



Exploration & Production

GENERAL SPECIFICATION

STRUCTURAL

GS EP STR 631

CALM buoy terminals

06	10/2009	Revised § 2, 5.1, 5.3 and 6.1
05	10/2008	Revised §2, §3.3, §4.6, §4.10, §5.1, §5.3, §6, added Appendix 1
04	10/2006	General review
03	10/2005	Addition of "EP" root to GS identification, Revised section: 4.11, 5.1, 6.7 and 7.16
02	10/2003	General review - Change of Group name and logo
01	10/2002	Second issue
00	07/2001	First issue
Rev.	Date	Notes



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1. Scope

This specification defines the general requirements for the design, fabrication and installation of a Catenary Anchor Leg Mooring (CALM) buoy.

This specification covers all types of CALM buoys moored in typical shallow waters (say 100 m or less). It does not cover other types of Single Point Moorings, such as SALM, SALS, ALP.

It covers the export of oil or condensate and should not be applied without careful assessment to LPG or LNG.

Deep water CALM buoys requiring a specific export line are mentioned in some aspects of this specification, but not covered in details due to the novel nature of the concept. Requirements for such a system are in the Project Particular Specification (PPS).

The purpose of the buoy is to moor a vessel, usually a tanker, by its bow to transfer one or more fluids between the buoy and the vessel. In certain cases, the vessel may be an F(P)SO permanently connected to the buoy, with an offloading tanker connected to the F(P)SO in tandem or alongside.

As a single point mooring, the CALM buoy allows the moored tanker, or the combination F(P)SO/tanker, to weathervane according to the environment while transferring fluids.

The CALM buoy system, hereinafter designated as the BUOY, shall typically consist of the following components:

- A **buoy body**, comprising a fixed part (connected to the risers) and a rotating part (connected to the floating hoses)
- **Mooring lines** and their **anchor points** to moor the buoy on the seabed
- **Floating hoses** connecting the buoy body to the tanker ship
- **Hawser line(s)** to moor the ship to the buoy
- One or more subsea Pipe Line End Manifolds, or **PLEM**, anchored to the seabed and providing a link between the submarine pipeline(s) and the risers
- **Risers** (or underwater hoses) connecting the PLEM to the buoy body. For deep and ultra deep water, the PLEM and risers may be replaced by **export lines**.

Therefore, the boundaries of the BUOY scope are:

- The spool piece between the PLEM and sealine (spool piece included in scope) or end of export line
- The end of the floating hoses on tanker side (tanker rail hose).

2. Reference documents

The complete BUOY shall be designed, manufactured, tested and installed in accordance with (in descending order of priority):

- The Project Particular Specifications (PPS)
- This General Specification
- Any other contractual specifications issued by COMPANY



- The rules of the Classification Society (CS) chosen by COMPANY
- Any other regulations recognised by the international petroleum industry, solely in the event that matters arise which are not covered in any of the above or are imprecise or arguable in the above regulations or standards.

The BUOY will comply with applicable International and National regulations.

CONTRACTOR shall obtain copies of all referenced documents and shall make them readily available to all personnel involved in the work.

In case of conflict, the most stringent requirement shall be applied unless derogated by written approval of the Company and CS.

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
ANSI B16.5	Pipe Flanges and Flanged Fittings
ANSI B16.20	Metallic Gasket for Pipe Flanges Ring Joint, Spiral-Wound and Jacketed
ANSI B31.3	Chemical plants and petroleum refinery piping
ASME Section VIII D1	Rules for Construction of Pressure Vessels
ASTM A 148	Standard Specification for Steel Castings, High Strength, for Structural Purposes
ASTM E 709	Standard Guide for Magnetic Particle Testing
AWS D1.1	American Welding Society Structural Welding Code
EN 1765	Rubber Hose Assemblies for Oil Suction and Discharge Services - Specification for the assemblies
IEC 60079-10	Electrical apparatus for explosive gas atmospheres - Part 10: Classification of hazardous areas
ISO 898-1	Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs
ISO 898-2	Mechanical properties of fasteners - Part 2: Nuts with specified proof load values. Coarse thread
ISO 19901-7	Petroleum and natural gas industries - Specific requirements for offshore structures - Part 7: Station-keeping systems for floating offshore structures and mobile offshore units

Professional Documents

Reference	Title
API RP 2A	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms
API RP 2SK	Design and Analysis of Station-keeping Systems for Floating Structures
API RP 2SM	Recommended practice for design, manufacture, installation and maintenance of synthetic fiber ropes for offshore mooring
API Spec 2F	Specification for Mooring Chains
OCIMF	Offshore loading Safety Guidelines with special relevance to harsh weather zones
OCIMF	SPM Hose System Design Commentary
OCIMF	Guide to Purchasing, Manufacturing and Testing of Loading and Discharge Hoses for Offshore Moorings
OCIMF	SPM Hose Ancillary Equipment Guide
OCIMF	Guide for the Handling, Storage, Inspection and Testing of Hoses in Field
OCIMF	Guidelines for the Purchasing and Testing of SPM Hawasers
OCIMF	Hawser Test Report
OCIMF	Recommendations for Equipment Employed in the Bow Mooring of Conventional Tankers at Single Point Moorings
OCIMF	Recommendations for Oil Tankers Manifolds and Associated Equipment
OCIMF	Mooring equipment guidelines
OCIMF	Single Point Mooring Maintenance and Operations Guide
SIGTTO	Guidelines for the Alleviation of Excessive Surge Pressures on ESD

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Noble Denton / TTI	Deep water Fibre moorings, an engineers' design guide First Edition Rev 0 - January 1999

Classification Society Rules

Reference	Title
ABS	Rules for Building and Classing Single Point Moorings
Bureau Veritas NI 493	Classification of Mooring Systems for Permanent Offshore Units
Bureau Veritas NI 432	Certification of Fibre Ropes for Deepwater Offshore Services
Bureau Veritas NR 494	Rules for the Classification of Offshore Loading & Offloading Buoys
Det norske Veritas OS E301	Position Mooring
Det norske Veritas OS E302	Offshore Mooring Chain
Det norske Veritas OS E304	Offshore Mooring Steel Wire Ropes
Det norske Veritas TNA 503	Flexible pipes and Hoses for Submarine Systems
IACS UR W22	Offshore Mooring Chain

Total General Specifications

Reference	Title
GS EP COR 100	Design of cathodic protection of offshore structures
GS EP COR 201	Supply of sacrificial anodes
GS EP COR 350	External protection of offshore and coastal structures and equipment by painting
GS EP COR 351	External protection of structures and equipment by painting. Floating structures
GS EP ELE 031	Design of earthing and bonding systems
GS EP ELE 079	Electric apparatus for potentially explosive gas atmospheres
GS EP ELE 151	DC uninterruptible power systems (UPS)
GS EP ELE 161	Electrical cables



Reference	Title
GS EP GEO 101	Offshore geotechnical soil survey
GS EP GEO 201	Offshore geophysical surveys
GS EP GEO 501	Meteorological and Oceanographic survey
GS EP INS 102	Instrumentation identification
GS EP INS 146	Design of generation and distribution of hydraulic energy
GS EP LSO 202	Personnel transfer between ships to ships and offshore structures
GS EP PLR 109	Design, fabrication and testing of submarine unbonded flexible pipes and risers
GS EP PLR 110	Design, fabrication and testing of submarine bonded flexible pipes for deepwater terminals
GS EP PLR 151	Design of steel catenary risers systems
GS EP PVV 111	Piping design specification
GS EP PVV 112	Piping material classes
GS EP PVV 142	Valves
GS EP PVV 143	Metallic pipes
GS EP PVV 144	Fittings
GS EP PVV 145	Flanges
GS EP PVV 146	Bolting for piping
GS EP PVV 147	Gaskets for piping and vessels
GS EP PVV 171	Steel piping fabrication
GS EP PVV 173	Pneumatic testing of above ground piping systems
GS EP SPS 024	Subsea mechanical quarter turn actuator (manually operated gearbox)
GS EP STR 201	Materials for offshore steel structures
GS EP STR 202	Cast materials for steel structures
GS EP STR 203	Forged materials for steel structures
GS EP STR 301	Fabrication of offshore steel structures
GS EP STR 401	Loadout, seafastening, transportation and installation of offshore structures
GS EP STR 403	Acceptance criteria of a support vessel for offshore works
GS EP STR 601	Floating units integrity management system requirements
GS EP STR 611	Determination of the location of an offshore terminal



Reference	Title
GS EP STR 661	FPSO - Design requirements for mooring and anchoring systems
GS EP STR 901	Design rules and construction standards for ancillary structures of offshore installations

3. General

3.1 Definitions

“Classification Society” designates any of the agreed Classifications Societies responsible for the classification of the CALM buoy.

“PPS” designates the applicable Project Particular Specifications.

“BUOY” means the complete CALM buoy system, including mooring system, buoy body, fluid transfer system from PLEM to floating hose and all buoy equipment.

“ENGINEERING” designates all drawings, calculations and procedures required for the design, fabrication and installation on site of the BUOY.

“WORKS” means all and any part of the works and services required to be performed by CONTRACTOR for the fabrication and installation of the BUOY.

“INSTALLATION” designates all operations necessary for the safe positioning of the buoy on its operation site, namely all transport, installation works, services and tests.

“MANUFACTURER” designates any subcontractor that has been awarded a contract for the supply of the buoy or any of its components.

“APPROVAL” means COMPANY written assent. Approval by COMPANY shall in no way relieve CONTRACTOR of any of his obligations, responsibilities or liabilities.

3.2 Classification/MWS

The CALM shall be classed by a classification society selected and/or approved by the COMPANY. The items covered by class include the buoy, the PLEM, the anchoring and anchoring points, the hoses, the hawsers and including all ancillaries and parts (piping, rotating parts, swivel, monitoring equipment, etc.).

The Classification Society shall be responsible for verifying the ENGINEERING and WORKS and will stipulate the design and operating limits of the CALM Buoy in the class certificate.

A Marine Warranty Surveyor (MWS) shall be responsible to verify the INSTALLATION.

The scope of work of the CS and MWS shall be approved by COMPANY and mutually agreed between COMPANY, CONTRACTOR and CS/ MWS prior to CS/MWS Contracting.

The programme of inspections and test required for the classification certificate renewal shall be approved by COMPANY and mutually agreed between COMPANY, CONTRACTOR and CS prior Contracting.

The CS and MWS are selected by COMPANY on a project specific basis.

3.3 Abbreviations

CALM	Catenary Anchor Leg Mooring
CS	Classification Society
FPSO	Floating Production Storage Offloading
FSO	Floating Storage Offloading
PLEM	Pipeline End Manifold
OLS	Offloading System
PPS	Project Particular Specification
SPM	Single Point Mooring
MWS	Marine Warranty Surveyor

4. Basis of design

All units are to be in SI (metric) system. All co-ordinates shall be given in the UTM, WGS-84 system and in the SITE national system.

4.1 BUOY design life

Unless otherwise specified in the PPS, the design life of a CALM buoy shall be 30 years. Possibility to perform drydocking or not during design life shall be clearly addressed in the PPS.

4.2 Project specific constraints

Any project specific constraints (such as existing local equipment and logistics, technical support available) will be indicated in the PPS along with all relevant drawings and shall be taken into account by CONTRACTOR in the design of the BUOY.

4.3 Maximum and minimum tanker size

The maximum and minimum tanker size and loading conditions to be accommodated by the CALM Buoy will be defined in the PPS and shall be motivated by an early specific study, based on the terminal needs and output characteristics, survey of local available tankers and desired size of parcels.

4.4 Marine operations

The marine assistance for the operations of mooring of the export tanker, handling the offloading lines, the means available (assistance tugs, service boat) shall be described in the PPS.

4.5 Fluid characteristics & pigging

The fluid characteristics will be provided in the PPS.

According to the fluid characteristics, the requirement or not to pig the sealine (with consequences on PLEM and possibly risers design) will be stated in the PPS and shall be based on an early specific study.

4.6 Flow rate and design pressure

The required flow rate (in m³/h) and design pressure are specified in the PPS, based on early specific study.

Requirement for flushing the lines shall be addressed in the PPS.

A detailed pressure drop calculation shall be performed, in order to determine and the offloading risers / OLS piping diameter and design pressure. The results of the pressure drop analysis shall be specified for all elements and equipment along the fluid path.

4.7 Site general chart, bathymetry, CALM Buoy location

If not already available, a geophysical site survey shall be conducted as specified in **GS EP GEO 201** to determine the local water depth and bathymetry map on the expected footprint of the buoy terminal, including the sealine.

A complete chart of the proposed mooring area and sealine route shall be included in the PPS. This chart is to show depth soundings (reduced to Chart Datum levels, to be the same as LAT levels), obstructions, all possible existing installations (platforms, sealines, cables, etc.), manoeuvring area, and where applicable the approach channel from deep water or an established navigation channel.

The site selection for the buoy implantation, and in particular the selection of required water depth and safety distances to existing installations (if any), shall be made according to **GS EP STR 611**.

Final site selection shall be safe with respect to possible existing installations and shall allow safe manoeuvring, mooring and complete weathervaning of the maximum tanker size established.

4.8 Metocean conditions

If not already available, a metocean survey shall be conducted as specified in **GS EP GEO 501**, to determine the local environmental conditions.

The directional wave, wind, current conditions and tides (MSL, HAT, LAT and storm surges) shall be specified for extreme environments (at least 100yr and 1yr return period), as well as for fatigue environments (scatter diagrams).

The metocean document shall also provide a general description of the zone of interest, identifying known processes, existence of prevailing directions, correlation or not between wind, waves and currents.

If the zone of interest is known to have current and wind reversals, the metocean document shall, if possible, indicate corresponding possible changes in direction, intensities and corresponding durations. Reversals shall be understood as changes in direction and intensities over time.

The applicable metocean conditions are stated in the PPS.

4.9 Site soil conditions

If not already available, an offshore geotechnical soil survey shall be conducted as specified in **GS EP GEO 101**.

The applicable soil conditions are stated in the PPS.



4.10 Hazardous area considerations

The buoy shall be considered at least as a hazardous area class 2 for all electrical equipment. Particular aspects such as break-away coupling operation, discharge capacities, vents, etc., have to be specifically addressed and may lead to zone 1 requirement.

Buoy is to be fitted with flammable gas detection system with visual and audible alarms. The alarm shall be transmitted to the FPSO/terminal control room. The monitoring system may be permanently installed system or portable equipment. The gas detection system is to give alarm when LEL reach 25%. Where a permanently installed system is provided, automatic shutdown of the installation is to take place when 50% LEL is reached in the hazardous area.

4.11 Monitoring

The need for global behaviour, motion, hawser tension, mooring line tension monitoring has to be addressed in the PPS.

For deep-sea application, mooring line tension monitoring and global behaviour recording are mandatory.

The tension monitoring system shall be designed for the service life of the buoy and powered from the buoy system (batteries to be regularly changed is not allowed). The system shall allow real time monitoring with settings of alarms/warnings to detect line breakage, over load or abnormal tension changes. The sampling frequency of the signals shall be sufficiently fine to derive statistical values such as Max, Min, Mean and RMS of the wave and low frequency tension over a period of time to be defined in the PPS. The whole signal of each line shall be transmitted to the FPSO if the communication system capacity between the buoy and the FPSO allows it. Otherwise the signals shall be locally stored for a period not less than one (1) year and post-treated, only alarms and statistics shall be transferred to the FPSO. Each mooring line shall be fitted with at least two (2) sensors for redundancy purpose. The sensors shall be bolted or welded (but not glued) on the chain connectors to a location that minimizes stress field disturbance in order to accurately derive the tension. The sensor shall be placed on the neutral axis to a location that avoids any residual bending moment. The measurement system inaccuracy shall not exceed 2%.

A motion monitoring system measuring the 6 degree of freedom shall be implemented. Particular attention shall be paid to the location of this system to define whether it has to be installed on the fixed or the rotating part of the buoy and the implication in terms of motions posttreatment. The sampling frequency of the signals shall be sufficiently fine to derive statistical values such as Max, Min, Mean and RMS of the wave and low frequency motions over a period of time to be defined in the PPS. This system shall be in place for at least 2 years. It may be a stand alone system with its own batteries. The storage capacity shall allow the whole signals recording for 2 years.

The clock of the tension and motion monitoring systems shall be synchronized with the clock of the FPSO ICSS.

5. Design

All deliverables identified hereafter for the design of the BUOY shall be provided by CONTRACTOR to COMPANY and CS for their APPROVAL prior to procurement and commencement of the BUOY fabrication.

5.1 Mooring system

5.1.1 Mooring system components and basic requirements

The mooring system of the buoy is composed of the following parts: *mooring lines*, *anchors*, *chain stoppers*, *connecting elements* and *hawser*.

For all components of the mooring system, the method of *installation*, tensioning, re-tensioning, monitoring, *inspection* and *maintenance*, as well as the possible need for *replacement* of components during service life shall be carefully assessed by CONTRACTOR at an early stage of design, as these operations can have an important impact on the choice of the mooring lines and their design. This is particularly important for **deep water** CALM buoy systems.

Particular attention shall be paid for the initial installation which may require few length adjustment to achieve the target position.

5.1.1.1 Mooring lines

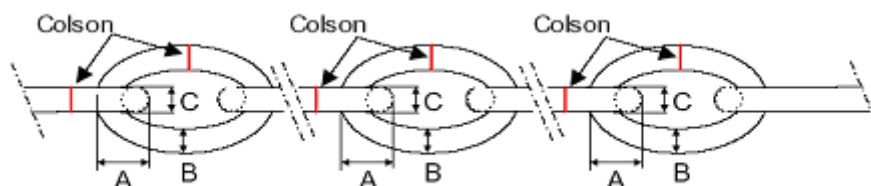
Mooring lines shall be made of offshore grade chain (**DNV-OS-E302**), steel wire ropes (**DNV-OS-E304**) or synthetic ropes (**BV NI 432**).

Grade of material shall be limited to R3S.

For **deep water** CALM buoy systems, connection between elements shall be done with H-links. The use of shackles is strictly submitted to a formal approval of COMPANY

Particular care shall be taken to limit and to evaluate local effects such as but not limited to in-plane and out-plane bending, shear, torsion, wearing in terms of strength and fatigue resistance in particular at the chain-stopper, hawse, anchors, etc.

A dimensional control of the 10 first links close to the stopper/shackle shall be performed prior to installing the lines. The following dimensions shall be measured (A, B and C):



Particular care shall be taken if synthetic lines are used for **deep water** buoys. In this case, CONTRACTOR shall refer to the CS guidelines, **API RP 2SM** and the Noble Denton "Engineers Design Guide to Deepwater Fibre Moorings" as preliminary documents for design guidelines.

5.1.1.2 Anchor points

If not already prescribed in the PPS, CONTRACTOR shall determine, with COMPANY APPROVAL, the most adapted type of anchors for the project, based on soil conditions, ease of installation, equipment availability, type of mooring, or other.

5.1.1.3 Chain stoppers

Unless otherwise specified in the PPS, the chain stoppers of the buoy shall be of the ratchet type, whose design is to be submitted to COMPANY for APPROVAL.



The chain stoppers shall swivel about a horizontal axis perpendicular to the direction of the anchor chain. The link gripped in the chain stopper shall be in a vertical plane to avoid working under a bending load.

Particular care shall be taken to limit and to evaluate local effects such as but not limited to in-plane and out-plane bending, shear, torsion, wearing in terms of strength and fatigue resistance.

5.1.1.4 Connectors

In the choice of connectors, CONTRACTOR shall demonstrate that the arrangement chosen will permit easy installation and replacement of those sections particularly exposed to wear and corrosion.

CONTRACTOR shall also demonstrate that the connectors have equal or greater properties than the mooring lines in terms of strength and fatigue resistance.

The material of the bushing of the connector bearings shall be of low friction to minimize the stick/slip angle of the connector and therefore the Out of Plane Bending. As far as wear is concerned, a safety factor of 2 on the bushing material thickness is required.

5.1.1.5 Hawser

If the BUOY is used to directly moor offloading tankers, there shall be two separate and identical (2) hawsers each connected to its own chafe chain, if mooring ships are over 150,000 tonnes deadweight as required by OCIMF "Recommendations for equipment in the mooring of ships at single point moorings".

If the BUOY is used to moor an F(P)SO (semi)permanently, with offloading tankers connecting to the F(P)SO, there shall be two (2) identical, redundant hawsers between the BUOY and F(P)SO, and one (1) hawser between the tanker in tandem and the F(P)SO.

The hawser, hawser make up shall follow OCIMF guidelines and fittings to be as per OCIMF standards. The chaffing chain for mooring on the tanker side shall be made by the chain Manufacturer. A special link between diameter 76 mm and diameter 54 mm links shall be provided instead of a Kenter link to avoid risk of blockage through the stopper.

The hawser shall be protected by polyurethane sheathing over a length of 10m on both ends to protect the nylon from chafing.

The use of a hook with manual release is recommended and should be confirmed in the PPS.

Hawser-storage on a reel between offloading may be assessed.

One spare hawser shall be supplied and properly store according to MANUFACTURER recommendation.

Protections of the buoy body and/or turntable against hawser chafe chain ragging shall be fitted and renewable.

5.1.2 Design criteria

5.1.2.1 Offset limits

The allowable offset limits of the buoy, both in intact and damaged conditions, are based on the type of riser/export line to be accommodated, local water depth and metocean conditions. As

such, the offset limits shall be determined in conjunction with the riser/export line design analysis, as well as by advice from riser/export line MANUFACTURER.

Final offset limits shall be shown by CONTRACTOR to be compatible with riser design tolerances.

5.1.2.2 Mooring line length

If drag anchors are used, no uplift force shall be accepted for intact or damaged conditions, in either extreme or operational environments. A typical one (1) shot of chain length (27.5 meters) shall always remain on the seafloor.

For vertically loaded anchors, such as piles, the line length and corresponding amount of uplift shall be compatible with the anchor design.

5.1.2.3 Hawser length

Hawser length shall be determined to minimise fishtailing, slackness and high loads in the hawser during tanker offloading as well as the risk of collision.

5.1.2.4 Maximum tension limits for mooring lines and anchors

Safety factors for maximum tension in mooring lines vary according to references. However, for dynamic analysis, standard safety factors as defined by **API RP 2SK** for steel anchor lines and drag anchors, and **API RP 2A** for anchor piles, as modified by the following table, are applicable. Suction anchors safety factors are to be confirmed in the PPS. In addition, any two lines broken damage case shall be analysed with a safety factor of 1.1 unless otherwise specified in the PPS. Summary tables of recommended values are provided below:

Mooring line	Mooring system condition	
	Intact	Damage
(Quasi static)*	2.00	1.43
Dynamic	1.67	1.25

Drag anchor	Mooring system condition	
	Intact	Damage
(Quasi static)*	1.80	1.50
Dynamic	1.50	1.3

Piles anchor	Mooring system condition	
	Intact	Damage
(Quasi static)*	2.00	1.50
Dynamic	1.50	1.30

* For reference only, since quasi static analysis is only valid for preliminary studies.

5.1.2.5 Corrosion and wear allowance

In addition to the above safety factors, a corrosion and wear allowance for the anchor lines and connecting elements shall be taken into account for the determination of final diameters/sizes of the lines make up. The following values apply, in mm per year of service life on line diameter:

Splash zone and connections	0.4
Intermediary zone or catenary	0.2
Touch down zone, seabed	0.4

5.1.2.6 Maximum tension limits for hawser and related equipment

The Safety Factor for hawsers loads shall be three (3), meaning that the final hawser selected shall have a minimum wet guaranteed breaking load (in used condition) of three times the extreme load found in the design analysis.

Factor to be checked with calculation method (quasi-static/extreme).

The strength of the ancillary equipment (such as the hook and its supports) and the chain stopper of all size of expected tankers at SPM shall be such that it is not the weak point in the line. Protection by calibrated weak point at a value not lower than the extreme load can be envisaged if required.

5.1.2.7 Fatigue life

Unless fatigue design curves are provided by the MANUFACTURER, **API RP 2SK** curves shall be used for conventional material and cable construction types.

The fatigue life of any component of the mooring system (chains, wire, shackles, Kenter links, chain stoppers, etc.) shall be at least ten (10) times the design life for current line (tension/tension) and local effects (OPB/IPB fatigue).

5.1.2.8 Contacts

There shall be no contact between mooring lines and risers/export lines and pipes/PLEM.

5.1.2.9 Synthetic lines case

In the absence of a unified reference, the design criteria for synthetic mooring lines shall be based on CS guidelines, **API RP 2SM** or **Noble Denton / TTI** "Deep water Fibre moorings, an engineers' design guide", whichever is more conservative. As a minimum the safety factor defined in 5.1.2.4 shall be increased of 10% for polyester ropes and 20% for other synthetic ropes.

Additional design criteria, as compared to steel wire mooring, shall be defined for:

- Minimum tension
- Creep rupture
- Line length due to elongation
- Tension - bend and axial compression fatigue
- No contact with seabed.



The upper part of the synthetic rope shall remain at all times at a minimum water depth of 100 m.

5.1.3 Design procedure

5.1.3.1 Methodology

CONTRACTOR is required to provide a detailed description of the methodology and numerical tools used for the determination of mooring lines, anchors and hawser loads, which are to be reported in the design load report. If the numerical tools used are not publicly recognized, evidence for quality controls and calibrations shall be provided. The proposed methodology shall comply with all requirements and paragraphs stated hereafter.

The mooring system study shall consider two main configurations: *stand-alone* (no tanker connected) and *operational* (buoy with tanker and tug(s) connected, or buoy with F(P)SO, tanker and tug(s) connected).

In any case, quasi static analysis is only acceptable for preliminary design. Final detailed design shall be based on a dynamic analysis. Quasi-dynamic analysis (in the sense of Bureau Veritas safety factors) will be accepted only if line dynamics are proved to be insignificant.

For deep water application time domain fully coupled model shall be used.

For details not covered in the present specification, **API RP 2SK** for steel mooring design, **API RP 2SM** / Noble Denton "Engineers Design Guide to Deepwater Fibre Moorings" for synthetic mooring lines and requirements in **GS EP STR 661** shall be used.

5.1.3.2 Model tests

Model tests shall be performed for CALM buoy in particular when the design has unconventional features, such as a CALM Buoy in deep or ultra deep water, or CALM buoy in very shallow water and harsh environments, or when the CONTRACTOR has not already performed model tests for a similar terminal. The decision not to perform model tests will be made on a project specific basis.

The aim of the model test is to confirm the design results and determine the operational limits.

If tank tests are performed, a specific test program shall be prepared and submitted to COMPANY in a separate document, prior to the model tests and after preliminary numerical simulations, so as to determine specific test objectives. Model tests preliminary considerations to be followed are indicated in **GS EP STR 661**.

If prior model test data is used to supplement numerical models, CONTRACTOR shall prove the relevance of the model test data to the project and describe clearly how it will be used in the design methodology.

5.1.3.3 Risers/Export lines

For deep water CALM terminals, CONTRACTOR shall include the influence of the export lines in the mooring calculations, as coupling effects between the buoy and export lines may not be negligible.

For deep water CALM terminals, particular attention shall be paid to the possible modification of the system stiffness and buoy RAOs due to the presence of export lines, and additional drag load and damping due to current on export lines. Those effects are to be evaluated through a

fully coupled analysis, in which case the design of the mooring lines and export lines, which are part of the fluid transfer system, shall be made together.

5.1.3.4 Hawsers

For the operational cases, the hawser dynamic loads induced by both horizontal and vertical motions at the hawser extremities shall be taken into account.

5.1.3.5 Input data file

The complete input data file used for numerical simulations shall be provided by CONTRACTOR to COMPANY, and shall be included in the design load report.

The input data file shall contain at least the following information:

- Environmental conditions and parameters, bathymetry characteristics
- Buoy, F(P)SO, tanker and tug(s) characteristics
- Mooring lines characteristics creeping and stiffness in used conditions
- Hawser characteristics (stiffness in used conditions)
- Wind and current forces (areas, coefficients and corresponding forces at different headings)
- Hydrodynamic data (added mass, radiation damping, first order wave forces, RAOs, mean drift)
- Damping coefficients and expressions (viscous, mooring lines, slow drift)
- Slow drift forces.

Following are some specific requirements on some of these items:

5.1.3.5.1 Hydrodynamic data

Refer to [GS EP STR 661](#).

Hydrodynamic data shall include effects of changes in tanker draft for the full and ballast conditions, unless it is demonstrated that the effect is insignificant.

Unless more precise data is available, tanker ballast draft can be taken as 40% of the full draft.

5.1.3.5.2 Wind and current forces data

Wind and current forces can be obtained from [OCIMF](#) for tankers or from [API RP 2SK](#) guidelines, or from recognized software such as WINDOS for wind forces.

For tankers in shallow water, the effect of under keel clearance shall be taken into account, as this will increase lateral loads due to current.

5.1.3.5.3 Damping data

Refer to [GS EP STR 661](#).

5.1.3.5.4 Slow drift data

Refer to [GS EP STR 661](#).

5.1.3.5.5 Hawser data

Characteristics of hawser (Minimum Wet Breaking Load, load-elongation curve, weight, etc.) shall come from specifications of a recognized MANUFACTURER.

5.1.3.6 Design load case matrix

A design load case matrix shall be prepared by CONTRACTOR for the *stand-alone case* and *operational case*, for both *intact* and *damaged* cases. The two matrices shall summarize all cases studied, and shall be included in the design load report.

The stand-alone case shall correspond to the 100 yr return period events. The operational case shall correspond, as a first approximation, to the 1 yr return period events. The corresponding waves, wind and current conditions shall be defined in the PPS.

The damaged case shall correspond to the failure of one (1) mooring line, which will be either the most loaded line or second most loaded line, whichever is the most critical from the strength point of view. In addition, any two lines broken damage case shall be analysed with a safety factor of 1.1 for stand alone case unless otherwise specified in the PPS.

The operational case shall consider at least two drafts for the tanker, namely the ballast draft and fully loaded draft. In case of an FSO and tanker connected to the buoy, the two cases FSO fully loaded/tanker on ballast, FSO on ballast/tanker fully loaded shall be covered.

For both stand-alone and operational cases, the water depth giving the maximum design forces shall be selected.

When dealing with squall events, the designer shall not consider any corrective or improving actions from the tugs that would minimize the line tension results. The full time series of the squalls as provided in the metocean specification shall be used in the computation.

Notes on operational cases:

To determine the load cases direction-wise, CONTRACTOR shall find the combinations in direction of wind/wave/current that lead to the maximum design forces for the mooring, anchors, risers and hawser. For this exercise, CONTRACTOR will usefully consider all information provided in the metocean design basis, in particular prevailing environments directions and existing correlations of environments, if any identified. If not, a systematic approach shall be used to determine worse cases, as part of the methodology to be described.

To determine the load cases intensity-wise, CONTRACTOR shall use the wind/wave/current intensities associated to each direction, up to ± 22.5 deg. For example, if a current coming from the North is considered, its associated intensity shall be the maximum of the NE, N, NW intensities.

5.1.3.7 Sensitivity analyses

Due to the importance and uncertainties on wave periods and wave spectra on floaters motions, the design load case matrix shall include, for the identified sizing cases, a sensitivity study on the wave period (± 2 seconds) and spectrum parameters.

In practice, the steady one-minute mean average wind can be used for preliminary design. In detailed design, the influence of wind dynamics shall be checked for the extremes due to the possible influence on slow drift motion of the tanker.

Other sensitivity analyses may be required if other uncertainties are identified, which can have an impact on the mooring design.

5.1.3.8 Wind/current reversals

Due to the importance of current and wind reversals on the behavior of the moored tanker, the design load case matrix shall cover at least two cases of such reversals, if any are identified in the metocean report.

When dealing with squalls, the full time series of the squalls as provided in the metocean specification shall be used in the computation.

5.1.3.9 Extreme response analysis

Frequency domain analysis can be used for initial design, determination of the sizing cases and screening when numerous simulations are needed (typically for operational case).

Time domain simulations, with minimum duration of 3 hours, shall then be performed on the sizing cases.

Statistics of extremes can be determined according to **API RP 2SK** guidelines for frequency domain results, provided that the peaks are shown to follow a narrow banded, Rayleigh distributed process. For time domain analysis of critical cases, storm duration of 3 hours shall be simulated at least five (5) times, and statistical fitting techniques (such as Weibull) shall be used to determine Most Probable Maximum values over the 3 hours storm duration.

The extreme response analysis shall provide maximum loads in anchor lines, anchor points, and hawser, as well as buoy maximum excursions, all according to the design load case matrix.

For deep water, **fully coupled** time domain simulations are to be run.

In particular, the chosen rating of main bearing shall be stated and design maximum hawser mooring load shall be shown to be less.

The no contact criteria as defined in 5.1.2.8 shall be checked under survival and operating cases.

CONTRACTOR shall advise, based on results for operating conditions, the bollard pull requirements for a tug assisting during the offloading operations.

5.1.3.10 Fatigue analysis

A fatigue analysis shall be performed at least on the most loaded and critical mooring line (including chain stoppers) according to a methodology to be described by CONTRACTOR, such as the one described in **API RP 2SK**.

The fatigue curves and stress concentration factors used shall be clearly identified and justified.

For Deep Water CALM Buoy, the particular project specification shall define the percentage of time when a lifting tanker is moored at the buoy. It is emphasised that the presence of the lifting tanker will significantly modify the hydrodynamics of the buoy and therefore affect the fatigue lives of the mooring line components.

For deep water, fatigue analysis shall include the damage induced by the Out of Plane Bending and, the use of Rayleigh distribution shall be validated against rain flow counting method.

5.1.3.11 Anchor point design

Following the determination of design loads on anchors, CONTRACTOR shall perform the anchor point design according to the type of anchor selected.