PETROBRAS	TECHNICAL SPECIFICATION	Nº:	I-ET-3010.2K-1357-962-PX9-001
	CLIENT: SRGE		SHEET: 1 of 28
	JOB: BÚZIOS 12		
	AREA: FPSO FOR BÚZIOS 12		
	TITLE: **SPREAD MOORING SYSTEM REQUIREMENTS**		SUB/ES/EDA/EAI
			INTERNAL

INDEX OF REVISIONS

REV.	DESCRIPTION AND / OR AFFECTED SHEETS
0	ORIGINAL.
A	SECTIONS 4, 6.2 AND 6.4.3 UPDATED.
B	SECTIONS 4, 6.2, 6.4.1, 6.4.3, 6.4.4, 10 AND APPENDIX A UPDATED AND 6.4.10 CREATED. REPLACEMENT OF THE TERM “LOI” BY “EFFECTIVE DATE” AS INDICATED.

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E
DATE	06/01/2025	07/03/2025	12/09/2025			
EXECUTION	DXSF	DXSF	DXSF			
VERIFICATION	B14Q	B14Q	B14Q			
APPROVAL	NTHF	CBI5	NTHF			

INDEX

1. INTRODUCTION

1.1. SCOPE

This document establishes the minimum mandatory technical requirements to be complied with for the FPSO spread mooring 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 AND DEFINITIONS

AHV	Anchor Handling Vessel
BOT	Build-Operate-Transfer
CG	Center of gravity
CS	Classification Society
CONTRACTOR	Refers to the company responsible for the design, construction (or conversion), assembly, transport, installation and operation of the FPSO.
FAT	Factory Acceptance Test
FPSO	Floating Production Storage Offloading Unit (also Unit)
GTD	General Technical Description
IMR	Inspection, Maintenance and Repair
KOM	Kick-off Meeting
LLLC	Installation link

MBL	Minimum Break Load
METOCEAN	Meteorological and Oceanographic Data
MLP	Mudline Point
MPM	Most Probable Maximum
NPD	Norwegian Petroleum Directorate
OCIMF	Oil Companies International Maritime Forum
OLB	One Line Broken
PLC	Programmable Logic Controller
QTF	Quadratic Transfer Function
RAO	Response Amplitude Operator
ROV	Remotely Operated Vehicle
SELLER	Refers to the company responsible for the BOT process.
SF	Safety Factor
SWL	Safe Work Load
VLCC	Very Large Crude Carrier
WD	Water Depth

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 FPSO design life.

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 calibration, etc.).

Please refer to project GTD's for the required design life.

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).

2.3. LOCATION

The FPSO will be installed offshore Brazil, in the Búzios field of Santos Basin. The Unit heading is 180 deg relative to true North and WD at location is circa 1960 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 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 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 current and wind / waves coming from the same direction, and a non-collinear approach, with currents up to 45 deg apart of wind / 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 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 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.

SELLER/CONTRACTOR shall provide adequate cathodic protection for the mooring system and balcony structure.

4. CONTROL AND MONITORING

The control systems of the mooring hook-up system shall be provided with dedicated PLCs. Refer to the GTD for additional provisions.

The control panels shall include readings from the machinery monitoring sensors with data and event logs.

The local control panels shall provide the required functions, indications and alarms to ensure easy and safe operation. Where several winches are used, the control panel may be a common centralized console to operate all equipment from the same stand.

The local control panels shall be installed in a manner that ensures operator safety against potential line breaks, preferably using enclosed and weather-proof cabins, and located as close as safely possible to the winches to enable visual monitoring of operations.

The control panels shall be rated IP66 and compatible with the area classification (hazardous / non-hazardous) and a marine / salty / aggressive environment with water splashes.

All indicators and controls shall be clearly labeled. The readout from indicators shall be easily readable in bright sunshine. All information displayed on the control panel shall be in the English language, unless otherwise stated in the technical documentation.

As a minimum, the control panels shall include the following controls and alarms:

▪ Proportional speed control for paying-out or paying-in (joystick) with an automatic return to the neutral position (brakes on after coming to a stop) and a dead band around the 'zero speed' position to avoid unintended movements.

▪ A switch to toggle between ‘tension release’ and manual / speed modes (if applicable).

▪ Stall load limiter to enable safe operations at lower loads. SELLER/CONTRACTOR shall inform the lowest stall load settings possible and associated accuracy.

▪ HPU start and stop.

▪ HPU hydraulic pressure display.

▪ Load indication via calibrated load cells fitted to each winch frame or via direct pressure/load conversion from calibrated pressure transducers. A 'hydraulic pressure vs. load' chart shall also be provided by SELLER/CONTRACTOR.

▪ Length totalizer and pay-in / pay-out speed.

▪ Event logs.

▪ Emergency stop push button.

▪ Chain stoppers control and position monitoring.

▪ Alarm lights due to low oil level in the HPU reservoir, high oil temperature, power pack general alarm.

▪ Shutdown lights due to low-low oil level in the HPU reservoir, high-high oil temperature, power pack malfunction, automatic pay-out stop (due to achieving the minimum required length of chain / rope in storage).

▪ Automatic pay-out stop bypass (enclosed button) to be used in chain disposal or rope change-out operations.

For chain jacks / linear winches, an automatic / manual mode switch shall also be provided. In automatic mode, the winch shall perform the step-by step-movement of the stoppers / grippers. In manual mode, the following controls shall be available:

▪ Rams extend and retract.

▪ Opening of each stopper / wedge independently.

▪ Both stoppers / wedges open (lockable function).

5. TOWING SYSTEM

SELLER/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:

▪ Simultaneous operations of attending tug / positioning boats during the hook-up campaign.

▪ Interference between towing / stationkeeping boat lines and surrounding structures onboard the FPSO.

Smit-brackets, chocks and support structures shall have a minimum SWL of 320 mT.

SELLER/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).

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

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

SELLER/CONTRACTOR shall also design and supply all mooring lines. See APPENDIX A – 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.

SELLER/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 2 deg due to installation issues. Particularly for cluster NW, the minimum spacing between fourth and fifth mooring lines, clockwise direction, shall be 3.8 deg due to seabed obstacles.

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 operational and temporary 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 in Table 1. The anchoring radius shall be considered from the fairlead point to the anchor coordinate for each mooring line. The preliminary riser configurations for the mooring analysis are informed in I-ET RISER. Riser configuration for final mooring analysis will be confirmed at KOM.

Table 1 – Mooring pattern

Cluster	FPSO Corner	Anchoring Radius / WD	WD @ Anchoring Devices [m]	Mooring Pattern [deg]
NW	AFT-SB	1.3	~1900	69.5
SW	FWD-SB	1.5	~1930	
SE	FWD-PS	1.4	~1930	93.0
NE	AFT-PS	1.1	~1900	

For the tender process, the loads imposed by the riser system on the FPSO (vessel ballasted at nominal position, static loads) informed in Table 2 may be adopted. This information is preliminary and will be confirmed at the KOM.

Table 2 – Static risers loads

Vessel Axis	Firms [kN]	All Risers [kN]
Fx (to FWD)	-750	-798
Fy (to PS)	292	1654
Fz (to UP)	-76861	-102451

Marine growth shall be modelled by a suitable increase of line weight and drag diameter, to be justified by SELLER/CONTRACTOR during execution phase. 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 3 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 extreme environmental design cases and at ballast draft only for the temporary conditions (storm safe and pull-in).

In addition to ISO and CS requirements, SELLER/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. Separate results for the vessel mean offsets and low-frequency displacements shall be presented in the Mooring Analysis Report.

The FPSO nominal position is established as the design coordinates given in DE-SUBSEA LAYOUT. SELLER/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 3 – 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 (2)	Intact	9.5 (3)	No risers	1-year	1-year	1-year
		12.0	No risers	1-year	1-year	1-year
Operational	Intact	7.0	Phase 1 / All risers	1-year	1-year	1-year
	OLB	7.5	Phase 1 / All risers	1-year	1-year	1-year
Extreme Environment	Intact	9.0	Phase 1 / All risers	100-year	100-year	10-year
				10-year	10-year	100-year
	OLB	9.5	Phase 1 / 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: Pull-in design case shall be evaluated for two different offsets as stated in Table 3. First scenario (9.5% WD) is considered for rigid risers and second scenario (12.0% WD) for flexible risers.

Note 3: This limit is preliminary and will be confirmed by Petrobras.

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.

SELLER/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 6400 kN for the intact condition and 8000 kN for the damaged condition. This information is preliminary and will be confirmed at the KOM.

SELLER/CONTRACTOR shall inform the maximum tensions and uplift angles at the MLP of each mooring line, for intact and OLB cases. 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.

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

- Stationkeeping boats can be disconnected and released (storm-safe condition).
- The FPSO is ready for pull-in operation (pull-in condition).

After defining the number of mooring lines required for pull-in condition (rigid and/or flexible risers), SELLER/CONTRACTOR shall inform the offset rosette associated with the weather conditions to be provided by PETROBRAS.

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

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

- MPM tensions at fairlead and mudline levels of each mooring line for all operational and temporary conditions. The tension at mudline for the temporary condition should not trespass the maximum mudline tension results for the centenary environmental loads.
- 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.

The complete as-laid numerical model shall be provided for PETROBRAS to deal with future changes in the SUBSEA LAYOUT.

6.3. MOORING BALCONY

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

SELLER/CONTRACTOR shall consider the minimum longitudinal distances of 48 m between the aftmost riser slots and the respective nearest fairleads and 50 m between the forwardmost 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 SELLER/CONTRACTOR's responsibility.

Mooring line transfer and hook-up procedure shall be completely diverless, including any kind of sea-fastening removal below the mooring balcony (e.g. fairlead sea-fastening) and contingency operations such as pennant or messenger line breakage.

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

All equipment and rigging utilized in the mooring line transfer (e.g. pennants, messenger lines/fiber ropes and connectors) must be carefully selected, ensuring not only the capacity

to withstand the anticipated loads but also the inevitable wear and tear that is inherent during handling on the mooring balcony and onboard the installation vessels.

The fiber rope used to support the load during installation chain transfer to the vessels must be a HMPE (High Modulus Polyethylene) with a Minimum Breaking Limit of 120 tons or more. The rope must have a cover designed for protection against external abrasion and cutting in its first third of length or 25 m, whichever is higher, considering the protected third on the FPSO side (instead of the installation vessel end). It must also be reasonably easy to handle by the rigging crew onboard the mooring balcony and installation vessels. Finally, a slightly positive submerged weight (i.e. no buoyancy) is advisable to minimize propeller suction risk.

SELLER/CONTRACTOR shall not specify the use of non-torque-balanced segments (such as six strand wire rope) in series with synthetic rope segments.

SELLER/CONTRACTOR shall guarantee that all mooring materials assemblies with each other, including also with PETROBRAS interface.

SELLER/CONTRACTOR shall supply one additional mooring line, complete with all its accessories and the same specification as that of the longest mooring line.

The proposed mooring line components configuration shall be submitted for PETROBRAS evaluation.

6.4.2. FIXED POINTS

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

The supply and installation of the anchoring devices is excluded from SELLER/CONTRACTOR's scope of work up to a maximum of 28 devices. In case the SELLER/CONTRACTOR's system concept requires more anchoring devices, the exceeding number shall be designed, supplied and installed by SELLER/CONTRACTOR.

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

6.4.3. CHAINS

Offshore studless mooring chains, 142 mm diameter grade R4, shall be supplied for all mooring chains.

Top chains shall be supplied with common links in both ends. At the top chain segments a corrosion rate of at least 1.0 mm/year shall be considered. The length of the top chain segment must ensure that the top polyester remains below a minimum depth of 100 m 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.

Top chains for each mooring line shall be partitioned in two segments: lower top chain segment and upper top chain segment. The lower top chain segment shall be supplied with 90 m length.

The top chain length for analysis purposes, i.e. from top polyester to fairlead, should be pursued values around 180 m, and, after considering installation analysis, top chain maximum length shall be 300 m.

At the bottom chain segments ISO19901-7 shall be considered when defining the corrosion allowance.

INSTALLATION AND TOP CHAIN SEGMENTS

SELLER/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 (10 m radius) and bathymetry measurement errors (0.5% WD) shall be taken into account.

SELLER/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 chain. The design of thimbles and shackles shall consider maximum width of 750 mm. For larger dimensions, the design shall be submitted for PETROBRAS evaluation. The polyester ropes shall be provided with chafing/spacer chains to enable the use of shark jaws to hold the mooring lines during installation. The spacer chains shall be partitioned in two segments for operational purposes. The first spacer chain segment shall be supplied with 6 common links, and the second spacer chain shall be supplied with 10 m length. The upmost polyester segment shall be provided with a chafing chain with 6 common links only. Figure A.1 details the requirements for chafing/spacer chains and other components.

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 lengths in multiples of 50 m. The rope length and diameter shall be limited as follows:

▪ For ropes with a diameter up to 208 mm, the nominal maximum length shall be limited to 1000 meters (measured at 20% MBL);

▪ For ropes with a diameter larger than 208 mm and up to 240 mm, the nominal maximum length shall be limited to 700 meters (measured at 20% MBL);

▪ Polyester ropes shall be supplied limited to 240 mm of diameter.

All polyester ropes shall be supplied with the same diameter and MBL. If the required length of polyester ropes varies between different clusters, the top polyester rope segment shall be supplied with the same length for all mooring lines in all clusters. Variations in length should be accommodated by adjusting the bottom and/or intermediate polyester rope segments as needed. Polyester ropes of different lengths shall use color-coded terminations to be easily identified based on its length.

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.

SELLER/CONTRACTOR shall supply six installation links (one per cluster and two additional), 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, provided that it resists mooring line liberation from AHV deck by quick-release, and that it is adequate for heaving-in chains at zero degree with vertical.

Fairlead sea-fastening must not interfere in the mooring line hook-up sequence (any clashing risk must be evaluated). The use of sea-fastening pins should be carefully evaluated to avoid line or pin breakage during removal.

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

SELLER/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)

SELLER/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 and also taking into account the environmental conditions for hook-up operations, friction losses, etc. The minimum dynamic amplification factor to be considered shall be 1.5 for pre-tension levels lower than 200 mT and 1.75 otherwise.

The chain jack handling system shall provide means to avoid pendular movement or inadvertent structural collision of the chain jack during transition between chain stoppers in offshore operations.

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.

6.4.10. IN-LINE TENSIONERS

Devices specified in item 6.4.9 and 7 can be substituted by in-line tensioners as long as it follows the described below.

a) There shall be a single in-line tensioner per mooring line. The in-line tensioner shall be compatible with chain diameters established in 6.4.3.

b) Mooring lines equipped with in-line tensioners shall have a standardized top chain segment 180 meters long.

c) The in-line tensioner shall be connected to chain segments at both ends. The referred chain segments shall be located right after the deepest fiber rope segment of the mooring line.

d) The mooring line equipped with the in-line tensioner as required in item c) shall be suitable for pre-deployment on the seabed, before the arrival of the Unit at the location.

e) Whether the in-line tensioner is not qualified to meet the requirement in item d) and its pre-deployment is not feasible, the in-line tensioner shall be replaced from the position specified in item c) to the top chain segment. In this case, the in-line tensioner shall be located right before the shallowest fiber rope, complying with item h).

f) Between the fiber rope segment and the chain connected to the in-line tensioner, for both configurations mentioned in item c) and e), a sacrifice rope segment 100 meters long shall be placed. The purpose of the sacrifice rope is to be cut off, allowing to retrieve and maintain the mooring line, if necessary.

g) The sacrifice rope segment mentioned in item f) shall have the same specifications as the other rope segments in the mooring line.

h) Considering a path from the fairleader towards the bottom, a sufficient surplus of chain shall be provided downstream the in-line tensioner, either for tensioning or retensioning operations, allowing the achievement of the design pretension of each mooring line in both cases.

i) The in-line tensioner cannot be the weakest point of its associated mooring line, being able to withstand extreme loads, as well as providing the necessary fatigue life, taking into consideration corrosion and wear allowances. The in-line tensioner design shall be certified and achieve all CS requirements.

j) For the in-line tensioners, the following on-vessel pieces of equipment are still necessary:

1- there shall be provided means of locking each top chain segment on the mooring balcony.

2- on each mooring balcony, there shall be a rotating winch, with the following characteristics:

- The winch can be retrievable or not permanent. A fixed support structure for the winch shall be provided on each mooring balcony. The support structure shall be equipped with a set of sheaves that allow them to access each chain position, normally.
- On each mooring balcony, there must be a means of retrieving the winch for transportation by a Support Vessel, when feasible, envisaging its storage and/or maintenance of the equipment onshore. For the handling of the winches, the requirements in GTD shall be met.
- The winch drum shall be able to house at least 250 meters of steel cable, whose minimum breaking load is equal or greater than 960 kN.

- The winch design shall meet the requirements of ANSI B30.7 Standard (or similar) and be certified by the CS.
- The steel cable shall be terminated with an appropriate end-link, which is compatible with the top chain diameter.
- The steel cable termination and its element of connection with the top chain segment shall be able to pass through the equipment defined in j).1, without interferences.
- The steel cable and its accessories shall be certified by the CS.
- The capacities of the rotating winches shall be sufficient to hold the weight of the top chain segments, whose lengths are described in item b) and their associated dynamic loads during the hook-up operation.
- The steel cable pull-in speed shall be 4 meters per minute, at least.
- The rotating winch will be used for the top chain segment hook-up, only. Once the one end of the top chain segment is held by the chain-stopper associated with the mooring line to be installed, the remaining segments of the mooring line (chains, fiber ropes, the in-line tensioner itself, etc.) are connected to the other end of the top chain segment on the deck of the AHTS.
- The four fixed rotating winches (one per mooring balcony) shall preferably be electrically driven. Alternatively, they can be associated with Hydraulic Power Units (HPUs), according with the arrangement described in item 7.

k) The in-line tensioner shall be compatible with installation by an AHV vessel, considering the stern roller dimensions of 3 m in diameter and 5 m in length.

7. HYDRAULIC POWER UNITS

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

The HPUs shall be self-contained skid units with adequate access and sufficient ventilation for maintenance purposes. The units shall incorporate easy access for removal of replaceable equipment and for routine maintenance activities.

8. OPERATIONAL PROCEDURES

8.1. GENERAL

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

All operational procedures for the FPSO towing, hand-over and also mooring lines installation / de-installation operations on the FPSO side shall be designed by the SELLER/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.

8.2. TOWING

Refer to the contract.

8.3. 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. SELLER/CONTRACTOR will be notified 30 days in advance and shall witness the operation onboard PETROBRAS' vessels.

SELLER/CONTRACTOR shall be responsible for the CS approval of the tensioning operation and final certification of the whole mooring system.

The mooring lines installation and de-installation procedures (FPSO side) shall be issued by the SELLER/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.

8.4. INSPECTION, MAINTENANCE AND REPAIR

SELLER/CONTRACTOR shall assure the FPSO will have suitable facilities to enable in-service maintenance and repair of the mooring hook-up system during the operational life of the system.

The safety requirements, methodology and frequency of inspection and maintenance activities shall be clearly stated in the IMR manuals. The manuals shall include all IMR procedures of the overall packages and the individual components contained in the package, including means of troubleshooting and dismantling/re-assembling the equipment.

Components that may require replacement within the FPSO design life shall be identified as such, along with all necessary procedures to achieve the required life.

The maintenance manual shall also include a preservation procedure for long term storage in offshore condition.

Lubrication systems shall be centralized for ease of maintenance and access. SELLER/CONTRACTOR shall supply a lubrication chart and list with recommended lubricants for all supplied equipment.

SELLER/CONTRACTOR shall provide sufficient fluorescent luminaries, inside and around the equipment and HPUs (as applicable) to enable safe operations at night.

9. TESTING AND COMISSIONING

The purpose of testing is to prove that all equipment and components operate satisfactorily and comply with the requirements of the project specification.

SELLER/CONTRACTOR shall provide the schedule of inspections and tests (FATs and commissioning) of the mooring hook-up system for PETROBRAS.

All standard items shall be provided with certificates guaranteeing grade, strength, conformity with the applicable standards and CS requirements.

Each equipment and its associated components shall be inspected and tested to verify proper form, fittings, dimensions and functioning. All tests shall be performed in accordance with written procedures to be approved by PETROBRAS.

As a minimum, the following tests shall be performed:

Instrument / Electrical Tests

All instruments shall be tested and calibrated, including relief valves.

Pressure Tests

All components shall be tested, except previously factory-tested components with testing documentation (e.g. control / relief valves, which shall be calibrated). The test pressure shall be in accordance with component specification.

Leak Tests

The complete hydraulic circuit shall be leak tested after assembly in accordance with GTD requirements.

Load Tests

Any lifting equipment provided by SELLER/CONTRACTOR shall be subject to a static load test at stall load capacity and a dynamic load test at nominal load capacity. Sheaves shall also be load-tested. The equipment shall be clearly marked with its SWL.

Functional Tests

The complete assembly functional test shall be performed together with the HPU system, at the shipyard, and shall include:

- Running test for 24 h (no load on the winches) in order to tune up all electro-hydraulic system, verify synchronization of all equipment, check tightness of hydraulic connections, electrical isolation, noise and vibration levels, cooling system performance, etc. A 'flow vs. pressure diagram' shall be plotted for each assembled motor pump to verify the performance and settings.
- A representative load and function test for each operating mode.
- Static brake / stoppers tests above the stall load capacity.
- Low load conditions.
- Emergency stop tests.
- Manual controls tests.
- Functional testing of instruments, alarms and controls.
- Verification of interlock functions.
- Calibration of relief valves (calibration certificates shall be available).
- Calibration of load measuring devices.
- Skidding and parking systems (if applicable).
- Trial fittings of sheaves and other items (if applicable).

10. RESPONSIBILITIES

SELLER/CONTRACTOR shall be responsible for:

- Harbor tugs and Pilots for the Unit whenever required.

- Developing the FPSO towing and hand-over procedures, including the sail-away from Brazilian sheltered waters to the installation site. SELLER/CONTRACTOR shall engage the towing master.

▪ Developing the mooring hook-up, chain-stopper replacement, and all other operational procedures necessary for the FPSO on-site installation including CS approval when applicable, engaging the mooring master.

▪ 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 A – MOORING MATERIALS SCOPE OF SUPPLY.

▪ 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, SELLER/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. Unit shall be able to receive up to 2 mooring lines every 24 h.

▪ 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).

PETROBRAS shall be responsible for:

▪ Design and CS approval of the anchoring devices, including their installation.

▪ Issuing the hook-up procedures (AHV side) based on the information provided by the SELLER/CONTRACTOR.

▪ Supply of mooring materials according to APPENDIX A – MOORING MATERIALS SCOPE OF SUPPLY.

▪ Storage and loading of the mooring materials supplied by the SELLER/CONTRACTOR on the PETROBRAS AHV fleet. In case of inspection findings, SELLER/CONTRACTOR will be notified.

▪ Providing AHVs for stationkeeping and hook-up operations.

▪ 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.

APPENDIX A – MOORING MATERIALS SCOPE OF SUPPLY

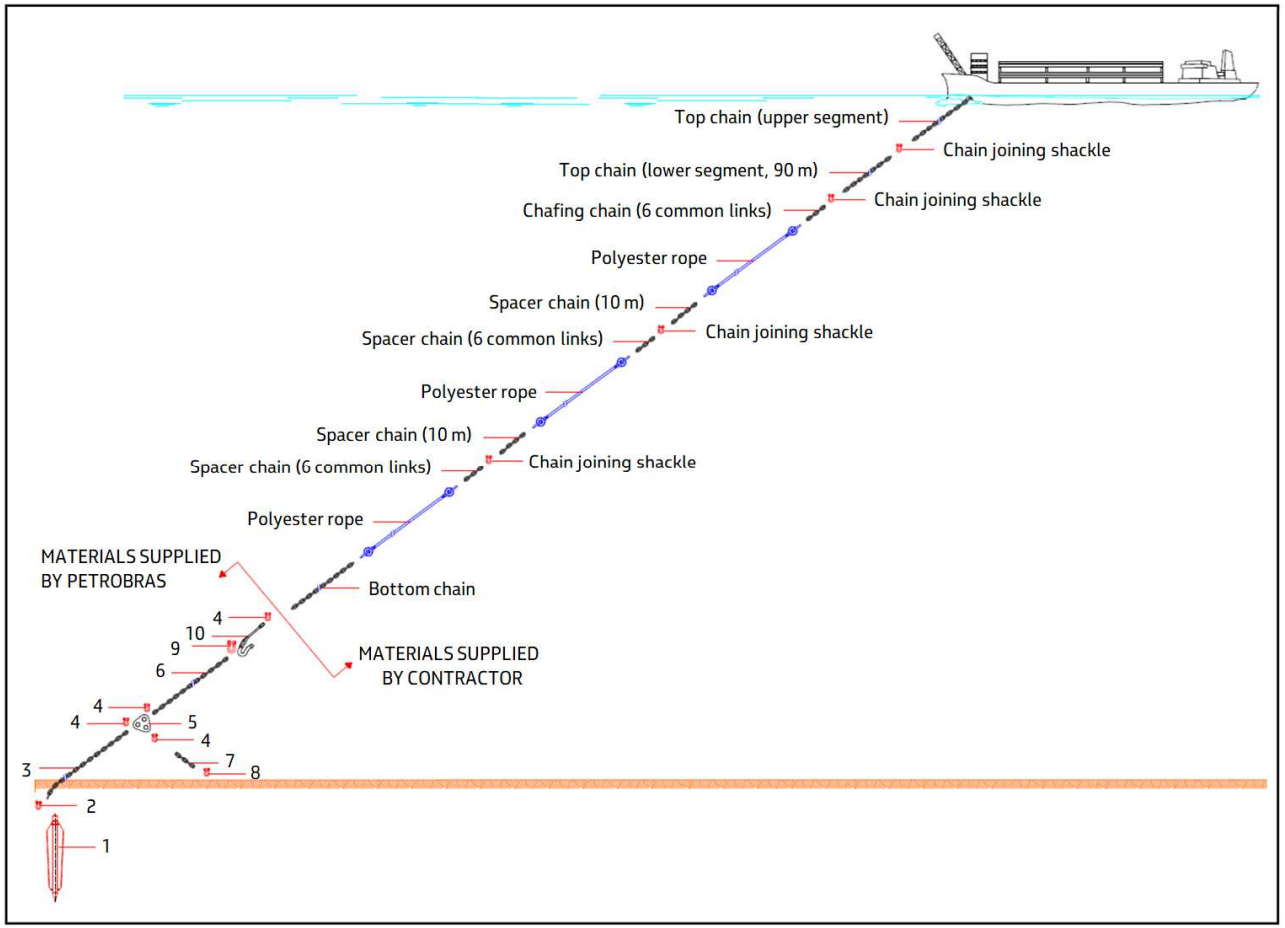

Figure A.1 - Mooring material scope of supply

PETROBRAS	TECHNICAL SPECIFICATION	Nº I-ET-3010.2K-1357-962-PX9-001	REV. B
	FPSO FOR BÚZIOS 12		SHEET 24 of 28
	SPREAD MOORING SYSTEM REQUIREMENTS		SUB/ES/EDA/EAI
			INTERNAL

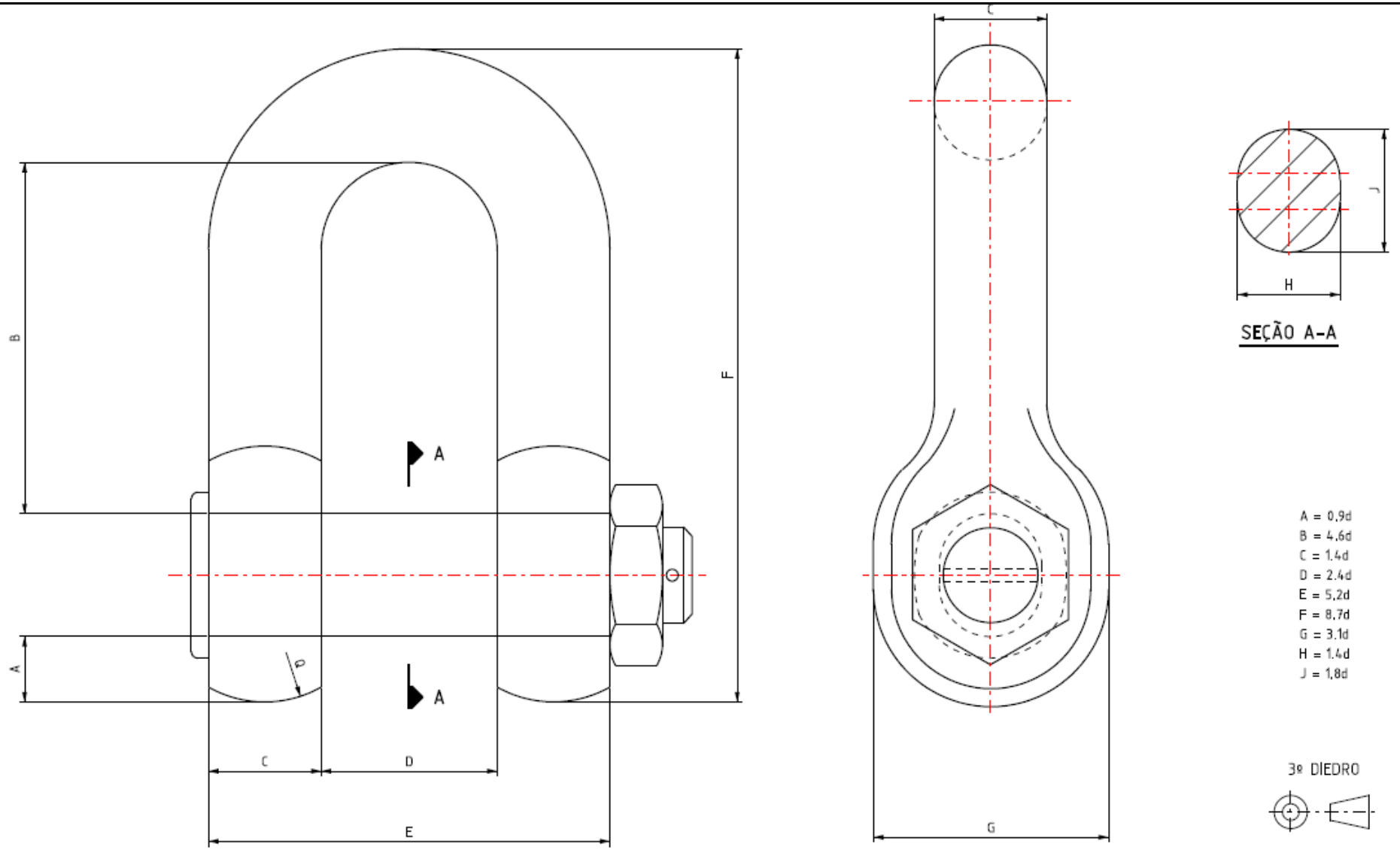

Figure A.2 - Anchor shackle Grade R4S for torpedo pile connection (item 2)

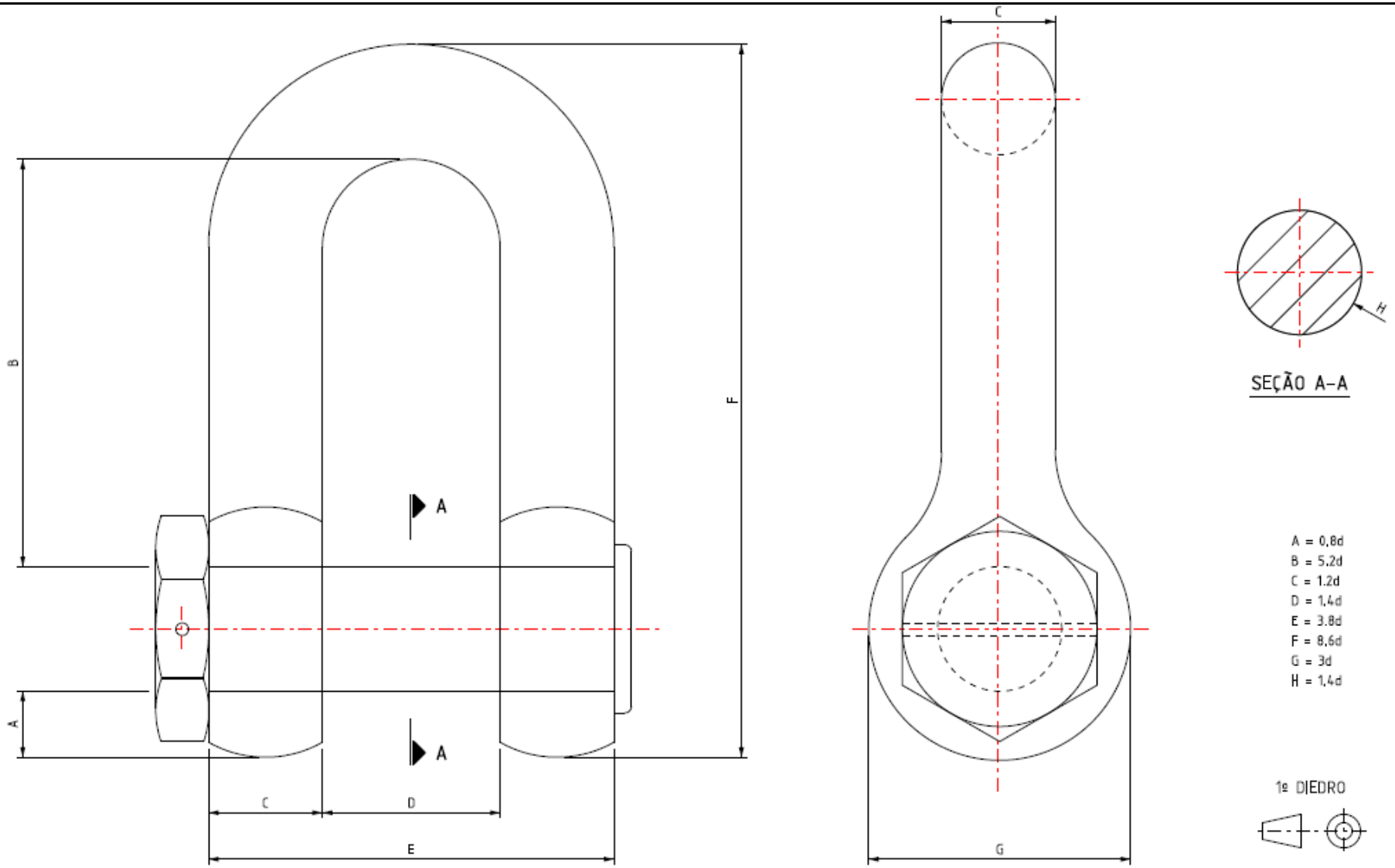

Figure A.3 – End joining shackle Grade R4S (item 4)

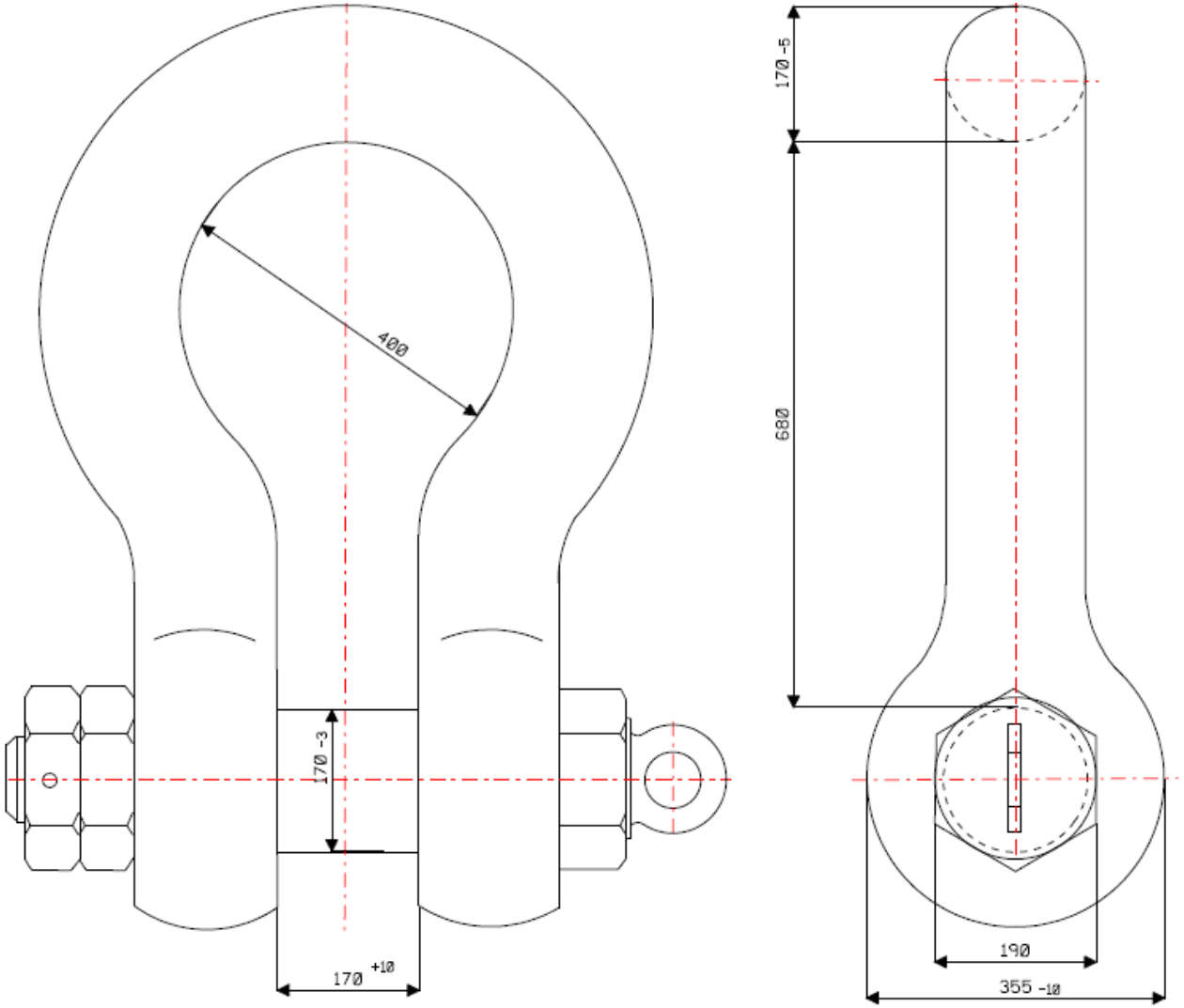

Figure A.4 – KS 50 shackle Grade R4S, MBL 15059 kN (item 9)

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

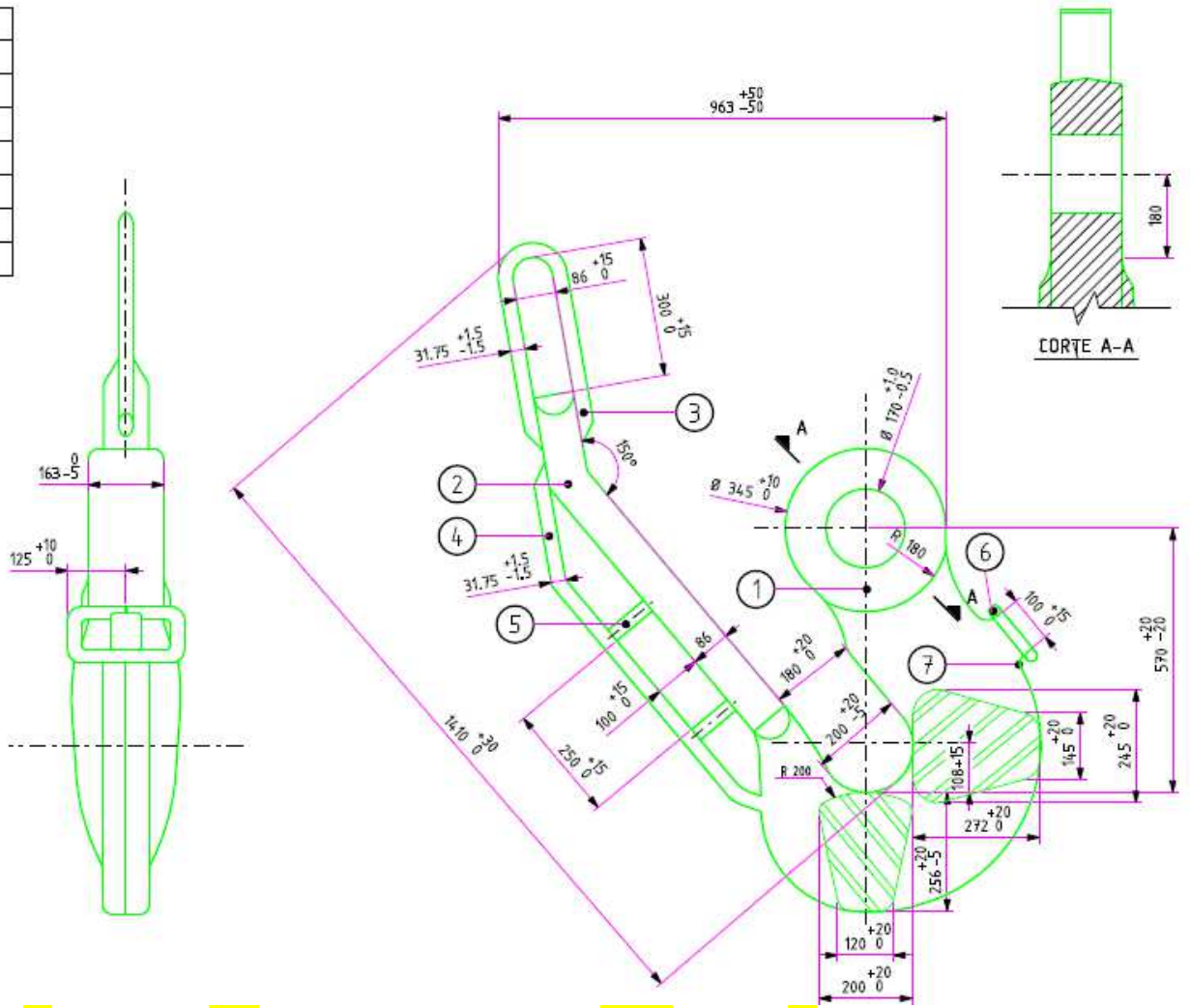

Figure A.5 – KS 50 hook Grade R4S for chain DN 120 mm, MBL 15059 kN (item 10)