

GENERAL SPECIFICATION

STRUCTURAL

GS EP STR 652

F(P)SO - Steel hull design requirements

Rev.	Date	Purpose of the revision
14	12/2016	Minor modifications of § 5.4, 5.6, 6.3, 6.5, 6.7
13	05/2015	Organisation change - January 2015
12	10/2012	Minor modifications of § 2, 3, 4.2, 6.1, 6.2, 6.3, 6.4, 6.6, 6.7
11	01/2012	Minor modifications of § 1, 2, 4.1, 5.5, 5.7, 6.1, 6.2, 6.3, 6.4, 6.5, 8
00	02/2001	First issue

Owning entity: DSO/TEC	Managing entity: DSO/TEC/STR
Other Approving entity(ies):	

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1. Scope

This specification aims at defining the minimum requirements on structure and naval architecture which are applicable to the design of a F(P)SO Floating (Production) Storage Offloading hull in both new building or conversion projects. Application for FPU projects will be subject to a Project Particular Specifications that will provide detailed interpretation of this General specification.

Other requirements which are applicable to the design of a F(P)SO (safety, layout, systems...) are defined in [GS EP STR 651](#).

Requirements on structure and naval architecture which are applicable to the construction of a F(P)SO are defined in [GS EP STR 653](#).

It does not address any structural design requirements for modules or packages, which will be ultimately placed on the F(P)SO deck, and to risers related to subsea production equipment. Those are defined in [GS EP STR 102](#) and [GS EP STR 103](#).

General requirements for Offshore Steel Structure design are given in [GS EP STR 100](#).

A Weight management system shall be established and follow [ISO 19901-5](#) as completed by [GS EP STR 001](#).

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

Where national regulations exist, their provisions and those of the standards and codes to which they refer shall apply, supplementing or amending the provisions of this document.

If there are no national regulations covering all or part of the subject of this document, the following reference documents are applicable as described in the following sections. When not explicitly referred in the following sections they may be used as guidance when relevant.

Attention is drawn to [IMO MEPC.139\(53\)](#) which is fully applicable.

Only the main reference documents are mentioned; the Contractor shall be responsible for complying with all secondary reference documents dealing with the subject of this document.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and addendums, is the latest revision published at the effective date of this document.

Reference	Title
American Bureau of Shipping FPI	Guide for Building and Classing Floating Production Installations
BV NI537	Guidelines for the Design of the Means of Access for Inspection, Maintenance and Operation of Commercial Ships
BV NR445	Rules for the Classification of Offshore Units
DNVGL-RU-OU-102	Floating production, storage and loading units
DNVGL-ST-N001	Marine operations and marine warranty

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Reference	Title
DNV-RP-C201	Buckling Strength of Plated Structures
DNV-RP-C206	Fatigue Methodology of Offshore Ships
DNV-RP-H103	Modelling and analysis of marine operations
EN 1337 (Parts 1; 2; 3)	Structural bearings - Parts 1; 2; 3
IACS Recommendation No.47	Shipbuilding and Repair Quality Standard
IACS Recommendation No.90	Ship Structure Access Manual
ICLL	International Convention on Load Lines 1966
IMO IS 2008	International Code on Intact Stability 2008
IMO MARPOL 73/78	International Convention for the Prevention of Pollution from Ships
IMO MEPC.139(53)	Guidelines for the Application of the revised MARPOL Annex I Requirements to Floating Production, Storage and Offloading facilities (FPSOs) and Floating Storage Units (FSUs)
IMO MODU	Code for the Construction and Equipment of Mobile Offshore Drilling Units
IMO MSC.151(78)	Adoption of amendments to the International Convention for the Safety of Life at Sea, 1974, as amended
IMO MSC.158(78)	Adoption of amendments to the technical provisions for means of access for inspections
ISO 19901-5	Petroleum and natural gas industries - Specific requirements for offshore structures - Part 5: Weight control during engineering and construction
ISO 19904-1	Petroleum and natural gas industries - Floating offshore structures - Part 1: Monohulls, semisubmersibles and spars
ISO 3730	Shipbuilding and marine structures - Mooring winches
ISO 7825	Shipbuilding. Deck machinery. General requirements
ISO 9089	Marine structures. Mobile offshore units. Anchor winches
Kinkead A.N. JRINA	A method for analysing cargo protection afforded by ship structures in collision and its application to LNG carriers (1979)
Lloyd's Register of Shipping FOI	Rules and Regulations for the Classification of a Floating Offshore Installation at a fixed location
NORSOK N-004	Design of Steel Structures - Annex L: Special Design Provisions for ship shaped units
SOLAS	International Convention for the Safety of Life at Sea
TSCF	Outfitting related structural defects
TSCF 2016	Guidance Manual for Tanker Structures 2016

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Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and addendums, is the latest revision published.

Reference	Title
GS EP COR 100	Cathodic protection of offshore structures
GS EP COR 101	Internal cathodic protection of equipment and storage tanks
GS EP COR 351	External protection of structures and equipment by painting. Floating structures
GS EP LSO 110	Environmental effects considerations for helidecks
GS EP LSO 201	Towing of Watercraft
GS EP LSO 202	Personnel transfer between watercrafts and between watercrafts and offshore structures
GS EP MEC 300	Noise and Vibration of Rotating Machine Packages
GS EP STR 001	Weight monitoring and weighing offshore and onshore units
GS EP STR 003	Crane for floating offshore installations
GS EP STR 004	Riser / Umbilical Pulling Rig, Pulling and Mooring Winches
GS EP STR 005	Lifting Appliances other than cranes and winches
GS EP STR 100	Offshore steel structures - General
GS EP STR 101	Design of offshore jacket and subsea structures
GS EP STR 102	Design of offshore topside structure
GS EP STR 103	Design and fabrication of skids and equipment supporting structures
GS EP STR 105	Boat landings and bumpers
GS EP STR 108	Requirements for evaluation of finite elements analysis and results
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 601	Floating Unit Integrity Management System Requirements
GS EP STR 603	Hull and Mooring Monitoring
GS EP STR 651	General principles for a F(P)SO design
GS EP STR 653	F(P)SO - Hull fabrication requirements

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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 and onshore installations
GS EP STR 902	Pultruded fire resistant fibre reinforced plastic floor grating

3. General

3.1 Definitions

For main definitions, refer to [GS EP STR 651](#) and [GS EP STR 100](#).

3.1.1 General

The following definitions are also used in the present document:

- Loading manual includes all information required for F(P)SO loading management, including hydrostatic properties, still water hull girder loads, intact and damage stability. The Trim and Stability booklet or manual is included in the Loading manual.
- Particular Project Specification(s) (PPS): Document(s) issued by Company that define specific requirements or design basis for the project.

3.1.2 Offshore Areas and Ship Areas

A F(P)SO shall be designed to [ISO 19904-1](#), offshore standards such as the Rules for Offshore Units of the designated Class Society. ([American Bureau of Shipping FPI](#), [BV NR445](#), [DNVGL-RU-OU-102](#), [Lloyd's Register of Shipping FOI](#) or equivalent) These standards cover material selection, design (methodology, allowable stress, fatigue criteria), fabrication details (welding and tolerances), Inspection and test requirements.

The hull structure elements may be split in two zones: Offshore and Ship Areas.

Offshore Areas designate all major appurtenances fixed on the Hull structure, which are specific to F(P)SO and do not exist as such on ships. The Offshore Area includes the element, its support and the corresponding Hull reinforcement, which encompass the hull structure, the design of which is influenced by the loads induced by the element.

Ship Areas cover areas which are not defined as Offshore Areas. Ship Areas may be designed to Ship Rules where allowed by Offshore Rules.

This division shall be defined in the "Area definition plan" (refer to section 6.3.3 and section 6.6.1 for structural category definition) during basic engineering. Offshore Areas may be expanded during detailed design, if detailed FE analysis shows increased influence of loads due to offshore elements on Ship Areas.

This classification shall also be recalled on all design and construction documents including but not limited to structural drawings, welding plan, Inspection and testing plan, etc.

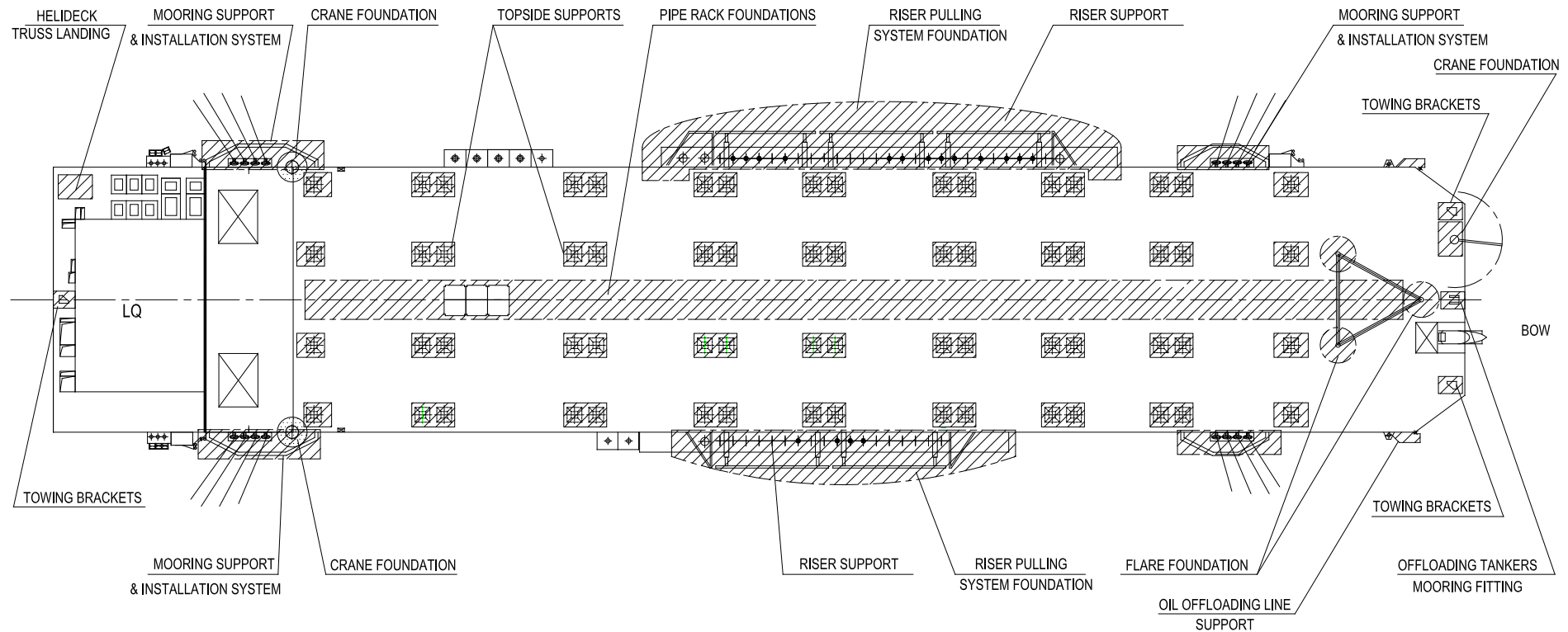
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The Offshore Areas shall **at least** include:

- Mooring lines stopper attachments, supporting structure, mooring installation / tensioning equipment supporting structure, protectors and protectors foundations
- Risers (including offloading line) support attachments, supporting structure, riser installation equipment (including supporting structure), protectors and protectors foundations
- Turret structure, its connections to the hull and the hull turret moon pool
- Foundations for turret access structure (Turret access structure shall be engineered according to **GS EP STR 102**)
- Tandem loading / offloading equipment supporting structure
- Cranes foundations
- Flare stack structure and foundation
- Topsides Support structures and foundations
- Topsides Pipe-rack Support structure and foundations
- Caisson structure and foundation
- Helideck support structure and foundations
- Telecom mast and foundations
- Towing brackets and foundations
- Fenders supports and foundations.

Refer to the typical drawing showing Offshore Areas.

TYPICAL OFFSHORE AREAS



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3.1.3 Service life / Design life

The service life is the specified duration of service on site. It starts at first oil and ends at the end of oil production.

The design life includes the service life and all the phases from float-out through production to decommissioning including outfitting, towing, integration, installation, hook-up and decommissioning. The design life shall be taken into account, especially for fatigue analysis and corrosion protection system design.

3.1.4 Draught

The design draught is defined in section 5.2.3.

The minimum operational draught is defined as the draught corresponding to the following configuration:

Topsides	Mooring lines	Risers	Cargo	Slop	Process tanks	Bunker	Ballast
Initial Net weight dry	Connected tensioned	Connected empty	Empty	Empty	Empty	10%	Minimum for nominal trim and heel

Outfitting located on side shell shall be safely operable for any draught between design draught and minimum operational draught.

3.1.5 Fatigue sensitive area

A fatigue sensitive area is a structure component with calculated fatigue damage (at the end of the design life) equal or above 75% of the allowable value.

3.2 Abbreviations

ALARP	As Low As Reasonably Practicable
BHD	Bulkhead
BV	Bureau Veritas
CFD	Computational Fluid Dynamics
CL	Centre Line
Class	Classification Society
CoG	Centre of Gravity
COW	Crude Oil Washing
DNV	Det Norske Veritas
DO	Diesel Oil
FE(A)	Finite Element (Analysis)
F(P)SO	Floating, (Production), Storage and Offloading unit
FPU	Floating Production Unit

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GM	Metacentric radius
GS	Company General Specification
HTS	High Tensile Steel
IMO	International Maritime Organization
KG	Vertical Center of Gravity
LCG	Longitudinal Center of Gravity
LQ	Living quarter
MBL	Minimum Breaking Load
MWS	Marine Warranty Surveyor
NDE	Non Destructive Examinations
OOL	Oil Offloading Line
PFP	Passive Fire Protection
PPS	Particular Project Specification
QA/QC	Quality Assurance / Quality Control
RAO	Response Amplitude Operators
ROV	Remote Operated Vehicle
STI	Specific Thickness Increment
SWBM	Still Water Bending Moment
SWL	Safe Working Load
TCG	Transverse Center of Gravity
Thk	Thickness
VCG	Vertical Center of Gravity

3.3 Classification and flagging

The Hull shall be designed and built in compliance with the rules of a Classification Society designated by Company.

Refer to **GS EP STR 651** for basic classification and flagging requirements. The full notation shall be defined in PPS.

4. Conditions of operation

4.1 Design data

The following design data shall be provided by Company in PPS:

- Service life duration (typically 20-year)
- F(P)SO location

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- Station keeping system type (spread moored, turret moored, disconnectable...)
- Site environmental conditions
- Fluid properties (densities, corrosiveness, temperature etc.)
- Type and characteristics of vessels considered for F(P)SO logistics and offloading (Supply vessel, crew boat, off-take tanker, methanol or other product supply tanker, etc.)
- Helicopter type
- Crude oil parcel (size and offloading frequency) and minimum storage requirements

4.1.1 Environmental conditions

Environmental data related to the construction and integration sites shall be submitted to Company and MWS for review.

Environmental data pertaining to the tow operations shall be validated by Company and MWS. Refer to **GS EP LSO 201**.

4.1.2 Fluid density

The following fluid densities shall be defined in PPS:

Fluid	Purpose	Value to be provided	Default value
Produced oil	Global loading and stability	Max blend density value likely to be encountered	0.90 t/m ³
	Storage volume calculation	Min blend density value likely to be encountered	0.80 t/m ³
	Local scantling	Max density from any oil well	0.95 t/m ³
Produced water	Global loading and stability	Mean operational density	1.025 t/m ³
	Local scantling	Max operational density	1.025 t/m ³
Fluids in process tanks	Global loading and stability	Mean operational density	1.025 t/m ³
	Local scantling	Max operational density	1.025 t/m ³

Produced oil densities shall be given at storage and reference (15°C or 60°F) temperatures.

For the most common fluids to be considered for F(P)SO design, the following reference densities shall be used unless different values are provided in PPS.

- Diesel oil: 0.860 t/m³
- Industrial/Fresh/Potable water: 1.000 t/m³
- Methanol 0.800 t/m³
- Sea/ballast water 1.025 t/m³

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4.1.3 Structural design temperature

The structural design temperature shall be selected considering the temperatures to be experienced by the F(P)SO on site, on construction sites and in seas crossed during transport. All these areas shall be considered as operation areas.

The structural design temperature shall not be higher than 0°C and shall be approved by Class.

4.2 Loading configurations

Company Reserve: Company Reserve as defined in [GS EP STR 001](#) shall be considered in all loading cases where topside weight is mentioned.

4.2.1 Temporary phases

All temporary configurations shall be considered. Following table shows a typical loading matrix that shall be confirmed during project phase depending on fabrication method and construction schedule.

Configuration	Topsides Dry	Mooring & Risers	Operating Loads	Future	Bunker
Outfitting at quay	No	No	No	No	To be defined
Tow to topsides integration yard	No	No	No	No	To be defined
Integration	Yes	No	No	No	To be defined
Tow to field	Yes	No	No	No	Yes
Mooring, risers, OOL installation	Yes	Progressive loading (1)	No	No	Yes
On site decommissioning	Yes	Progressive unloading (1)	Partial (2)	Yes	Yes
Dry docking and decommissioning	Yes	No	Partial (2)	Yes	No

(1) Mooring and riser loads to be considered in accordance with specific phase.

(2) Partial operating loads (Topsides not completely drained).

For these configurations, the environmental conditions to be considered shall be in accordance with DNV Rules for Planning and Execution of Marine Operations [DNVGL-ST-N001](#) and [DNV-RP-H103](#).

Ballast configurations shall be defined for temporary configurations. During tow, the draught shall be selected to allow sea water lift operations, to ensure operational functions (cooling water, fire water, ballast water...), to minimize slamming and, together with bow flare and bulwarks, to avoid the occurrence of green water.

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4.2.2 Operational configurations

Each phase of operation shall be considered: initial phase and future phase(s) where future modules and future risers are to be installed.

Operational configurations are configurations normally occurring during unit operation including loading and offloading sequences and nominal conditions of process tanks if any. For these configurations, the mooring lines are connected with pretension; the riser and export lines are installed and filled with nominal fluid and operating loads are nominal. Loading and offloading sequences shall be developed so as to minimise the ballast operations and still water hull girder loads.

Operational configurations shall also include the configurations where any single tank is out of service for inspection or maintenance. The F(P)SO shall continue unrestricted operations with any single ballast tank, cargo tank, process tank, cofferdam, void space, being inspected. The loading and offloading sequences shall be revised to cope with the non-availability of any one tank. In such circumstances, the loading and the offloading shall be possible with nominal performances.

Loading and offloading sequences are to be approved by Company.

Some specific operational configurations are defined in the following table:

Configuration	Operation phase	Topsides	Cargo tanks	Slop tanks	Process tanks	Bunker	Ballast tanks
Fully laden	Future	Gross weight Operating	Nominal storage	Full (98%) of sea water	Max nominal level	Full	As required for nominal trim and heel
Ballast	Initial and future	Gross weight Operating	Dead stock	Min Nominal level	Min nominal level	10%	As required for nominal trim and heel

Inspection configuration and consequences are presented in the next table.

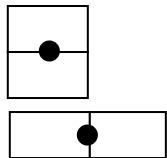
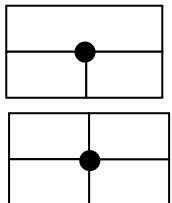
4.2.3 Repair configurations

The repair configurations shall be investigated for any combination of:

- 2 adjacent tanks out of service: light repair
- 3 or 4 adjacent tanks out of service: heavy repair.

In case of light repair, specific constraints on tanker arrival may be set up during the repair duration (reduced window, demurrage etc.). The unit production capacity shall not be reduced and it shall be possible to off-load the design parcel.

In case of heavy repair, production and offloading shall not be stopped but may be performed at a reduced rate according to the capability of the F(P)SO. Contractor shall document the remaining production and offloading capabilities.

Configuration	Hot work location	Consequence	Production	Off-loading	Environment
Inspection	Any tank	1 tank out of service	Nominal	Design parcel	Full class notation
Light repair		2 tanks out of service	Nominal	Design parcel with constraints acceptable	10-year conditions Site and seasonal specific
Heavy repair		3 or 4 tanks out of service	Reduced	Reduced parcel	10-year conditions. Site and seasonal specific

4.2.4 Accidental configurations

These configurations correspond to the condition of the F(P)SO during an accidental event as defined in section 4.3.5 or any rule damage or human error configuration as defined in section 6.1.2.2.

Hull, risers, topsides and mooring shall withstand such accidental scenario leading to draught, heel and trim variation, in combination with load effects due to 1-year environmental conditions.

4.2.5 Post-accidental configurations

After damage event, corrective actions may be considered, provided they are easy and ordinary actions such as ballast emptying or filling. However, action that could be detrimental to the environment, such as voluntary cargo release, is not acceptable.

Hull, risers, topsides and mooring shall withstand such post-accidental configuration.

4.2.6 Associated environmental conditions

For each configuration the environmental conditions indicated in the following table shall be considered. Operating and extreme conditions refer to offshore rules. For application of Ship rules, extreme conditions shall be considered as per selected navigation notation.

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Configuration	Environmental conditions		Remark
	"operating"	"extreme"	
Operational	1-year	100-year	Including single tank inspection
Repair	1-year	10-year	
Accidental		1-year	Accidental ratio to be met
Post-accidental		10-year	Design ratio to be met after corrective action.(ballasting)
Temporary	DNV Rules for Planning and Execution of Marine Operations and DNV-RP-H103		Local conditions of the area where the temporary configuration is experienced

4.3 Loads

The loads to be considered are generally those described in the Rules and Regulations. The following ones are either specific or have a particular importance for F(P)SO.

4.3.1 Environmental loads

For site conditions, loads provided by Class according to navigation notation or specific codes shall be considered as a minimum. In addition site specific data shall be considered when they are more demanding than Class rule application.

4.3.2 Thermal loads

Fluid temperature effects have to be assessed in the calculations when necessary (differential dilatations and potential thermal deflection).

4.3.3 Interface loads

In co-operation with designers of interfacing objects, interface loads shall be determined in operating conditions, extreme conditions and accidental condition, in accordance with offshore standards. At each design phase, margins shall be determined to cope with design evolution.

The determination of some load effects requires an iterative process involving the hull designers and the designers of interfacing features. This concerns principally topsides, mooring system and riser loads. The first loop of this process is generally initiated during pre-project by an integrated team. At further design stages, each loop is started with the values obtained at the end of the preceding loop. On hull side, sufficient margins shall be considered to ensure that the result of next loops is kept well within the hull capacities.

Other Interface loads can be determined by hull designer from the interfacing object definition specified by Company using for example direct calculation or reference to available literature such as general specification, recommended practice, industry standards... This concerns in particular towing loads, mooring of vessels (off-take tanker, product tanker, supply vessels...), helicopter load, etc.

4.3.4 Installation loads

In addition to loads incurred during construction process, installation loads shall be considered during topsides integration and site installation.

4.3.5 Accidental Loads

The hull shall be designed with due regard to the possibility of loads arising from accidental events such as collision, dropped objects, fire, explosion and other abnormal events such as mooring line failure or a riser bursting. Structural enhancements and/or protective structures shall be considered ensuring that the consequences of accidental loads do not compromise safety on the installation.

Refer to Classification Society Rules for Offshore Units and **GS EP STR 101**, concerning other design requirements for accidental loads.

Accidental loads shall be combined with hull girder loads resulting from 1 year environmental conditions and envelope from operational configurations.

4.3.5.1 Collision

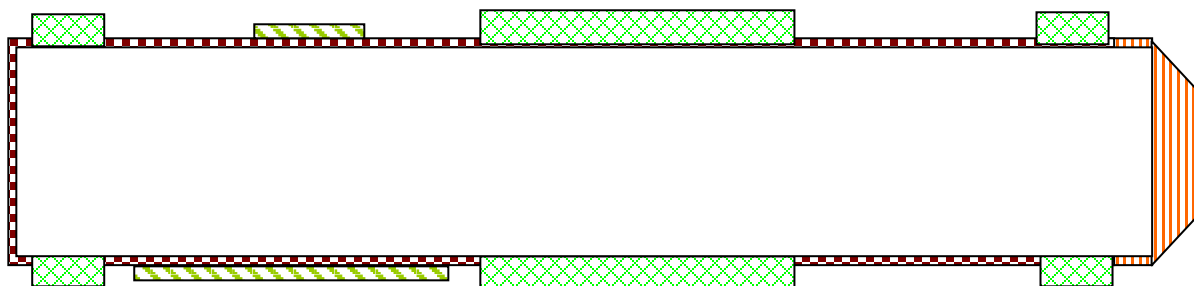
For collision study, impact energy shall be determined from the following data to be provided in the PPS:

- The characteristics of the vessels to be considered on site: supply vessel, product carrier (if applicable), off-take tanker
- The design collision speed that shall not be less than 1-year current speed on site.

As an example, the next table provides impact energies of a 7,000 t displacement supply vessel at 1 m/s and 1.4 m/s current speed.

7,000 t displacement supply	Added mass factor	1 m/s	1.4 m/s
Impacting by her bow	1.1	3.85 MJ	7.5 MJ
Impacting by her side	1.4	4.9 MJ	9.6 MJ

When protective structures are fitted around the critical appurtenances fixed to the side shell (moorings, risers), they shall be designed according to the next table.



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Impact design requirements for the design of the hull:

Legend	Area	Impacting vessel	Collision speed	Consequences	Hull Support structure (*)
	Protector	Supply	Not less than 1-year current	Energy may be absorbed by plastic deformation of the protective structure. Final clearance with protected item not less than 300 mm	Accidental criteria (offshore rules) to be respected
	Supply berthing	Supply	Refer to section 5.6.2	No damage	No damage

(*) Design of the hull's foundation for protecting structure shall include a reserve to ensure that the point of failure - in the event of overload - occurs at a point externally from the side shell plating. The hull foundation shall have a minimum 30% reserve compared to the strength of the protection frame attachment.

In addition, the collision energy levels corresponding to the following cases shall be determined in safety assessment:

Legend	Impact location	Impacting vessel	1st level	2nd level	3rd level
 Bow	On primary structure member	Off-take tanker and product tanker (if applicable)	Breach of shell	Contact with collision bulkhead	Breach of collision bulkhead
	Between primary structure members				
 Hull shell	On primary structure member	Supply vessel	Breach of shell	Contact with inner hull	Breach of inner hull
	Between primary structure member				
 Protector	Riser / mooring protector	Supply vessel	Contact with riser / mooring line	Breach of riser / mooring line	Breach of outside shell

The design basis of this collision study (hull shape, impact directions; localisation, etc.) shall be submitted to and approved by Company before launching the study.

Guidelines for the assessment of collision damage:

The extent of hull damage due to the different collision scenarios and impact energy levels shall be determined using the guidelines contained in the [NORSOK N-004](#) document.

Initial assessments to establish which are the most critical design conditions may be based on a simplified analytical method, such as proposed by [Kinkead](#) or other where accepted by Company. Nonlinear Finite Element analysis, using large deformation FEM software package such as DYTRAN, shall then be applied to the most critical scenarios found with the analytical method.

As a first approximation, the bow of the impacting vessels shall conservatively be considered infinitely stiff compared to the F(P)SO structure (whole energy absorbed by the F(P)SO).

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The amount of kinetic energy absorbed as strain energy may be assessed as per NORSOK above document, section 1.2.1. Rupture strain percentage shall be determined as per above NORSOK document, according to steel grade.

The acceleration on topsides and flare due to worse accidental impact shall be evaluated.

Post-collision analysis shall be performed to confirm the damaged hull structural integrity under the 1-year environmental conditions. The reduction of hull girder strength associated to the worst damage shall be evaluated and accounted for in these studies, assuming no further escalation of the damage.

4.3.5.2 Dropped objects and swinging loads

As a general principle, lay-out of the F(P)SO shall be developed in such a way to minimize risk of dropped object and swinging loads. However, in some instances, hull / living quarter structure may need to be reinforced in order to withstand possible energy from potential accident.

During basic design, handling analysis with possible risk-based approach or based on similar F(P)SO shall be performed. The evaluation of potential drop heights shall consider the height of the lift or set-down point compared to adjacent facilities, clearances needed to avoid other facilities or stored objects, and general operational considerations such as visibility to the crane operator. Similar kind of evaluations shall be performed for swinging loads.

From this, clear design basis shall be prepared for hull / living quarter area regarding dropped object / swinging load capacity. A drawing shall be issued showing in each location, the energy and surface that the structure shall withstand without collapse or penetration (punctual energy and spread energy).

Over the full extent of hull deck in the cargo area and above any hydrocarbon tank which may be outside of the cargo area, puncture of the deck plate is not acceptable and the hull deck structure shall not yield above 5% strain.

Higher deformations can be specified for the lay-down areas or similar working decks, up to the following limits:

- No perforation of plating
- Plastic deformation of secondary stiffeners up to 10% strain
- Primary structure remains in the elastic mode.

In any case, the dropped object must not lead to collapse of the lay-down area and the supporting pillars shall not buckle in the most unfavourable case. It shall be checked that structural failure will not lead to escalation.

Areas of open deck adjacent to lay-down areas will receive particular attention including for horizontal impacts due to swinging loads. The living quarter and the modules adjacent to the lay-down area, shall be checked against the swinging loads and protected, if necessary.

4.3.5.3 Fire

Safety analysis shall determine where structure may need to be covered with Passive Fire Protection. At the end of basic engineering, drawing shall be issued showing a mapping and rating of PFP requirements.

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During detail engineering, it shall be checked that assumptions of this analysis are still valid with regard to the actual layout of F(P)SO.

When necessary, an analysis of the structural response to fire shall be carried out with consideration to the locations and temperature profiles identified in the Topsides fire scenario analysis agreed with Company. For each fire scenario the following structural requirements shall be met:

- The resultant stresses in the structure shall not exceed the reduced yield stress of the structure
- Deformation of the structure shall not impinge on any safety critical operational equipment or lead to escalation of the situation
- The deformations shall not cause collapse of any part of the structure that supports any temporary safe refuge, escape route, or embarkation point within the required endurance period
- The structure of and supporting fire/blast walls and insulation material to critical areas shall maintain its integrity for at least the required endurance period.

4.3.5.4 Explosion

The hull and accommodation structure shall be capable of withstanding pressures resulting from explosion in combination with other loads imposed on the structure. In particular, the Hull Deck and accommodation superstructure front shall be capable of resisting the blast pressure. The blast over pressure shall not cause progressive collapse or penetration of the cargo tanks. The design pressures shall be obtained from the results of explosion analysis to be provided by Company or approved design guidance documents.

Design blast loading shall be provided in PPS and shall not be less than the values defined here below:

At basic engineering stage:

- The following minimum design blast over pressures shall be considered: 1 bar for the Hull Deck and topsides support structures, and 0.5 bar for the accommodation superstructure front bulkhead and adjoining blast walls. Calculation should be done with simplified (e.g. static) and conservative approach. 30% of back pressure (i.e. negative) shall be considered.
- An explosion analysis shall be performed to define blast pressure (peak and duration) for structural detail design with a margin not less than 15%. Drawing shall be issued showing the mapping of the design basis on the hull with reference to normalized pressure curves (example attached).

At detailed engineering stage:

- The design basis provided from basic engineering studies shall be considered. In addition, the design blast over pressures shall not be less than 1 bar for the Hull Deck and topsides support structures, and 0.5 bar for the accommodation superstructure front bulkhead and adjoining blast walls.
- An explosion analysis shall be performed to confirm the blast pressure (peak and duration) with final layout and check that design values are not exceeded.

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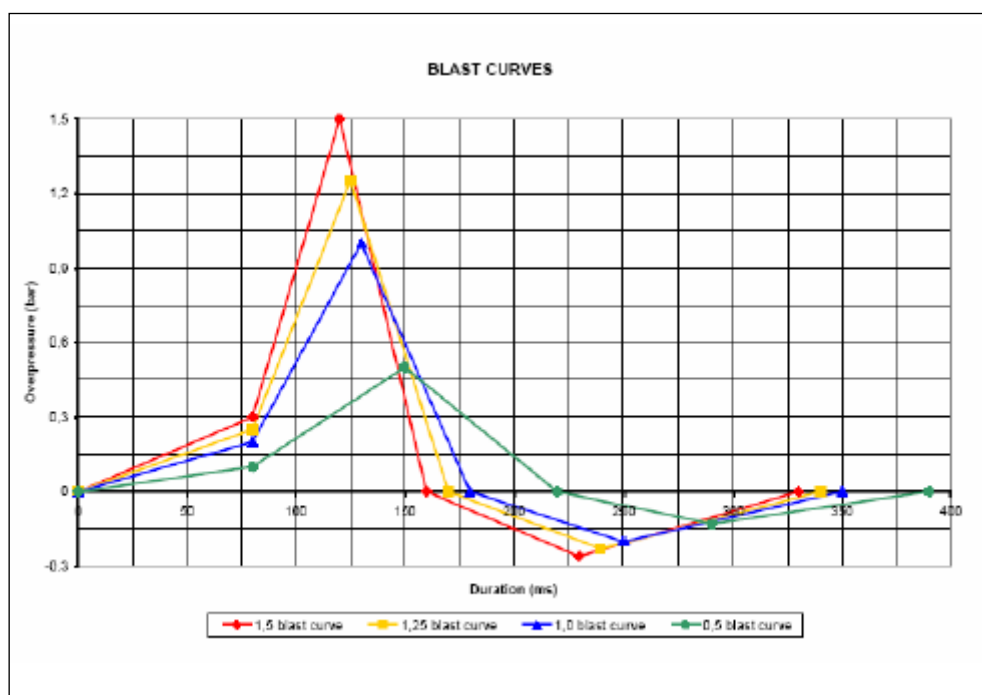
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The explosion resistance of Hull Deck, topsides support structure and accommodation shall meet the following requirements:

- Unless the effects of plastic deformation can be shown to be acceptable, the stresses in the structure should not exceed the increased yield stress associated with explosion resistance. Allowance for strain-rate enhancement of the yield strength shall not be taken greater than 10% on the static minimum specified value.
- Deformation of the structure shall not impinge on any safety critical operational equipment or lead to escalation of the situation
- The deformations shall not cause collapse of any part of the structure that supports any temporary safe refuge, escape route, or embarkation point
- The structure of and supporting fire/blast walls shall maintain its integrity.

Example of normalized pressure curves



4.3.6 Non-elastic analysis

Under accidental loads if elastic stress analysis cannot show that acceptance criteria are met, specific analysis such as elasto-plastic calculations may be performed to demonstrate the acceptability. Calculation method and acceptance criteria shall be submitted to Company approval. Strains shall generally be limited to 5%.

5. General arrangement

General arrangement of F(P)SO shall be in line with **GS EP STR 651**, Class notation requirement and Project particular specification.

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5.1 Hull shape

Consideration of a ship-shaped hull versus a box-shaped hull shall be given at the early design stage of the project. Possible areas of optimization using a ship-shaped hull are hull girder loads, drag loads, sea keeping on site / during tow, behaviour under collisions for tandem offloading, wave slamming and associated impact.

Design Objectives for hull shape in order of importance:

- Storage capacity and operability
- Passive Trim control in operations
- Accommodate machinery spaces and other internal spaces
- Still water hull girder loads minimization
- Maximize hull deck space
- Improved Hydrodynamic characteristics (sea keeping, slamming, green water, drag...)
- Course stability in towing.

5.2 Hull dimensions and Load line

5.2.1 Dimensions

In principle, hull dimensions should be determined during pre-project and confirmed or slightly modified during further project phases. The following drivers shall be considered to determining hull dimensions:

- Offloaded parcel and storage requirements
- Topsides and risers layout
- Operational draught and freeboard.

5.2.2 ICLL draught

For FPSO and FSO, the maximum draught will be calculated according to [ICLL](#) for ship type A: tankers.

For FPU, freeboard for ship type B according to [ICLL](#) shall be met.

5.2.3 Design draught

Unless otherwise specified, the design draught shall have a margin (typically 0.5 metre) on the [ICLL](#) draught to allow for future equipment addition. This margin may be reduced in the course of project development depending on possible future extensions and Company Reserves.

5.2.4 Scantling draught

The scantling draught shall not be less than the [ICLL](#) draught.

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5.3 Tank arrangement

IMO MARPOL 73/78 Annex I, Regulation 26 "Limitation of size and arrangement of cargo tanks" shall apply.

On new built unit, the cargo area shall have double sides. Double bottom shall be avoided unless relevant quantitative risks analysis, to be approved by the Company, demonstrates the level of risks is acceptable (ALARP) taking into account inspection, maintenance and repair on a long term basis.

In addition to the requirements of the selected Classification Society, special attention has to be paid to the operational aspects of the F(P)SO.

- Stored crude oil shall always be segregated from seawater.
- The hull subdivision shall be such that the probability of sloshing in tank is remote according to class rules for any level of filling.
- Crude oil pipes shall not cross vertical watertight bulkheads.
- Cargo pump room is not allowed.
- Temporary and permanent sea-chests and internal I-tubes are prohibited. External vertical caissons (fitted with strainer and submerged lift pump for sea water intake), running along the side shell shall be used.
- Design of tanks and related systems shall also account for temporary phases (refer to section 4.2.1).
- Arrangement shall allow for easy inspection, maintenance, repair of critical areas.
- Tank arrangement shall be in line with operation philosophy as defined in PPS, and loading/offloading sequence.

5.4 Tanks and tank capacities

All tank capacities shall be reported in ullage and sounding tables showing the total observed volume of the fluid in the tanks in the following conditions:

- No trim, no heel
- Towing case (1% trim by stern, no heel)
- Operating cases (trim by flare of 0.5%, 1.0%, 1.5%, no heel).

The ullage and sounding tables shall be established at both manual sounding point location and radar gauge location.

The tables shall be generated by the same software used for trim and stability calculations. The permeability shall be updated according to tank surveys.

In any event, the loading computer shall be able to generate ullages and sounding tables for any capacity at any combination of trim and heel.

As a general rule, any fluid that must be permanently available either for life support, for process or for field operation shall be stored in two independent tanks.

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5.4.1 Cargo storage volume definition

Refer to [GS EP STR 651](#).

The net capacity of a tank is defined as the net storable and recoverable volume of fluid in the tank at 98% filling, excluding volume of internal structures and dead stock at bottom.

Thermal expansion of oil between storage temperature and trading reference temperature (15°C) shall be accounted for when defining the net tank capacity.

Following table explains typical corrections to be accounted for in course of the design.

	<i>Pre-project and basic engineering</i>	<i>Detailed design</i>	<i>Final</i>
Maximum filling	98%	98%	98%
Internal structure	1.5% of geometric volume	To be calculated	To be computed from tank survey for cargo / process tanks and to be calculated as per as built drawings for other tanks
Dead stock	3% of overall tank	3% of overall tank	3% of overall tank

PPS may require a tank calibration campaign by Third Party under Flag and Company supervision. The Third Party will be approved by Company. All measurement procedures shall be approved by Flag and Company prior to the measurement campaign.

5.4.2 Cargo area arrangement

For F(P)SO with large storage capacity (typically in excess of 1.4 Mbbbls), tank arrangement shall be in three rows of tanks. In this case, the cargo tank configuration shall fulfil the following requirements:

- The cargo tanks of the same row (central or external) shall be approximately of equal size
- It shall be possible to isolate the tanks containing the volume of the required parcel before and during offloading operation.

When requested by PPS, process tanks such as produced water tank, wash tank or settling tank shall be provided. They shall be considered as part of the cargo area, and designed in such a way that inspection, maintenance and repair are feasible and easy. The impact on production rates shall be quantified. It shall be acceptable for the project.

5.4.3 Ballast tanks

Water ballast tanks will be situated along the sides, in fore and aft peaks and possibly within central cargo area to reduce still water bending moments. The required capacity shall be determined such that the F(P)SO fulfils the hydrostatic and global strength requirements for all F(P)SO loading conditions. The minimum width of the ballast tanks should be three metres.

Permanent ballast shall be avoided as far as possible. If permanent ballast is necessary, corrosion inhibitor shall be defined and qualified appropriate corrosion protection and

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maintenance program shall be submitted to Company. Tanks used for permanent ballast shall be filled at 98% filling capacity.

5.4.4 Slop tanks

Two equally sized slop tanks shall be located at the forward (flare) end of the cargo tank area. The capacity of each slop tank shall be determined according to [GS EP STR 651](#).

5.4.5 Potable water tanks

Two potable water storage tanks shall be located in the vicinity of the Living Quarters each with a capacity specified in PPS.

5.4.6 Fresh water tanks

Two fresh water storage tanks shall be located in the vicinity of the Living Quarters with a capacity specified in PPS.

5.4.7 Diesel Oil tanks

At least two Diesel Oil storage tanks shall be available. The capacity of each diesel oil storage tank shall be specified in PPS. Requirement for extra diesel oil storage capacity during start-up period shall be investigated. PPS shall define DO loading/offloading philosophy including maximum expected flows and standard parcel if relevant. Capacity of the DO tanks has to be checked for the towing phase.

Diesel Oil tanks shall be in compliance with [IMO MARPOL 73/78](#) Annex I, Regulation 12A "Oil fuel tank protection".

5.4.8 Methanol tanks / LDHI storage tank

The methanol tanks and/or LDHI tanks shall be isolated by cofferdam from tanks containing fluids at temperature above 40°C. Each of them shall have a minimum capacity allowing loading the standard delivery parcel (to be defined in PPS).

5.4.9 Hydraulic oil storage tanks

When required, hydraulic oil storage tanks shall be provided each with a capacity at least equal to the capacity of the hydraulic distribution systems.

5.4.10 Chemical tanks in hull

When chemicals are to be stored in bulk inside the hull, the following concerns shall be addressed at basic engineering stage; products identification; segregation requirements; material and corrosion protection; type of tanks (self-supported vs. built in structure); storage tanks redundancy; inerting requirements; layout constraints (inside hull and on hull deck); HSE constraints; tanks loading / manifolds arrangement.