

DEP SPECIFICATION

**GENERIC DESIGN AND ANALYSIS FOR STEEL
CATENARY RISERS AND CATENARY UMBILICAL
SYSTEMS FOR OFFSHORE STRUCTURES**

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DESIGN AND ENGINEERING PRACTICE

DEM1



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for generic design and analysis specifications for steel catenary risers (SCR) and catenary umbilical systems for offshore floating structures. It is applicable to:

- steel catenary risers of various configurations (e.g., import/export pipelines, flowlines, water injection lines);
- steel jumpers (elastic spans) between fixed and/or floating facilities (e.g., offloading risers, production jumpers between a wellhead facility and a storage facility);
- steel tube umbilical risers;
- steel tube umbilical jumpers suspended between fixed and/or floating facilities;
- steel lazy wave risers (SLWRs).

This DEP applies to all SCR systems and is intended to satisfy the need for a design basis document for all future SCR projects. It covers the structural and mechanical aspects of the design of the riser section of a flowline or a pipeline. It also covers analysis aspects of catenary umbilical riser tube bundles for the purposes of determining global motions/loads and fatigue life.

This DEP has been written based primarily on the API RP 2RD (First Edition, June 1998, Reaffirmed, May 2006, Errata, June 2009) and API RP 1111 (Fourth Edition, December 2009, Errata, May 2011). Other standards and specifications also referenced to prepare this DEP are listed in (7).

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual (DEM) 1 – Application of Technical Standards.

This is a revision of the DEP of the same number dated February 2015; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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This DEP is intended for use in facilities related to offshore oil and gas production. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

The word **may** indicates a permitted option.



1.3.2 Abbreviations

Term	Definition
AUT	Automated Ultrasonic Testing
BSEE	Bureau of Safety and Environmental Enforcement
DBD	Design Basis Document
DEM	Design Engineering Manual
DEP	Design and Engineering Practice
DSAW	Double Submerged Arc Welded
ECA	Engineering Critical Assessment
FEA	Finite Element Analysis
FPSO	Floating Process Storage Offloading
ID	Inside diameter
MAOP	Maximum Allowable Operating Pressure
MOC	Management of Change
MTM	Mill Tolerance Multiplier
OD	Outside Diameter
PIP	Pipe-In-Pipe
SCR	Steel Catenary Riser
SLWR	Steel Lazy Wave Riser
SMLS	seamless steel line pipe
TLP	Tension Leg Platform
TSA	Thermally Sprayed Aluminium
VIM	Vortex Induced Motion
VIV	Vortex Induced Vibration

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets (). Other documents referenced by this DEP are listed in (7).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a full revision of the DEP of the same number dated February 2015. The changes followed a requirements quality review and were not a technical update. The following are the main, non-editorial changes.

Section/Clause	Change
All	Restructured and clarified requirements, enforced use of shall/should/may for normative statements and separation of requirements.
Scope, Appendix F	Relocated Scope text around API 2RD second edition and associated Appendix F describing the changes to the Informative.
2. General	Removed redundant text already stated in Scope.
5.3.1, 5.4.3	Removed outdated text around ASME B31.8 and B31.4.
Appendix B, B.2	Relocated “shall” requirements from table notes to the body of the DEP

1.6 COMMENTS ON THIS DEP

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DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://swwww.shell.com/standards . Select “Submit DEP Feedback”, fill in the online form and submit.
DEP Standard Form (other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

2. GENERAL

This DEP contains generic design and analysis specifications for steel catenary risers and catenary umbilical systems for deepwater offshore floating structures.

1. This DEP shall be applied to:
 - a. SCRs of various configurations (e.g., import/export pipelines, flowlines, water injection lines);
 - b. steel jumpers (elastic spans) between fixed and/or floating facilities (e.g., offloading risers, production jumpers between a wellhead facility and a storage facility);
 - c. steel tube umbilical risers;
 - d. steel tube umbilical jumpers suspended between fixed and/or floating facilities;
 - e. steel lazy wave risers (SLWRs).
2. Throughout this document the terms “SCR” and “riser” shall be understood to refer to the applicable structures in (1, a through e).
3. The term “riser section” shall be understood to mean the entire suspended span, including the riser/host interface; it also includes the portion of the line, if applicable, that never leaves the seafloor but is still subjected to the axial dynamic loading from the response of the suspended portion.

The importance of the distinction between the riser section and the remainder of the line is that the riser section is designed to withstand dynamic loads.

The term catenary refers to the approximate catenary shape in which the riser hangs and is used to differentiate this type of riser from vertical, or top-tensioned, risers. Due to the finite bending stiffness of the riser, the static shape assumed by the riser will always have somewhat less curvature than a true catenary.

4. The riser design summary report shall contain at least the information listed in default table of contents in (Appendix E).
5. For each project utilizing this DEP, a project-specific SCR Design Basis Document (DBD) (referred to herein as the project-specific DBD) shall be created as an addendum to this DEP.
6. The DBD shall be subject to approval by the Principal.

The project-specific DBD will supplement this generic document by providing all project specific design criteria and procedures and will refer to the generic design basis, so that, taken together, the two will serve as the full design basis for the project. Component fabrication, installation, and operation issues are outside the scope of this design basis.

7. Project specific DBD shall include:
 - a. project overview from riser point of view;
 - b. design requirements and assumptions;
 - c. relevant geotechnical data and metocean data;
 - d. input parameter details used for riser design;
 - e. summary of the load cases and the associated host motions;
 - f. list of analysis performed for riser design;
 - g. list of deviations from this document.

3. SYSTEM OVERVIEW

3.1 SYSTEM DESCRIPTION

3.1.1 General

For the purpose of this document, a typical flowline, pipeline, or umbilical system can be considered as consisting of two parts: (1) the subsea section, which is that part of the system that lies on the seafloor and is sufficiently remote from the host to be free of dynamic loading, and (2) the riser section designed for dynamic service. The riser section contains the entire suspended span from the host to the seafloor, including the riser/host interface. It also includes the portion of the line that never leaves the seafloor but is subjected to dynamic loading from the response of the suspended portion.

3.1.2 SCR and SLWR

An SCR or an SLWR departs the host on a prescribed heading (the riser heading) and at a prescribed angle with respect to vertical (the departure angle). (Figure 3.1.1.1) and (Figure 3.1.1.2) define common terms used to describe the SCR and SLWR riser geometries, respectively. These terms refer to the nominal geometry of the riser under calm, static conditions with no vessel offset. An SCR consists of a suspended section and a bottom section (bottom section remains on the sea floor extending to the transition point to the flowline).

1. Although it remains on the seafloor, the bottom section shall be treated as part of the dynamic riser, as it experiences the dynamic loads of the riser.

Note also that the point of first contact between the riser and the seafloor (touchdown point) will move as the host moves.

3.1.3 Interface between riser and host

Proposed designs for the interface between the riser and the host vessel have included tapered-wall stress joints, rotationally flexible elastomeric elements (flexible joints), and flex-element used with flexible piping.

1. The interface between the riser and the host vessel shall accommodate relative rotation between the top of the riser and the host.

The stress joints and the flexible joint-flexible joint are the most common top terminations used with Shell SCRs to date. Figures 3.1.2.1 and Figure 3.1.2.2 show typical designs for the stress joints and the flexible joints, respectively.

3.1.4 Riser installation

Pipe sections are welded together on the lay vessel as the system is installed. For J-lay installation, the suspended portion of the line is typically supported on a pedestal by J-lay collars, which are welded between pipe sections during installation. For S-lay installation, the suspended span is maintained in tension by track type tensioners on the lay vessel.

3.1.5 Production risers and gas-lift risers

In subsea developments, produced fluids exit the wells into a subsea flowline system, which brings the production to a host facility for processing. Many flowline systems employ some combination of pipe-in-pipe (PIP) construction, insulation jacketing, or burial in the seafloor in order to keep produced fluid temperature sufficiently high to maintain system operability. Since flowlines are usually directly exposed to the wellbore, the internal pressures tend to be high, resulting in thick-walled designs

($D/t \sim 10$) driven by burst considerations.

To facilitate transport of produced fluids up the riser from seafloor to host, a gas-lift mechanism is sometimes employed. This typically involves the use of an additional gas-lift riser that carries gas from the host down to a tie-in point on the flowline just far enough upstream from its touchdown point to be free of loading due to riser dynamics. Gas-lift risers are typically exposed to the same pressure environment as the flowlines they serve, so their designs also tend to be thick-walled ($D/t \sim 10$) and driven by burst considerations.

3.1.6 Pipe-in-Pipe production risers

Pipe-in-pipe flowline designs present the additional design considerations of thermal loading, residual loading due to the installation process, and load sharing between inner (carrier) and outer (casing) pipes. Carrier pipe designs tend to be burst-driven and thick-walled ($D/t \sim 10$), and casing pipe tends to be less thick ($D/t \sim 20$) due to the absence of internal pressure, with design typically driven by collapse.

1. The annulus between the pipes is typically assumed to be at atmospheric pressure, but the appropriateness of this assumption should be checked for each project.

When using a flexible joint or stress joint, the pipe geometry at the top of a PIP SCR typically transitions between pipe-in-pipe and single-pipe construction somewhere below the top termination. A forged and machined SCR transition bulkhead is used to provide this transition, as shown in Figure 3.1.5.1.

2. Because of the relatively large dynamic bending moments experienced near the top termination, the SCR transition bulkhead shall be located far enough away from the top of the riser that the bulkhead and associated welds have sufficient fatigue life.

A spacer pup joint provides the necessary spacing, as shown in Figure 3.1.5.2. Note that the dimensions of the spacer pup are typically not going to be the same as either the inner or the outer pipe of the PIP SCR.

3.1.7 Export risers

After undergoing separation and processing on the host, oil and/or gas may be introduced into a pipeline system for transmission to shore. These pipelines connect to the host via export risers, which tend to be larger and thinner-walled ($D/t \sim 20$) than flowline risers or gas-lift risers, due to lower operating pressures. The wall thickness of these risers is typically determined by collapse considerations.

3.1.8 Umbilicals

Umbilicals are generally utilized to control subsea equipment and to transport chemicals either to protect the flowlines or avoid hydrates. Over the years umbilicals have become larger and more demanding with respect to weight, size, length and carry more power and fluids. In most projects, umbilicals are designed by vendors, and the Principal design team will review the design documents.

1. Refer to ISO 13628-5 for the design criteria of the dynamic umbilicals that are not covered in this document.

Critical areas that are relevant to umbilicals are the top connection between I-tube and umbilical bend stiffener; bend stiffener design verification; umbilical pull-in mechanism; interference (clashing) issues; installation issues, such as tension loads and selection of the installation vessel; changes in diameter and associated problems with respect to fairings or strakes; I-tube design vs. required loads from umbilical (tension, bending, and fatigue); for turret based floating process storage offloading (FPSO) vessel concept the swivels, power limitations, installation and possible replacement.

3.2 SYSTEM FUNCTIONAL REQUIREMENTS

1. An SCR or umbilical system shall:
 - a. enable safe and effective transport of product to or from the host;
 - b. allow internal pigging for removal of flow obstructions if project requires;
 - c. withstand environmental, operational and accidental loads;
 - d. be installable from a pipe-laying vessel.
2. Quantitative functional requirements and project parameters such as service life, operating pressures, water depth, etc., shall be defined in the Project-Specific DBD.

Figure 3.1.1.1 Typical SCR configuration and terminology

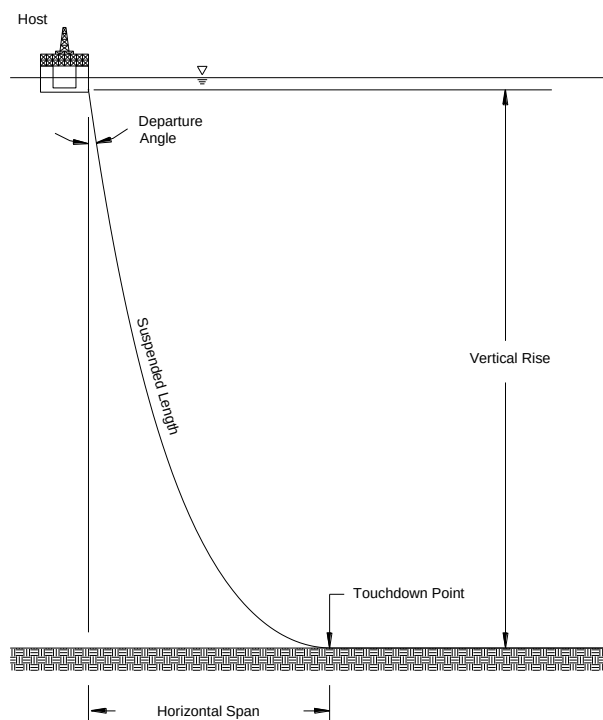
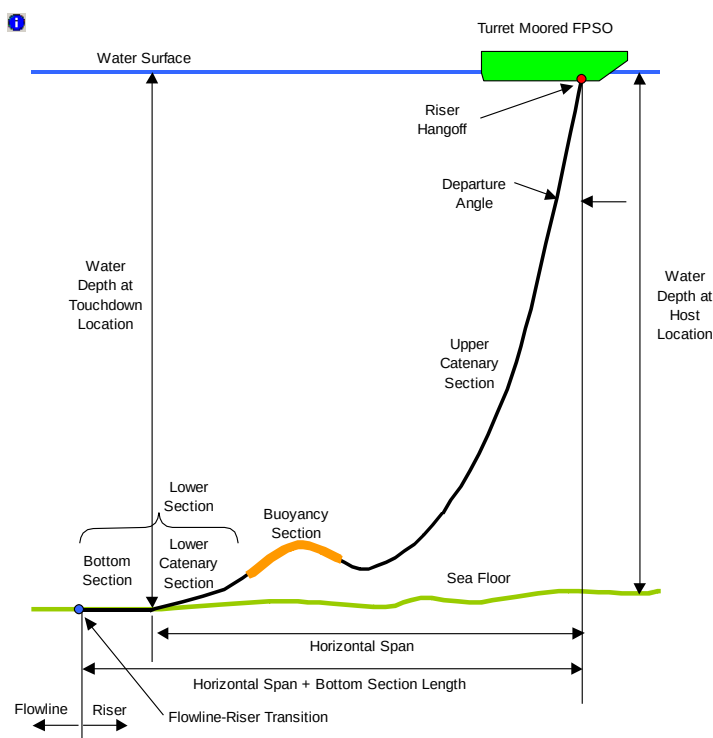
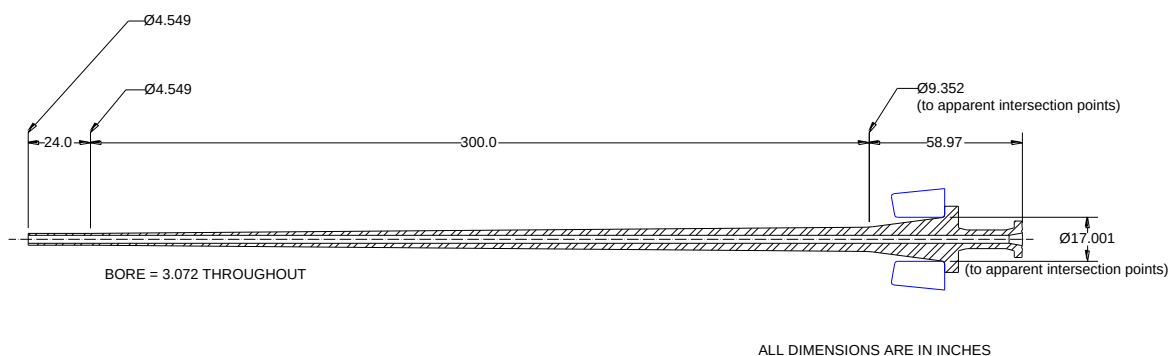
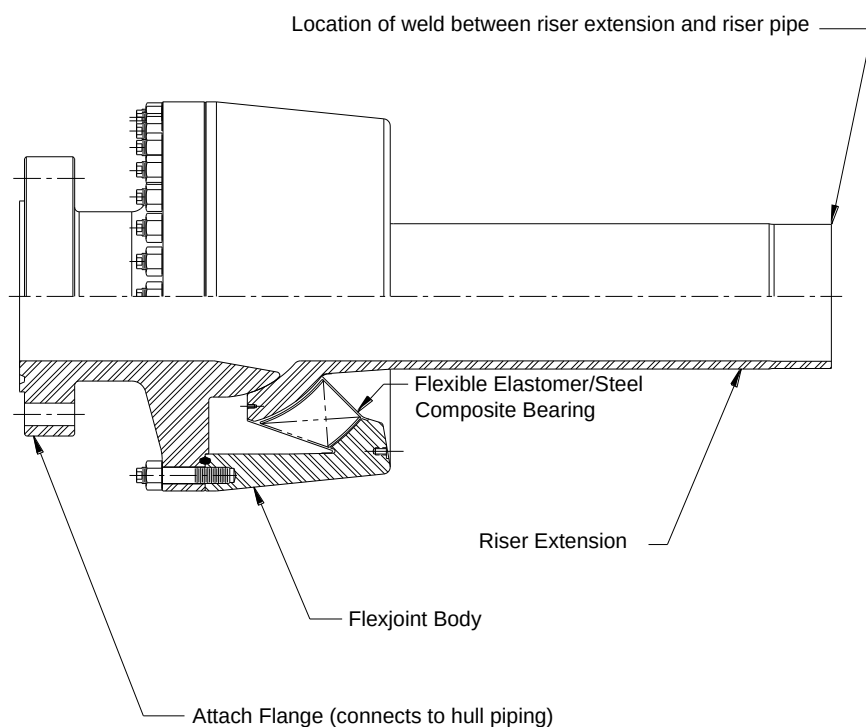
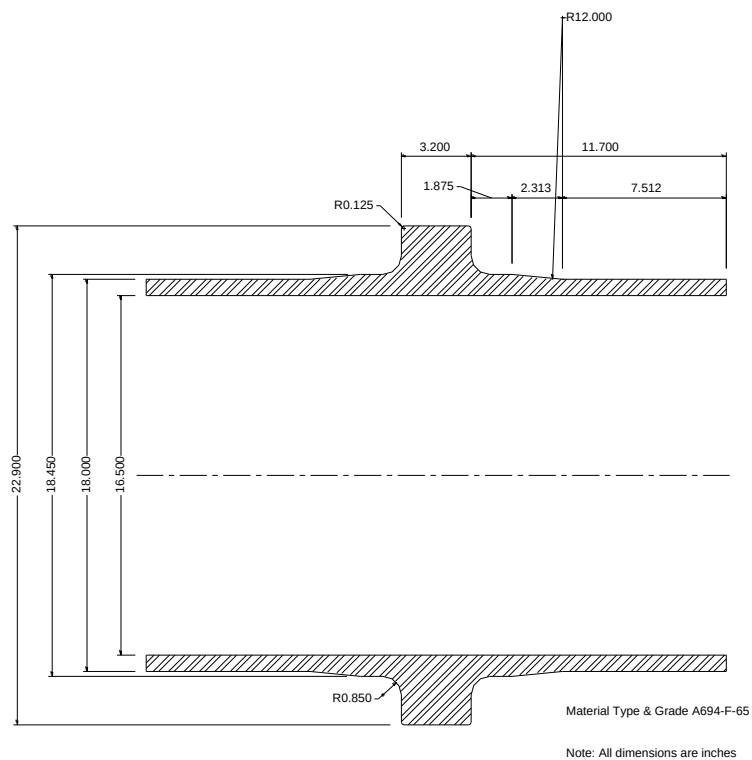
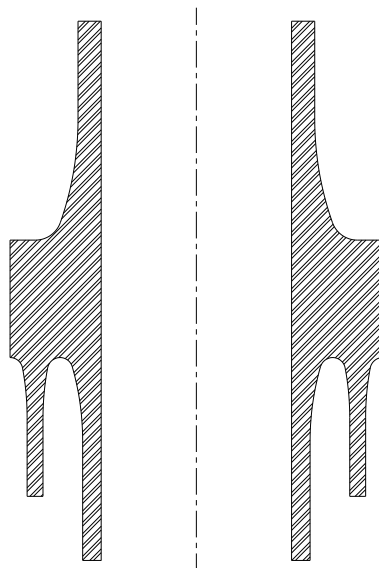
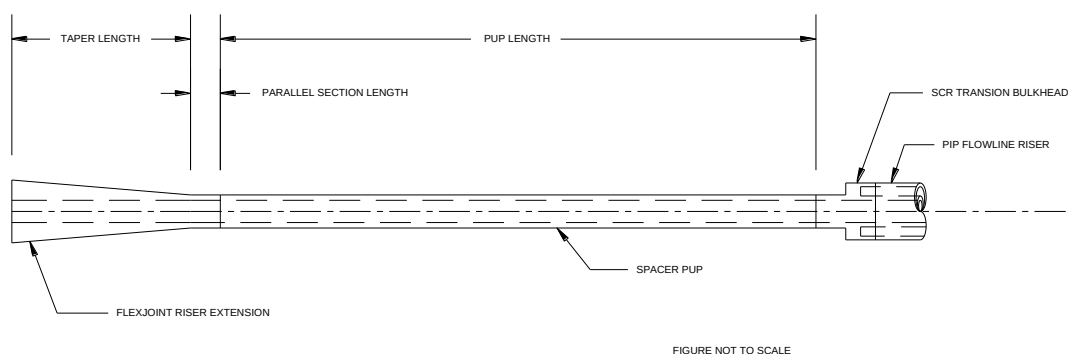


Figure 3.1.1.2 Typical SLWR configuration and terminology**Figure 3.1.2.1 Typical stress joint**

3. Dimensions for the typical stress joint are illustrative only; component shall be sized for each project.

Figure 3.1.2 Typical flexible joint**Figure 3.1.3.1 Typical SCR J-lay collar**

4. Dimensions for the SCR J-lay collar are illustrative only; component shall be sized for each project.

Figure 3.1.5.1 Typical pipe-in-pipe SCR transition bulkhead**Figure 3.1.5.2 Pipe-in-pipe SCR typical arrangement at top of riser**

4. GEOTECHNICAL DATA, METOCEAN DATA, AND HOST CONFIGURATION

4.1 GEOTECHNICAL DATA

Global dynamic analysis of marine riser systems requires a thorough description of the soil conditions that the riser is likely to experience during its service life. This data is region-specific, and very often site-specific within a region. General guidelines, definitions, and some regional descriptions on soil conditions can be found in ISO 19901-4 as background information.

4.2 METOCEAN DATA

Global dynamic analysis of marine riser systems requires a thorough description of the environmental conditions that the host platform and riser are likely to experience during their service lives. This data is region-specific, and very often can be site-specific within a region. General guidelines, definitions, and some regional descriptions on metocean design conditions can be found in ISO 19901-1 as background information.

1. For proper VIV damage assessment and riser interference checks, extreme current descriptions should reflect both the magnitude of the currents at various depths and the directionality of the current.
2. Should it be necessary to augment the extreme current criteria in the project-specific Metocean Design Basis with criteria developed solely for riser analysis, the additional criteria shall appear in the Project-Specific DBD.

4.3 HOST CONFIGURATION

Dynamic analysis of risers attached to a floating host is typically a two-step process.

First, the response of the host itself is determined using a detailed model of the host and a simplified model of any risers that may be present. This is done for each set of environmental conditions of interest, and the data are saved in host motion database files.

The detailed analysis of any given riser system can then be performed separately by imposing this host displacement response at the riser/host attachment point(s) as displacement boundary conditions on the interface elements (i.e., springs, rollers, flexible joints, etc.) that connect the riser to the host.

Several platform configurations are likely to occur during the service life of a given riser system. Variance in the number and size of installed risers, the presence or absence of a drilling rig, and tendon/mooring line adjustments in response to environmental influences all affect the motions of the host platform.

1. In analysing global riser response, a subset of platform configurations shall be selected which covers all possible configurations in a demonstrably conservative fashion for the type of analysis being performed.
2. The spectral description of the host motions for wave-frequency and low-frequency shall be proven to be satisfactory for both extreme event analysis and fatigue analysis.
 - a. Evidence that the host motions are adequate to provide quality results for riser analysis shall be subject to approval by the Principal and be documented in the riser design summary report.

5. DESIGN CRITERIA

5.1 GENERAL

In developing design criteria for any system, it is important to account for all failure modes (limit states) and system configurations.

1. The relevant limit states for SCRs SHALL [PS] include:
 - a. burst (excessive net internal pressure);
 - b. tension (excessive tension);
 - c. collapse (excessive net external pressure);
 - d. buckling (excessive bending);
 - e. combinations of the above limit states;
 - f. stress (excessive Von Mises, mid-wall stress);
 - g. fatigue (repeated loading and unloading);
 - h. rotation and Fatigue of flexible joint, if present;
 - i. stress and Fatigue of stress joint, if present.
2. For umbilicals, the following additional limit states shall be included in the design:
 - a. clamping forces to hold umbilical;
 - b. minimum bend radius;
 - c. tension requirements.

Additional requirements for umbilicals are outside of the scope of this DEP Specification and are addressed in design specifications and industry standards such as ISO 13628-5.

3. All structural components of the SCR system (including but not limited to flexible joint extensions, stress joints, transition joints, and other pipe joint components) shall satisfy the design criteria in this section.

5.2 APPLICABLE INDUSTRY CODES AND SPECIFICATIONS

Development of the design requirements of this document has been primarily based on the API RP 2RD and API RP 1111.

1. The design shall comply with API RP 2RD and API RP 1111, unless otherwise specified in the project specific DBD or required by local regulatory requirements.

Local requirements, e.g., compliance with ASME B31.8 and ASME B31.4 may impose stricter criteria. (See also Table 5.4.3.1.).

5.3 STATIC CHECKS

A riser is part of a pipeline system. Design criteria for the static checks of line pipes are defined in this section.

1. Line pipe static checks may be used to determine the required minimum wall thickness and the steel grade of the line pipe, the maximum allowable operating pressure, and the maximum allowable bending strains in the line pipe.
2. Refer to DEP 31.40.00.10-Gen. for other pipeline requirements.

5.3.1 Internal pressure design (burst)

1. Maximum allowable operating pressure (MAOP) shall be determined in accordance with API RP 1111 Section 4.3.1 and the requirements of DEP 31.40.00.10-Gen., Section 6.4.

5.3.2 Longitudinal load design (tension)

1. The maximum allowable effective tension, T_{eff} , due to static primary longitudinal loads shall be determined in accordance with API RP 1111 Section 4.3.1.1.

5.3.3 External pressure design (collapse)

1. External pressure design shall be in accordance with Section 4.3.2 of API RP 1111.

5.3.4 Combined external pressure and bending design (buckling)

1. Combined external pressure and bending design shall be in accordance with Section 4.3.2 of API RP 1111.

5.4 DESIGN LOAD CASES

5.4.1 Service levels

1. Design load cases shall be analysed for the purpose of verifying that the riser response quantities do not exceed allowable values.
2. Load cases shall be categorized into the following service levels:
 - a. normal operation;
 - b. hydrotest;
 - c. extreme;
 - d. survival;
 - e. installation.

Allowable Stress Increase Factors, K, are defined (based on API RP 2RD) for different service levels in Table 5.4.1.1 below. K values are used later to calculate the allowable stresses in Table 5.4.3.1.

Table 5.4.1.1 Allowable Stress Increase Factor, K

Riser Service Level	Upper Riser Section (Note 1)	Lower Riser Section (Note 1)
Normal Operating	1.0	1.0
Hydrotest	1.2	1.35
Extreme	1.2	1.5 (Item 4)
Survival	1.5	1.5
Installation	(Item 3)	(Item 3)

NOTE: 1. Upper Riser Section refers to the top one-third portion of the riser span; remainder of the riser (i.e., bottom two-third of riser span) is referred to as Lower Riser Section.

Installation operations are not addressed specifically in this document.

3. Once the installation methods and vessel types are known, a comprehensive dynamic analysis shall be done to ensure integrity of the riser and umbilical systems during installation.
 - a. Host and installation vessel dynamics shall be included in such analyses.

In the early phases of the project where little is known about potential installation vessels, a dynamic amplification factor of 1.3 may be considered.

4. A supplemental check with $K=1.2$ shall be done for the risers installed and operated in the U.S.
 - a. The criteria shall be in accordance with Table 2 of API RP 2RD, First Edition.

5.4.2 Load cases table

1. A table of all load cases for riser design shall be included in the Project-Specific DBD, with an appropriate *service level for each of the load cases*.

An example of design load cases is in Table 5.4.2.1 for reference purposes.

Contents and maximum internal pressures for each design load case can be found in the project specific DBD.

Some cases may need to be repeated with different combinations of riser contents and pressure. Similarly, the number of load cases to be analysed may increase due to multiplicity of host configurations.

An example of this would be a situation in which the host is moved away from its nominal position for a period of time in order to allow a drilling vessel to be positioned over the seafloor well pattern.

For any given project, therefore, a single case from the generic load case table, such as Table 5.4.2.1, may give rise to several individual design load cases differing in riser contents, internal pressure, and host vessel configuration (if applicable).

2. For each project, the riser design summary report shall contain a complete load case table similar to Table 5.4.2.1 that shows each individual load case considered.
3. Damaged host cases should include scenarios for broken mooring lines, flooded compartments, etc., as appropriate for the project.
4. Each design load case shall include the in-plane slack and in-plane taut environment headings and an out-of plane (normal to the plane of riser) heading for a collinear environment.

Project-specific conditions may require consideration of additional environment headings.

Table 5.4.2.1 Example design load cases

Riser/Host Condition	Minimum pressure at top of riser	Maximum pressure at top of riser	Design Environment	Service Level
Operating	0	Project Specific	1-year Storm	Normal
			100-year Operating Storm	Extreme
			100-year Current Dominated Environment	
Abandonment	0	Project Specific	100-year Abandonment Storm	Extreme
			1000-year Abandonment Storm	Survival
Hot Oiling	0	Project Specific	1-year Storm	Extreme
			10-year Current Dominated Environment	
Hydrotest	0	Project Specific	1-year Storm	Hydrotest
			10-year Current Dominated Environment	
Damaged Host	0	Project Specific	100-year Operating Storm	Survival