

GENERAL SPECIFICATION

PIPELINES - RISERS

GS EP PLR 152

Hybrid Riser Systems

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1. Scope

This document - which supplements the **GS EP PLR 100** - defines the minimum requirements for the functional, technical and performance requirements and acceptance criteria for the design, construction, delivery, testing, transportation, installation and operation of offshore hybrid riser systems including all associated equipment such as the flexible jumpers, latching system, buoyancy tank, buoyancy module and riser monitoring system.

2. Reference documents

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

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
API RP 2A-WSD	Planning, Designing, and Constructing Fixed Offshore Platforms-Working Stress Design
API RP 2T	Planning, Designing, and Constructing Tension Leg Platforms
API STD 2RD	Dynamic Risers for Floating Production Systems
AWS D1.1/D1.1M	Structural Welding Code - Steel
PD 5500	Specification for unfired, fusion welded pressure vessels
DNVGL-ST-F101	Submarine Pipeline Systems
DNVGL-ST-F201	Dynamic Risers
DNVGL-RP-F118	Pipe girth weld AUT system qualification and project specific procedure validation
DNVGL-RP-F203	Riser Interference
ISO 13628-5	Petroleum and natural gas industries - Design and operation of subsea production systems - Part 5: Subsea umbilicals
ISO 19902	Petroleum and natural gas industries - Fixed Steel Offshore Structures
SLARP JIP	Slug Loading and Response - Design Guidelines

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Reference	Title
GS EP COR 100	Cathodic protection of offshore structures according to DNV-RP-B401
GS EP COR 220	Three layer polyethylene external coating for pipelines
GS EP COR 221	Three layer polypropylene external coating for pipelines
GS EP COR 222	Fusion Bonded Epoxy (FBE) external coating for pipelines
GS EP COR 232	Composite/Syntactic foam used for buoyancy modules for permanent subsea applications
GS EP EXP 311	Plant integrity - Minimum inspection requirements
GS EP GEO 702	Requirements for design and installation of skirted foundations and suction anchors
GS EP ICS 004	3D CAD Models
GS EP PLR 100	Submarine pipeline systems
GS EP PLR 109	Design, fabrication and testing of submarine unbonded flexible pipes and risers
GS EP PLR 151	Design of steel catenary riser systems
GS EP PLR 205	Carbon steel, pipe manufacturing for pipeline applications according to API SPEC 5L and DNVGL-ST-F101
GS EP PLR 430	Automated Ultrasonic Testing of pipeline girth welds according to DNVGL standards
GS EP PVV 141	Piping Material Data Sheets
GS EP PVV 154	Ball valves according to API SPEC 6D or API SPEC 6A
GS EP PVV 155	Gate, Globe and Check Valves
GS EP PVV 610	Welding of piping and pressure containing equipment

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Reference	Title
GS EP SPS 002	Design of Subsea Stations
GS EP SPS 004	Subsea Valves
GS EP SPS 006	Service valves in subsea stations
GS EP SPS 007	Subsea Connection Systems
GS EP SPS 009	Corrosion protection of subsea stations
GS EP STR 001	Weight monitoring and weighing offshore and onshore units
GS EP STR 100	Offshore steel structures - General
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

3. General

3.1 Definitions

For the purpose of this specification, the following definitions are interpretations irrespective of any other meanings the words may have in other connections:

Work Means the design, construction, delivery, testing, transportation, installation and operation of hybrid riser systems.

Project Specification Project specific document defining the functional requirements for equipment and systems required for a field development project.

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3.2 Nomenclature and abbreviations

AUT	Automatic Ultrasonic Testing
BHR	Bundle Hybrid Riser
BT	Buoyancy Tank
Ca	Added mass coefficient
Cd	Drag coefficient
Cf	Design case factor (reference API STD 2RD)
Cm	Inertia coefficient
CP	Cathodic Protection
CRA	Corrosion Resistant Alloy
CT	Coil Tubing
D	External Diameter, dimensional tolerance in DNVGL-ST-F101 , section 7
ECA	Engineering Critical Assessment
EOL	End Of Life (density of foam including seawater absorption)
F	Fracture arrest requirement in DNVGL-ST-F101 , section 7
FAT	Factory Acceptance Test
FMD	Flood Member Detection
FMECA	Failure Modes Engineering Critical Assessment
FPS	Floating Production Support
FPSO	Floating Production Storage Offloading Unit
GL	Gas Lift
HAZID	Hazard Identification Study
HAZOP	Hazard and Operability Study
HIRA	Hazard Identification and Risk Assessment
HRS	Hybrid Riser System
IMMR	Inspection Maintenance Monitoring and Repair
L	Length
LAT	Lowest Astronomical Tide
LRA	Lower Riser Assembly
MPI	Magnetic Particle Inspection
MUT	Manual Ultrasonic Testing
NDT	Non Destructive Testing
PIP	Pipe-in-Pipe
PPS	Project Particular Specification

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P-M	Pierson-Moskowitz
QA/QC	Quality Assurance / Quality Control
RAO	Response Amplitude Operator
RBGL	Riser Base Gas Lift
RBS	Riser Base Spool
Re	Reynolds number
RMS	Root Mean Square
ROV	Remotely Operated Vehicle
SLHR	Single Leg Hybrid Riser
PPS	Project Particular Specification
SN	Stress vs. Number of Cycle
SMYS	Specified Minimum Yield Strength
TOFD	Time of Flight Diffraction
U	Supplementary requirement for pipe material in DNVGL-ST-F101 , section 7
URA	Upper Riser Assembly
UTS	Ultimate Yield Strength
VIV	Vortex Induced Vibration
VIM	Vortex Induced Motion
WSD	Working Stress Design
WT	Wall Thickness

4. System description

4.1 General

Hybrid Riser System (HRS) uses vertical riser pipe(s) coming up from the riser base foundation.

The system is tensioned at the top through a buoyancy tank via an articulated connection, and is anchored at the riser base with a foundation.

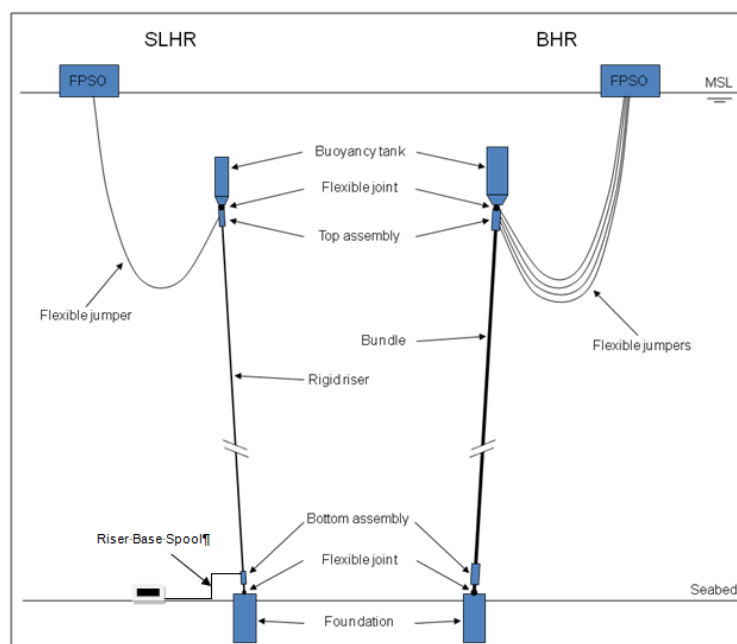
The buoyancy tank ensures positive tension in the riser pipe at all times.

A flexible jumper is connected to the tensioned vertical riser via a gooseneck connection or similar. The jumper hangs in a catenary shape and proceeds from the riser top to hang-off at the FPS via an I-tube. The flexible jumper performs an important dynamic function, decoupling the dynamic FPS motions from the rigid riser pipe(s).

Two concepts of HRS are covered by this specification:

- Bundle Hybrid Riser (BHR)
- Single Leg Hybrid Riser (SLHR).

Figure 1 - HRS



4.2 Bundle Hybrid Riser, BHR

4.2.1 BHR description

A BHR is made with a single structural pipe in the centre of the riser bundle: the core pipe; this core pipe provides the system structural support from the buoyancy tank down to the riser base foundation.

Gathered around this pipe are the other lines which transport the fluids.

All the lines are structurally separated from each other, and collectively form a bundle system. Any necessary insulation is provided by insulation material inserted between/around risers in the bundle. Extra buoyancy (in addition to the large buoyancy tank at top of riser bundle) is provided by discrete/continuous syntactic foam buoyancy modules along the vertical bundle length. The BHR system is illustrated in Figure 2.

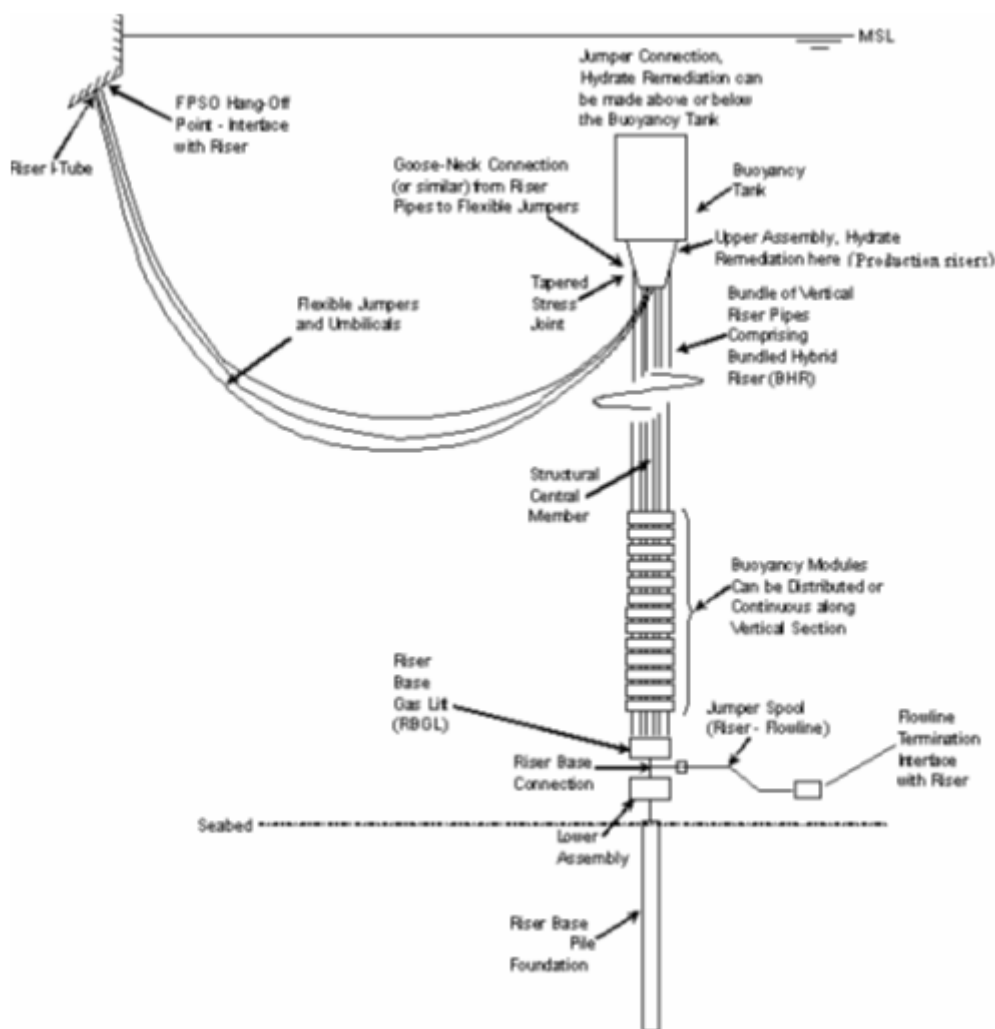
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Figure 2 - BHR



4.2.2 BHR architecture selection

The BHR architecture can be sorted in two main categories:

- BHR with the buoyancy foam up thrust distributed along the core pipe
- BHR with the buoyancy foam up thrust acting on the top of the tower.

The following options can be considered in the BHR architecture:

- Flexible jumpers connected on top of the buoyancy tank with the tank integrated to the top of the bundle, or flexible jumpers connected to a top assembly located below the buoyancy tank with the buoyancy tank connected to the top assembly via a flexible joint.
- Rigid risers enclosed within the buoyancy foam or distributed at the periphery of the buoyancy foam. Note that the buoyancy foam may not be uniformly distributed along the bundle.

4.3 Single Leg Hybrid Riser, SLHR

4.3.1 SLHR description

A SLHR is made of one individual riser tensioned with a buoyancy tank connected at the top. The concept of the riser is similar to the BHR concept.

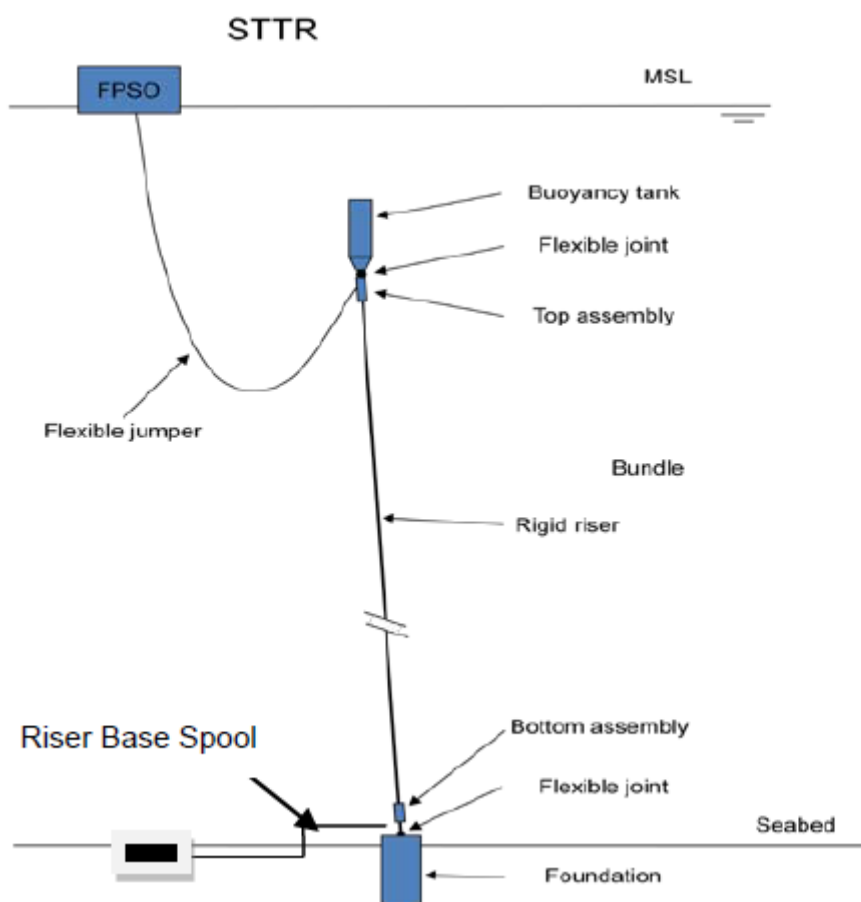
The SLHR conveys water, production or gas.

For flow assurance requirement the production riser can be gas lifted.

One flexible, or two in case of gas lift, links the top of the SLHR to the FPS.

The SLHR system is illustrated in Figure 3.

Figure 3 - SLHR



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4.3.2 SLHR architecture selection

The SLHR architecture consists of:

- Either a single riser e.g. gas export, service, gas or water injection riser, or for Production Riser, a single PIP or PIP COR to accommodate thermal or/and flow requirement
- Seabed foundation
- Bottom assembly structure for connecting the bottom of the riser to the riser base spools
- Top assembly structure for connecting the top of the riser to the flexible jumpers
- Buoyancy tank.

The buoyancy tank up-thrust acts on the top of the rigid riser.

The flexible jumpers are connected to a top assembly with the buoyancy tank connected to the top assembly via a flexible joint in case of non-integrated buoyancy tank.

5. Functional and Design Requirements

5.1 Introduction

This section highlights the functional and design requirements that shall be addressed for Top Tensioned Risers.

HRS design shall fully comply with the requirements and recommendations of the General Specifications listed in Section 2 and with additional requirements specified herein.

5.2 Overall Requirements

The overall functional design requirement of HRS shall provide a safe, practical and cost effective solution to transport the process products to and from the seabed flowlines from and to the FPS.

The design of HRS shall allow inspection and monitoring after installation and during the whole field life.

The top flexible jumpers and the riser base spools shall be replaceable without removal of the riser section.

The HRS system shall meet the following functional requirements:

- Convey and retain fluids at the required pressure, temperature, density and flowrate between the flowline and the FPS for hydrotest, leak test, pre-commissioning, commissioning, normal operation, abnormal and shutdown conditions.
- Provide adequate thermal insulation performance and process remediation systems for the flow assurance performance requirements of the production and gas lift systems.
- Allow for through riser operations for hydrate and integrity management as per PPS.

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- Provide means to monitor performance and allow required inspection, maintenance and repairs to be performed in place.

5.2.1 Design Requirements

The HRS components shall be designed taking into account the following core design requirements:

- Field proven equipment and techniques is preferred. New technology which provides improved performance is to be submitted to Company approval.
- The design phase to include procedures with the objective of achieving safe handling and operation through all stages of assembly and testing, transportation, installation, monitoring / maintenance, commissioning / decommissioning, operation and retrieval / abandonment.
- The design of the risers and auxiliary equipment is to be performed in every respect on the basis of a design service life specified in the PPS, with no plans for maintenance, repair or requirement for replacement.
- Design accounts for the requirements associated to future development phase, if requested by the project.
- The design takes into account all loads and constraints resulting from construction, installation, inspection, repair, monitoring, maintenance, functional and operation loads, loads due to environmental conditions, FPS motions and loading conditions, accidental conditions, and if relevant, retrieval and abandonment of the riser and flowline systems. All components are to be designed with the objective of minimising stress concentration (overall cyclical stress range) and providing the most direct load path possible; Stress concentrations that are unavoidable are to be proven to be of no adverse impact to the performance of the riser.
- All Structural Finite Elements Analysis (FEA) is to be performed according to **GS EP STR 108**.
- Materials selected meets the performance requirements of the components, considering strength, fatigue, ductility, fracture toughness, sour service, corrosion resistance (including any mitigating methods such as use of corrosion inhibition, coatings etc.) and compatibility with the CP system.
- Components are to be designed for all accidental scenarios. The accidental scenarios to be considered need to investigate at least the following conditions: extreme environment, partial loss of riser tension due to either buoyancy tank compartment flooding or buoyancy module degradation, 2 off mooring line failure and associated offset, extreme vessel position and pressure communication between any two compartments. These scenarios are not to lead to any progressive damage or failure of the HRS.
- Manufacturing tolerances are carefully controlled and taken into account during the design phase.
- The HRS is designed for normal pigging inspection as well as intelligent pigging activities defined by the IMMR strategy.

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- Riser design includes full detailed design and analysis of all associated components and ancillaries (e.g. anti-VIV devices, riser monitoring devices and supports, CP anodes design with attachment and means of protection, anti-fouling coating, anti-abrasion coating or protections).
- Hydrodynamic behaviour of the riser is carefully detailed. Shielding effect and potential risk of galloping is to be analysed. For non-circular geometries, hydrodynamic behaviour of the riser bundle is to be validated with basin tests unless agreed otherwise with Company.
- All relevant assumptions, applicable data, load conditions and acceptance criteria are to be documented in Contractor's Design Basis.

5.2.2 Performance Requirements

The design, configuration and construction of each of the various HRS elements shall utilize appropriate field proven solutions and installation practices. For new concepts or new materials/components, qualification testing or experimental verification are to be identified at an early stage to minimise possible impacts on both the design and procurement of the system.

The design, configuration and construction shall provide:

- Compliance to accommodate the environmental and operating conditions, hydrodynamic loadings, FPS motions and excursions that the HRS will be subjected to throughout field life.
- Containment of hydrocarbons, injection and control fluids throughout the design life under defined normal, upset or shutdown operations and accidental or damaged vessel conditions.
- Strength, fatigue life, corrosion and erosion resistance for the intended service to satisfy the required margins against failure due to cracking, leakage, rupture, collapse or buckling under the design conditions; with collapse resistance of pipe calculated for straight and bend configurations. Calculation methodology for pipe bends is to be documented.
- Protection from external corrosion effects (without introducing detrimental conditions; such as hydrogen embrittlement), that could affect HRS materials.
- Reliability and redundancy of buoyancy system for the field life under defined normal or upset operations and accidental or damaged conditions.
- Adequate long-term polymer material 'ageing' and resistance to degradation due to hydrostatic pressure, temperature and mechanical loading exposure during the defined life of the field.
- Specific IMMR strategy and associated repair procedure.
- Clearance from other structures, risers, umbilical, components in the hang off area and mooring lines as per requirement of [DNV-RP-F203](#).
- Hang-off loads within the identified capacity values under all operating and upset conditions identified through HAZID and HAZOP processes (e.g. loss of buoyancy tank compartment).

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- Sufficient horizontal distance between the base of the riser and the vessel is such as to ensure:
 - Prevent clashing with the vessel, mooring system and other risers
 - Avoid Interference between adjacent HRS / BT.

5.3 Installation requirement

At all stages of installation phase, the sequence of operations shall be reversible.

In case of installation by towing, Contractor shall:

- Develop a specific weight control procedure/tool for the bundle.
- Ensure integrity of the riser in case of any towing line rupture during the tow.

The HRS shall be able to be installed prior or after to arrival of the FPS.

Field proven equipment and techniques shall be used unless newly developed techniques have been subject to Company approved qualification process.

All steps of installation need to be detailed with special attention to the critical steps, as ballasting operation, weight transfer (e.g. transition from negatively to positively buoyant) and upending.

HRS Docking and Buoyancy tank ballasting procedure shall be subject to dedicated HIRA review, considering as a minimum the following risks:

- Accidental flooding of a buoyancy tank compartment
- Accidental flooding of riser.

All equipment shall be designed with the objective of achieving safe handling and operation through all stages of assembly and testing, transportation, installation, commissioning, operation and removal.

5.4 Precommissioning

Precommissioning activities program shall be developed in order to accommodate requirement for all components of the riser system.

- After hook-up operation, leak test of the HRS system (from Flexible jumper to RBS FLET).
- Pressure test to fulfill the requirements of the applicable flexible design code and applicable rigid pipeline design code.
- Acceptance criteria is to be defined by the most stringent design code selected for the design.
- In case of flexible damage during installation, the integrity pressure test of the flexible jumper is required. This test can be performed with the flexible jumper connected to the HRS, but not at the design condition of a component in the system. If the integrity

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pressure test is not possible with the flexible jumper connected; an alternative test procedure will be considered.

5.5 Material Selection

Contractor shall ensure that all structural components and risers are fully compliant with the intended service duty, pressure, temperature, fluids, for the entire design lifetime and in accordance with relevant Company general specifications.

Contractor shall be responsible for selecting the materials and coatings for all elements constituting the hybrid riser, in accordance with this specification and relevant Company general specifications.

Materials for the riser and associate components shall be selected to meet the performance requirements in terms of strength, ductility, weldability, resistance to corrosion, erosion and wear.

Contractor shall develop a materials selection philosophy based on the project life cycle covering all design, operational and interface aspects.

The following factors shall be highlighted during the material selection process.

- CP and acceptable stress levels are to be detailed in the selection of material subjected to fatigue or sustained high loading.
- Electrical potential induced by CP, is to be made acceptable with steel material performance.
- Special material handling or other relevant control requirements during each stage of the HRS life cycle is fully addressed and implemented for carbon and non carbon steel materials.
- Effects of material corrosion is fully considered during each stage of the HRS fabrication, transportation, testing, installation and operating life.
- Facilities to allow a CP survey in-situ are identified. As a minimum, CP survey plates are to be implemented:
 - On top and bottom assemblies
 - On buoyancy tank
 - At each mid riser length
 - On mid water arch (if any)
 - Any specific bolting assembly.
- Consideration of polymer compatibility and field life degradation.
- Castings are not acceptable in dynamic riser applications.

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Where H₂S is present in the conveyed fluid, the following shall apply:

- A detailed material evaluation carried out for the riser.
- No plastic strain is allowed during operations for carbon steel pipes designed for sour service.
- For all parts subject to fatigue loading, impact of H₂S on fatigue performance of the system is to be evaluated.

Specific issues associated with CRA-clad or CRA-lined carbon steel such as mechanical resistance, fatigue (including corrosion-fatigue if relevant), and manufacturing tolerances shall be addressed during the design.

Use of CRA-clad shall be agreed with Company and as a minimum includes:

- Visual verification of the cladding integrity
- Electronic inspection techniques that have been bench marked
- Increase frequency of pipe cross section inspection.

Weld overlay, cladding performed using weld overlay methodology, and lined pipe are not allowed for the rigid riser pipe section.

Cladding shall be in accordance with **GS EP PLR 205**. Company should be consulted for further guidance on use of CRA-clad.

5.6 Electrical Continuity in System

HRS system components shall be designed to be in direct electrical contact with each other.

Where coatings or elastomers are present that will prevent direct electrical contact, appropriate electrical straps shall be provided to ensure continuity.

Electrical continuity between the buoyancy tank and the URA and the foundations and LRA, shall be provided using specific low resistance continuity bonding where other metal-metal electrical paths cannot be assured.

5.7 Gas Lift Injection Systems

To overcome the effects of the hydrostatic head and enable the produced fluids to flow to the FPS, gas lift may be required at the base of each production riser depending of the PPS requirement.

Gas lift injection point shall take place as close as possible to the mud line and should not have any low point to avoid liquid retention.

Gas Lift connection shall be designed to reduce as much as possible mechanical weak points in the system.

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Contractor shall consider the possibility of production fluids entering the gas lift system and account for this in the material selection and gas lift system design.

The pipe work of the gas lift system at the lower riser assembly structure shall be designed to account for the differential thermal expansion and contraction between the production line and the gas lift lines.

The pipe work of the gas lift system shall be insulated to meet the thermal requirements defined in the PPS.

Selection of gas lift configuration shall be studied considering operational scenario, thermal requirement and any parameters, as material selection that may impact the design of the system.

The riser base gas lift system shall be designed as a minimum in accordance with the relevant codes and standards listed in Section 2.

5.8 Corrosion and Cathodic Protection Design

The risers shall be protected against internal and external corrosion.

Internal corrosion shall be controlled by chemical injection and selection of a wall thickness corrosion allowance defined in the PPS.

External corrosion shall be controlled by a suitable combination of anti-corrosion coating and cathodic protection.

The design and selection of the riser CP system shall be compatible with CP system of the FPS, buoyancy tank, flowline and adjacent subsea systems.

Sacrificial anodes shall be mounted on the HRS structure.

Reliance on the influence of CP of any adjacent structures shall not be permitted.

Sacrificial anodes for the cathodic protection shall meet the requirements of **GS EP COR 100**.

Erosion analysis for the production risers shall be performed by Contractor.

5.9 Inspection, Monitoring, Maintenance and Repair (IMMR)

The design of HRS shall allow Inspection, Monitoring, Maintenance and Repair after installation and during the whole field life as per requirement of **GS EP EXP 311**.

Contractor shall take into account in the riser design the requirements for accessibility and for potential needs for repair of any component that may be subject to normal or abnormal wear.