Installation Vessel will be required inside the FPSO 500 m exclusion zone (welding of the flexible / stress joint of rigid risers). The Installation Vessel will be provided with gas detectors to mitigate related risks. The minimum acceptable distance for this work shall be agreed with PETROBRAS during execution phase
- Pull-in / pull-out operations will be performed with the risers full of water except for the Gas Export risers, which will be installed empty (to be confirmed, if applicable)
- Pull-in / pull-out operations shall not interfere with any pre-installed adjacent risers
- The Unit shall be considered in any draft, with process plant and all facilities operational
- The Unit shall be considered moored with no riser installed up to all risers installed
- Contact forces and deflection angles of the pull-in main winch cable inside the bellmouths and receptacles need to be evaluated. CONTRACTOR shall ensure integrity of cables and FPSO structures under the specified pull-in / pull-out procedures
- Flexible risers and umbilicals will be equipped with bend-stiffeners and will be pulled by means of a pull-in head or a bull nose. Detailed information will be provided by PETROBRAS during execution phase
- Rigid risers will be pulled by means of a rigging connected to the rigid riser stress / flexible joint top flange. A hook will be provided by the Installation Vessel to be connected to the main cable socket by the FPSO personnel. Detailed information will be provided by PETROBRAS during execution phase
- Considering the harsh environment and the typical small weather windows predicted in the area, pull-in / pull-out procedures shall minimize diving operations
- Preparation activities must be fulfilled in advance, before the Installation Vessel reaches the non-returning point (to be agreed with PETROBRAS during execution phase)
- Readiness for subsequent pull-in operations encompasses all preparation activities, including paying the main cable to the agreed transfer WD

## 10. RESPONSIBILITIES

CONTRACTOR shall be responsible for:

- Developing the mooring hook-up, risers pull-in / pull-out, chain-stopper replacement, bellmouths replacement, pull-in cables replacement and all other operational procedures necessary for the FPSO on-site installation

- Mooring system design and CS approval
- Supply of all mooring legs, including the spare line, with jewelry and all necessary temporary materials to be used onboard the FPSO during hook-up operations. See APPENDIX B – MOORING MATERIALS SCOPE OF SUPPLY
- Delivery and unloading of mooring materials within 600 km from TBD. The materials shall be delivered customs-cleared 30 months after issuance of the LOI
- Supervising the loading of the mooring materials on the PETROBRAS AHVs and the mooring lines installation operations. In case of inspection findings such as dimensional non-conformities, CONTRACTOR shall immediately take action to correct the issue
- Operating the mooring equipment onboard the FPSO, 24 hours/day, during the hook-up and tensioning phases in up to two different works fronts / clusters
- Mooring chain and jewelry cutting for removal from onboard the FPSO, after the final tensioning of the system and final disposal of these excess materials (if applicable)
- Risers pull-in every 5 days, including preparation in advance considering the Installation Vessel non-returning point. Details will be discussed during execution phase
- Providing the readings of the POS and MRU (Motion Reference Unit) systems in real-time for the Installation Vessel during the pull-in and pre-comissioning operations
- Returning the riser pull-in materials (riggings, PLRs, etc) to the Installation Vessel in up to 15 days after the riser connection on the Unit by means of the FPSO main cranes
- Opening the PLR and riser top valves in up to 5 days after the rigid risers is installed for flooding the line and closing the PLR and riser top valves in up to 2 days after the rigid risers is flooded for the hydrostatic test (if applicable)
- Receiving the seawater and dye from the hydrostatic tests onboard the FPSO (if applicable)
- In case of the Gas Export SLWR, drying with MEG (or similar) and inertization with $N_2$ are also performed during the pre-comissioning and these products shall also be received onboard the FPSO. Refer to the GTD for the complete scope of work
- Installation of the diving equipment on the designated stations for all diving operations
- Providing accommodations for 8 POB from the SURF CONTRACTOR for the risers pre-comissioning activities (if applicable)

PETROBRAS shall be responsible for:

- Design and CS approval of the anchoring devices, including their installation
- Issuing the hook-up procedures based on the information provided by the CONTRACTOR
- Supply of mooring materials according to APPENDIX B – MOORING MATERIALS SCOPE OF SUPPLY
- Storage and loading of the mooring materials supplied by the CONTRACTOR on the PETROBRAS AHV fleet. In case of inspection findings, CONTRACTOR will be notified
- Mooring lines installation and hook-up operations on AHVs side
- Providing a temporary positioning system onboard the FPSO to assist on-site installation

- Providing supply boats to unload excess materials after hook-up / tensioning operations and delivery at the place defined in contract
- Providing one AHV with ROV to perform survey of the mooring lines during final tensioning
- Supply of the riggings for the risers pull-in / pull-out operations
- All diving activities for risers inspection campaigns

# APPENDIX A – RISER CONFIGURATION DATA

All information herein provided is preliminary and may be updated at the project KOM.

The riser configurations informed consider the field WD and connection points at 2 m (flexible risers) and 6 m (rigid risers) above keel in a typical FPSO at ballast draft (11 m). The operational fluids informed in Table A.1 were also considered to establish the riser configurations.

**Table A.1 – Operational fluids**

| Riser | Operational Fluid | Density [kgf/m$^3$] |
|---|---|---|
| Production | Oil | 1080 |
| WAG Injection | Water | 1050 |
| Service | Diesel | 850 |

For the stability and mooring analyses, the densities above shall be considered. For the top loads estimation, all risers shall be analyzed for the full of water (or heavier operational fluid) and empty conditions. All risers shall be considered full of water for the pull-in system assessment. See I-ET-RISER TOP INTERFACE LOADS ANALYSIS.

## FLEXIBLE RISERS

All flexible risers shall be considered in free-hanging configuration with top angle of 7 degrees. Tables A.2 and A.3 present the riser compositions and mechanical properties to be considered for the analyses. Drag Coefficient (Cd) and Added Mass Coefficient (Ca) shall be taken as 1.2 and 1, respectively.

**Table A.2 – Riser structures**

| Riser | ID [mm] | OD [mm] | Dry Weight Empty [kgf/m] | Axial Stiffness [kN] | Bending Stiffness [kN.m$^2$] |
|---|---|---|---|---|---|
| PO 8" Top | 211.80 | 404.92 | 330.88 | 2.65E+06 | 334.51 |
| PO 8" Inter | 213.10 | 369.74 | 249.68 | 1.44E+06 | 309.81 |
| PO 8" Bot | 213.10 | 407.26 | 347.69 | 1.84E+06 | 384.21 |
| GL 4" Top | 101.60 | 232.12 | 114.63 | 1.00E+06 | 24.42 |
| GL 4" Inter | 101.60 | 191.34 | 69.56 | 5.19E+05 | 10.79 |
| GL 4" Bot | 101.60 | 191.34 | 69.56 | 5.19E+05 | 10.79 |
| WAG 6" Top | 152.40 | 347.32 | 282.59 | 2.14E+06 | 120.54 |
| WAG 6" Inter | 152.40 | 287.54 | 177.95 | 8.01E+05 | 53.22 |
| WAG 6" Bot | 152.40 | 284.34 | 169.14 | 5.60E+05 | 51.36 |
| UEH | - | 163.80 | 50.80 | 4.80E+05 | 12.00 |

**Table A.3 – Riser compositions**

| Riser | L [m] | | |
|---|---|---|---|
| | Top Section | Intermediate Section | Bottom Section |
| PO8 | 400 | 1600 | 1200 |
| GL4 | 1000 | 1000 | 1200 |
| WAG6 | 1000 | 1000 | 1200 |
| UEH | 1000 | 1000 | 1200 |

Table A.4 presents the data related to the bend stiffeners for each riser function. To design the bellmouths, CONTRACTOR shall consider the use of extenders as shown in Figure A.1.

**Table A.4 – Bend-stiffener data**

| Riser | Db [mm] | Din [mm] | L [m] | d [m] | E [MPa] |
|---|---|---|---|---|---|
| PO8 | 1330 | 430.3 | 3.1 | 1.5 | 77 |
| GL4 | 800 | 257.5 | 1.8 | 1.5 | 77 |
| WAG6 | 1190 | 372.7 | 2.7 | 1.5 | 77 |
| UEH | 450 | 189.2 | 1.7 | 1.2 | 210 |

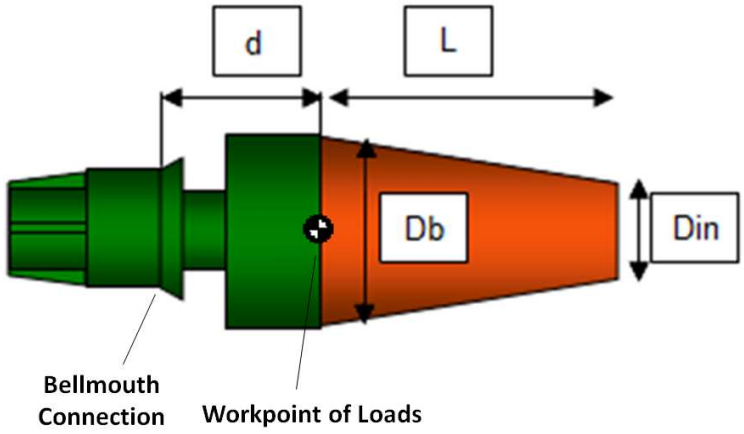



**Figure A.1 – Bend-stiffener dimensions and workpoint**

## RIGID RISERS

The rigid pipe properties, hydrodynamic coefficients and global parameters for rigid risers are presented in the tables A.5, A.6 and A.7, respectively.

Figures A.2, A.3, A.4, A.5 and A.6 present the top connector schematic, a straked cross-section schematic, the loads application point and the riser configuration parameters, respectively.

**Table A.5 – Rigid pipe properties**

| Wall thickness and diameters details | | Carbon steel |
|---|---|---|
| Production | External diameter [mm] | 271.2 |
| | Internal diameter [mm] | 203.2 |
| | Wall thickness [mm] | 34.0 |

| | | | |
|---|---|---|---|
| WAG Injection | External diameter [mm] | | 269.2 |
| | Internal diameter [mm] | | 203.2 |
| | Wall thickness [mm] | | 33.0 |
| Service | External diameter [mm] | | 149.6 |
| | Internal diameter [mm] | | 101.6 |
| | Wall thickness [mm] | | 24.0 |
| **Material properties** | | | |
| Carbon steel | Density [kg/m3] | | 7850 |
| | Young's Modulus [GPa] | | 207 |
| **External coating properties** | | | |
| Production | Thickness [mm] | | 40 |
| | Specific weight [kN/m³] | | 7.85 |
| WAG Injection | Thickness [mm] | | 3.0 |
| | Specific weight [kN/m³] | | 9.32 |
| Service | Thickness [mm] | | 3.0 |
| | Specific weight [kN/m³] | | 9.32 |
| **Buoyancy Module Properties** | | | |
| Production | Length [m] | | 2.4 |
| | Diameter [m] | | 2.3 |
| | Uptrust per Buoyancy Module [kN] | | 34.8 |
| | Associated weight [kN] | | 64.0 |
| | Modules | | 6 |
| | Distance between center to center of the Modules [m] | | 2x12 + 1x24 + 2x12 |
| WAG Injection | Length [m] | | 2.5 |
| | Diameter [m] | | 2.6 |
| | Uptrust per Buoyancy Module [kN] | | 46.8 |
| | Associated weight [kN] | | 85.6 |
| | Modules | | 8 |
| | Distance between center to center of the Modules [m] | | 24 |
| Service | Length [m] | | 2.5 |
| | Diameter [m] | | 1.3 |
| | Uptrust per Buoyancy Module [kN] | | 33.7 |
| | Associated weight [kN] | | 21.8 |
| | Modules | | 13 |
| | Distance between center to center of the Modules [m] | | 12 |
| **Strake properties** | | | |
| All risers | Shell Wall Thickness [mm] | | 15.0 |
| | Strake Vane Height [mm] | | 60.0 |
| | Density [kg/m³] | | 1149 |
| **Top connector** (2) | | | |
| Production / WAG Injection | Length [m] | Taper section (LA) | 6.5 |
| | | Straight section (LB) | 3.5 |
| | | Total active section (L) | 10.0 |
| | Top wall thickness (TWT) [mm] | | 85.75 |
| | Bottom wall thickness (BWT) [mm] | | 28.0 |
| | Elasticity Modulus (E) [GPa] | | 105.0 |
| | Density [kg/m³] | | 4500.0 |

Note 1: Inconel layer is an anti-corrosion internal coating.

Note 2: Values to be confirmed during the detailed design phase

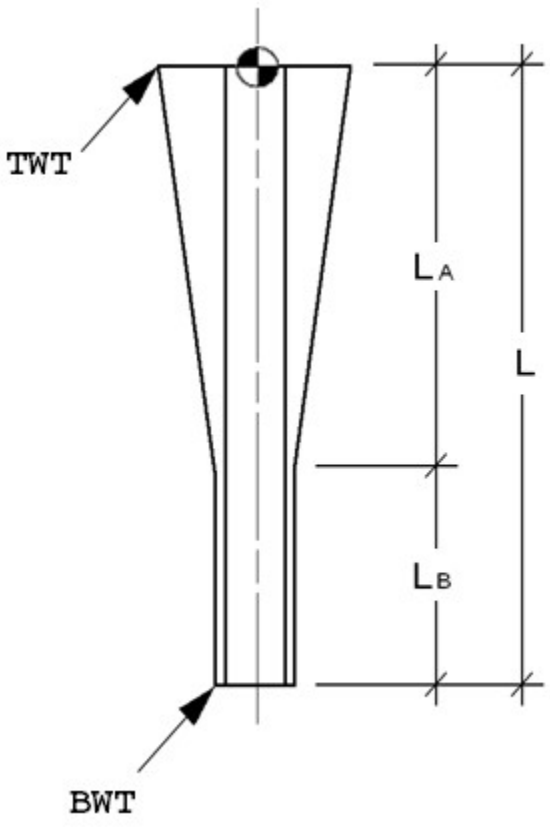



**Figure A.2 – Stress joint active section**

**Table A.6 – Hydrodynamic Coefficients**

| **Hydrodynamic coefficient for** | | **Extreme Analysis** | **Fatigue Analysis** |
|---|---|---|---|
| Coated pipe | Normal drag | 1.2 | 0.7 |
| | Tangential drag | 0.001 | |
| | Inertia Coefficient | 2.0 | |
| Coated pipe with strake | Normal drag | 1.6 | |
| | Tangential drag | 0.001 | |
| | Inertia Coefficient | 2.5 | |
| Coated pipe with buoys | Normal drag | 1.2 | 0.7 |
| | Tangential drag | 0.9 | |
| | Inertia Coefficient | 2.0 | |
| **Structural damping** | | | |
| Structural damping [%] | | 0.3 | |

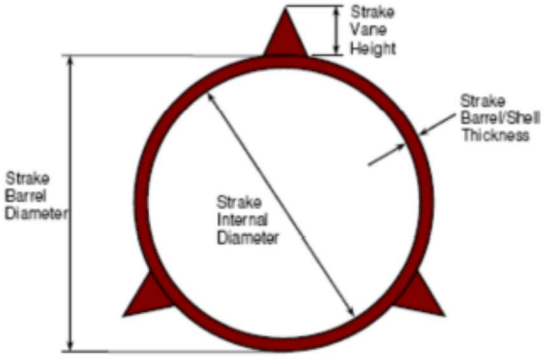



**Figure A.3 – Straked cross-section schematic**

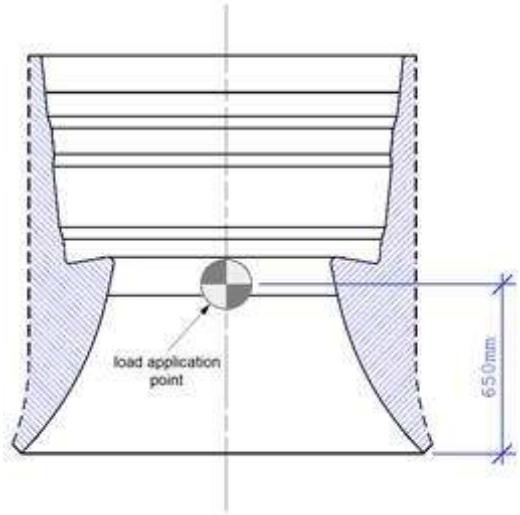



**Figure A.4 – Load application point for rigid risers**

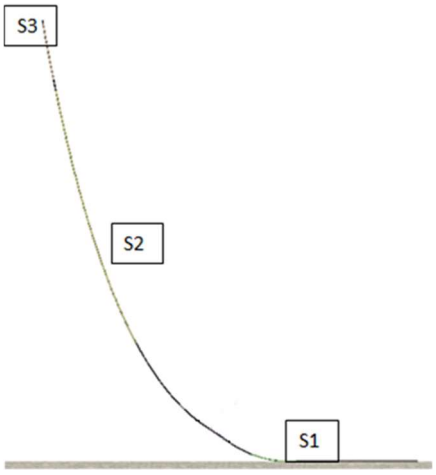



**Figure A.5 – Riser configuration parameters**

**Table A.7 – Rigid risers global parameters for operational fluid**

| Parameter | | Production | WAG Injection | Service |
|---|---|---|---|---|
| S1 [m] | Coated pipe | 884 | 1376 | 488 |
| S2 [m] | Coated pipe with buoys | 72 | 168 | 147 |
| S3 [m] | Coated pipe with strake | 1983 | 2010 | 2129 |
| S4 [m] | FXJ Extension | 6+1 | 6+1 | 6+1 |
| Total length [m] | | 2946 | 2946 | 2771 |
| Horizontal projection [m] | | 1518 | 2190 | 1194 |
| Top angle [°] | | 7.5 | 8.0 | 4.5 |
| Top tension [kN] | | 3595 | 2765 | 1374 |

Obs.: the riser horizontal projection informed above shall be fixed when considering different fluid densities.

## APPENDIX B – MOORING MATERIALS SCOPE OF SUPPLY

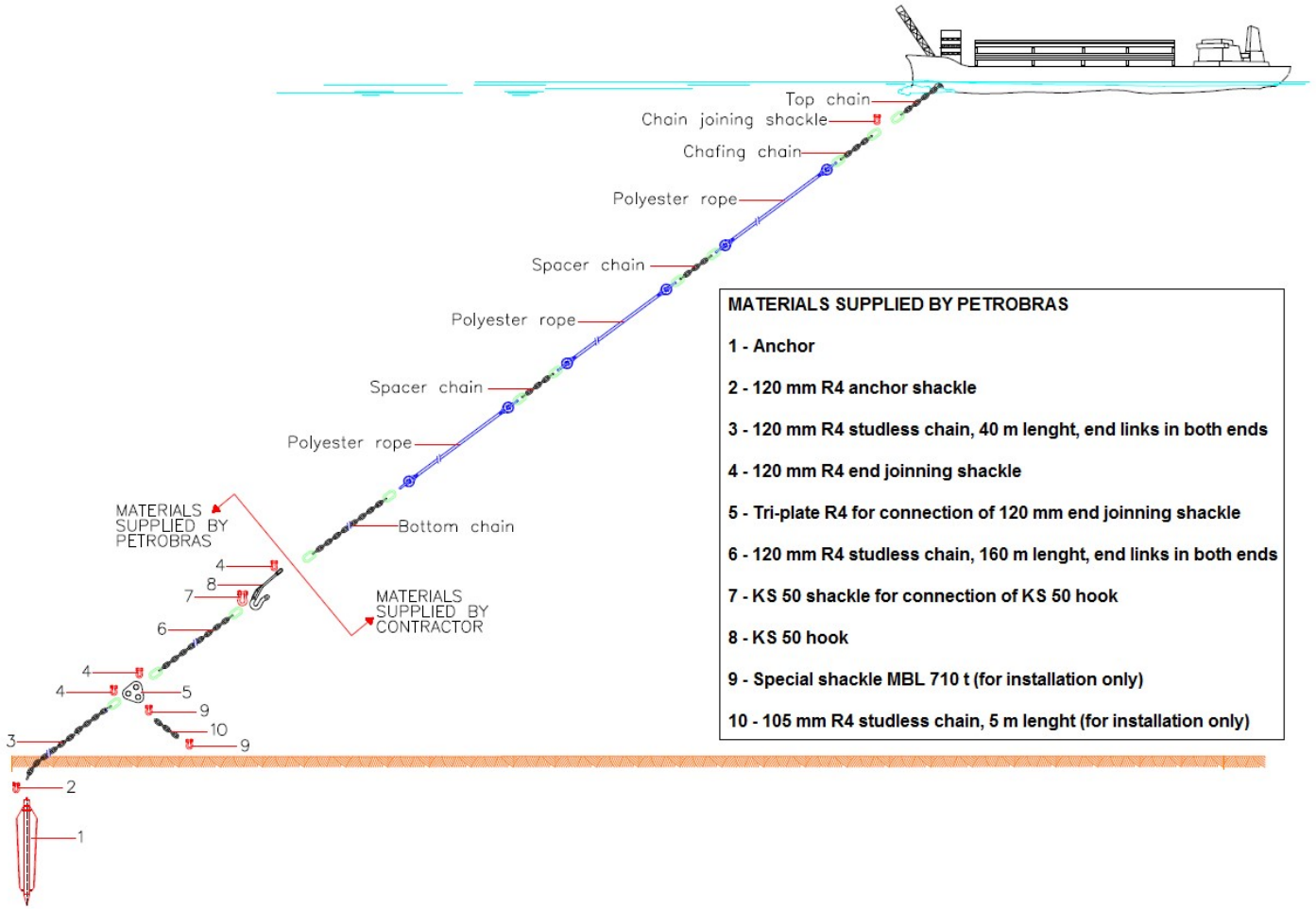



**Figure B.1 – Mooring material scope of supply**

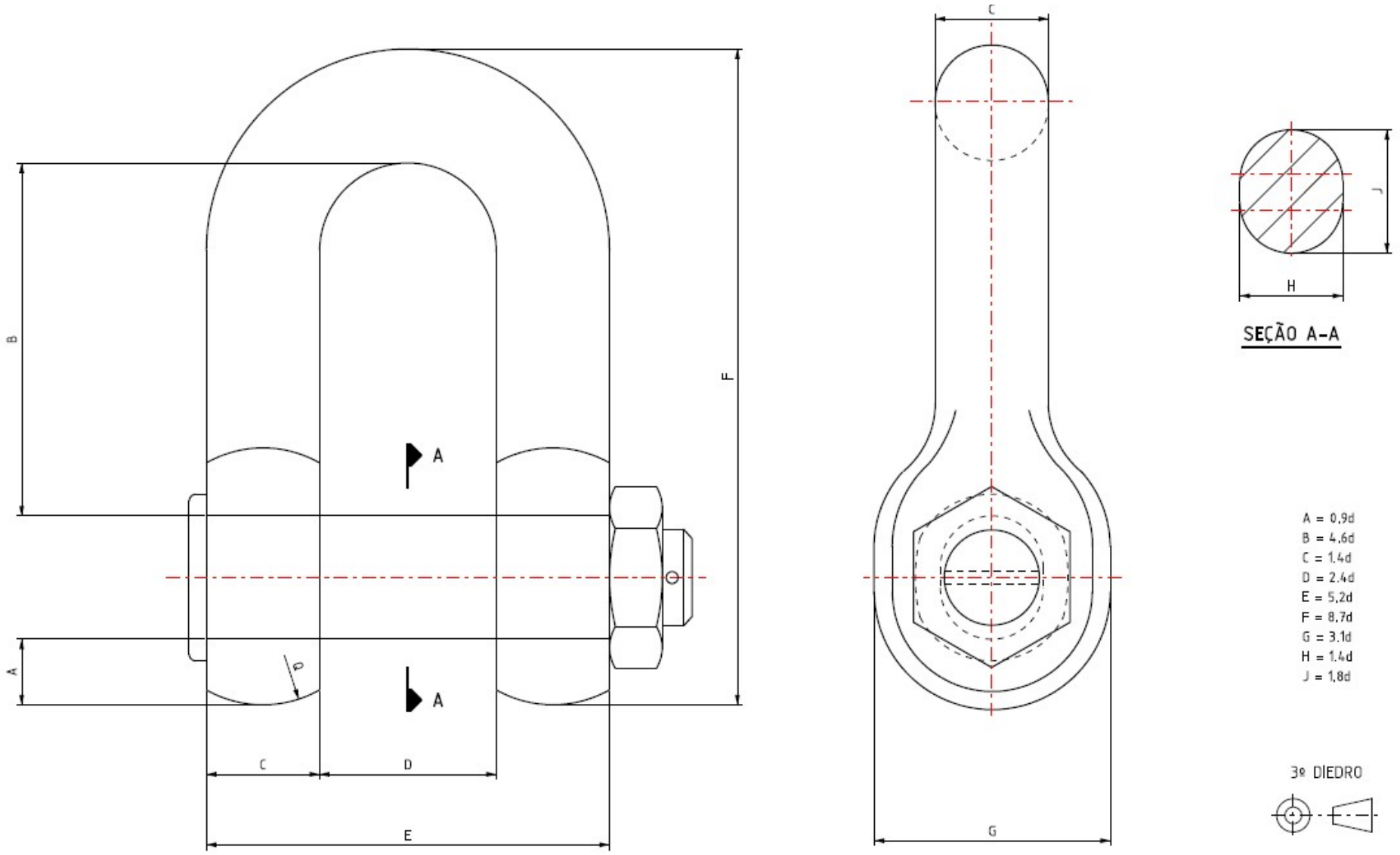



**Figure B.2 – Anchor shackle Grade 4 for torpedo pile connection (item 2)**

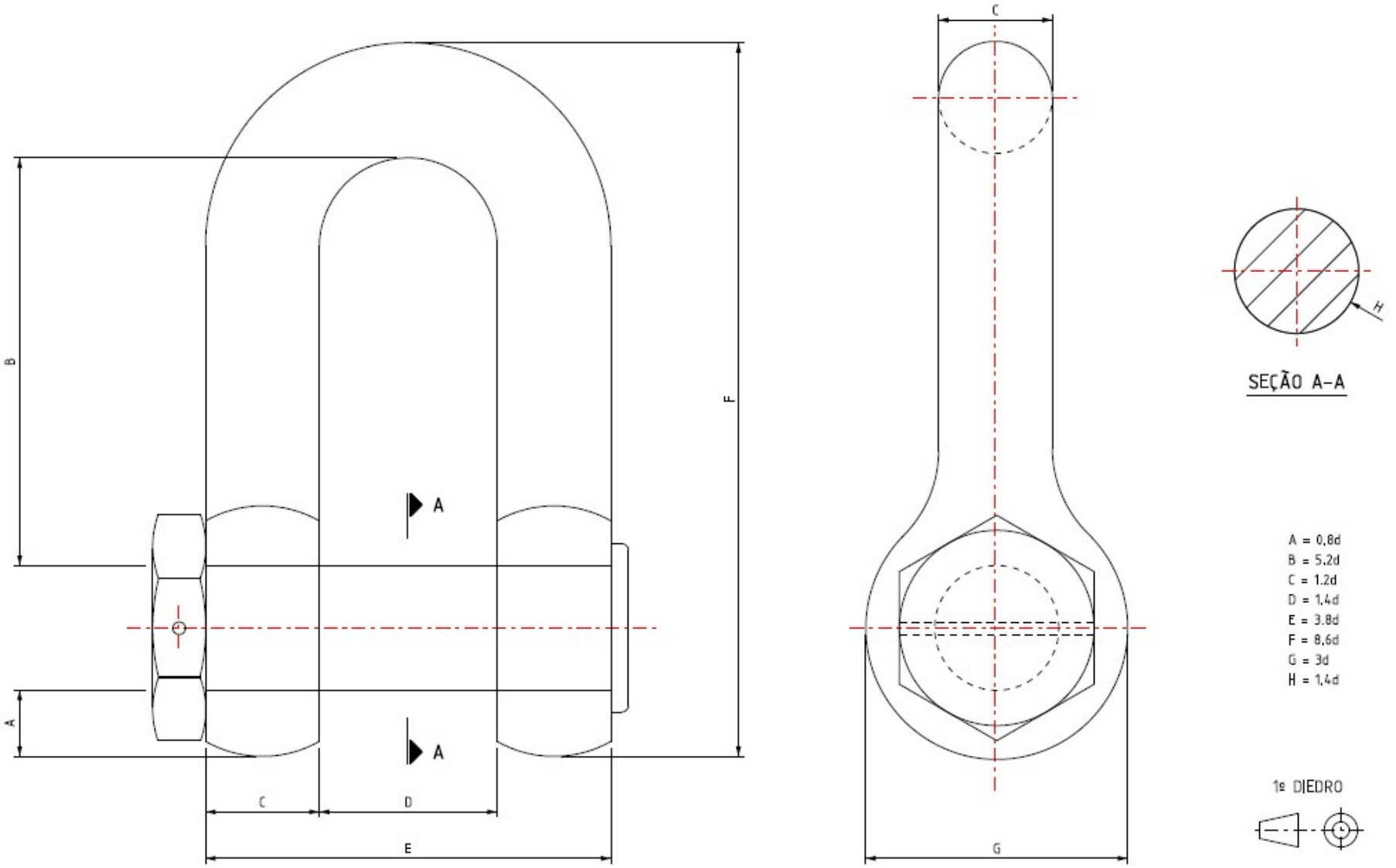



**Figure B.3 – Special end-shackle Grade 4 (item 4)**

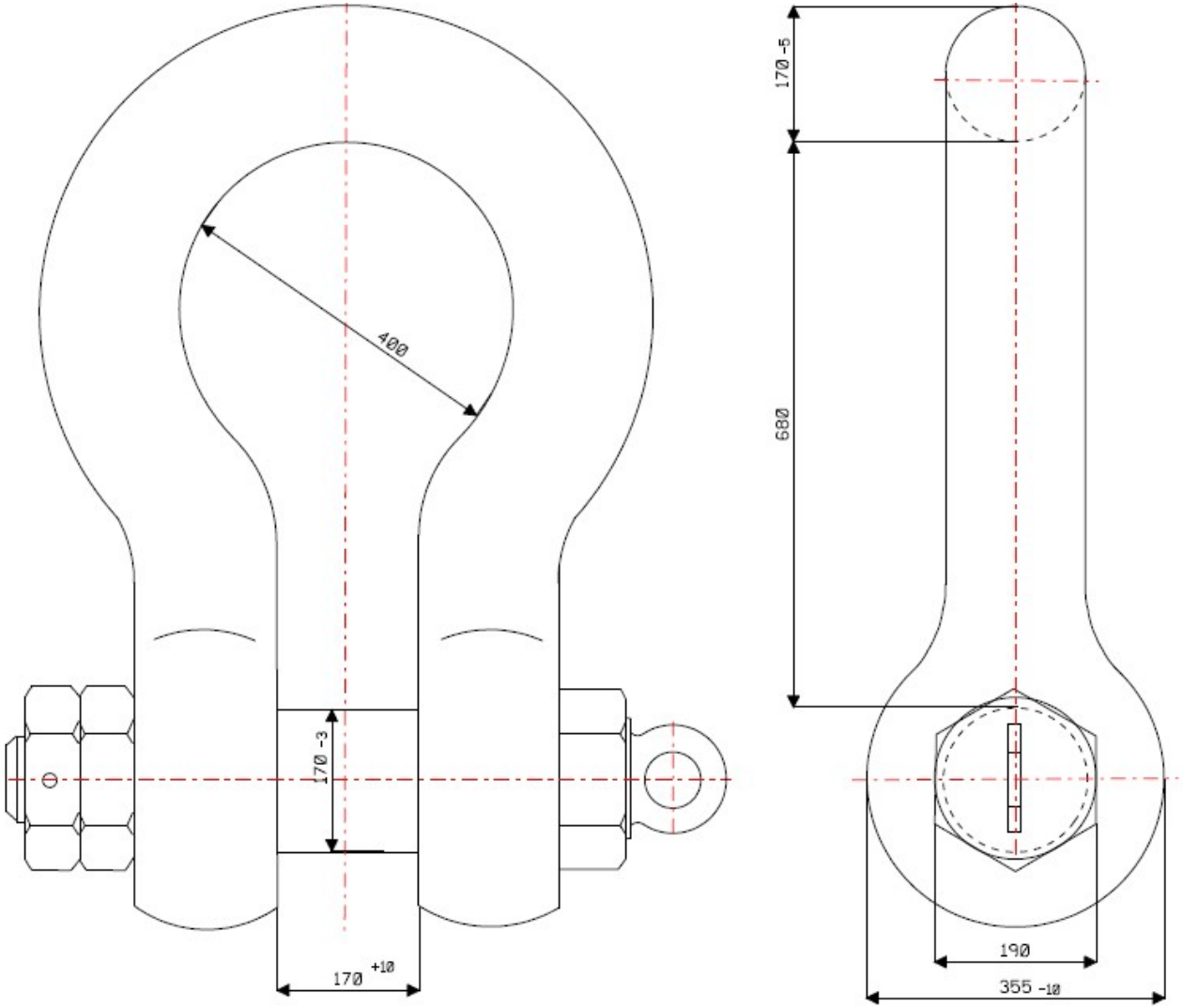



**Figure B.4 – KS shackle Grade 4, MBL 13590 kN (item 7)**

| ITEM | NAME | MATERIAL |
|---|---|---|
| 7 | SHIN | SAE 1045 |
| 6 | CONTIGENCY STRAP | SAE 1045 |
| 5 | SHIN | SAE 1045 |
| 4 | HALTER STRAP | SAE 1045 |
| 3 | CABLE GUIDES STRAP | SAE 1045 |
| 2 | STEM GUIDES | SAE 1045 |
| 1 | HOOK KS 50 G4 | SAE 4340 |

MATERIAL CERTIFICATION:

- BASE CERTIFICATE
- HEAT TREATMENT CERTIFICATE
- CERTIFICATE OF ORIGIN
- LONG TERM MOORING QUALITY CERTIFICATE
- PROCESS WARRANTY CERTIFICATE
- NOT REPORT
- MECHANICAL TESTS REPORT
- BREAKING LOAD & PROOF LOAD TESTS REPORT
- MEASUREMENT REPORT
- NAVAL CLASS CERTIFICATE BY CLASSIFICATION SOCIETY
- HARDNESS TEST REPORT
- TYPE APPROVAL
- RELEASE NOTE
- ACCORDING TO IACS-W-22
- PAINT WHITE COLOR

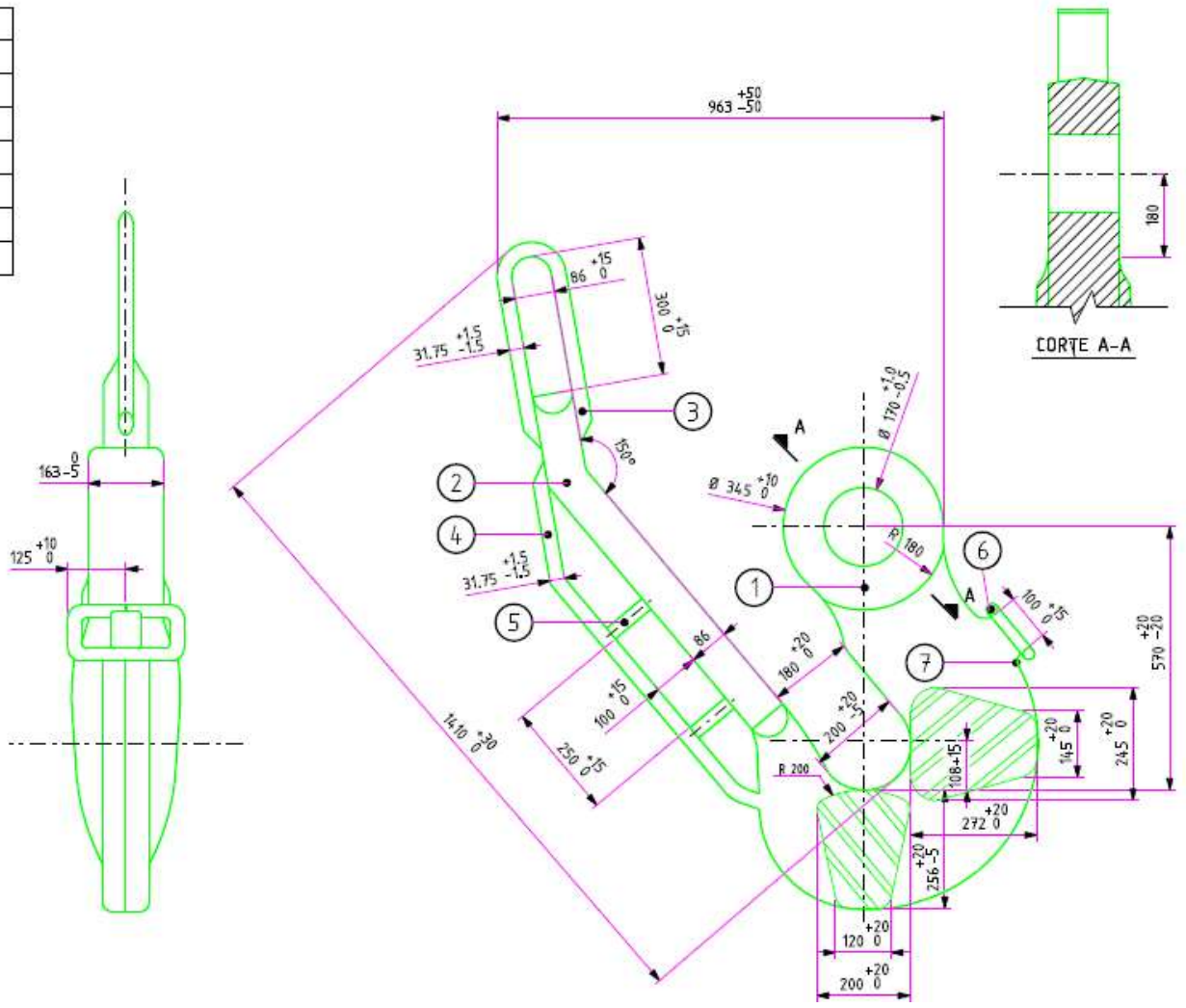



**Figure B.5 – KS hook Grade 4 for chain DN 120 mm, MBL 13573 kN (item 8)**