GUIDANCE NOTES
GD10-2020

CHINA CLASSIFICATION SOCIETY

GUIDELINES FOR SURVEY OF MARINE RISER SYSTEMS

2020

Effective from 1 June 2020

Beijing

Contents

Chapter 1 General

Section 1 General Provisions

1.1.1 General requirements

1.1.1.1 The purpose of the Guidelines is to provide a basis for the surveys of marine riser (hereinafter referred to as riser) systems, including survey rules and technical requirements during design, manufacture, installation and in-service.

1.1.1.2 The Guidelines present technical requirements for riser systems and main components of various riser systems. In addition to the provisions in the Guidelines, each component shall comply with the applicable requirements in the corresponding recognized technical standards.

1.1.1.3 The riser system shall comply with the applicable requirements in the Guidelines and/or the rules and standards specified by the owner, and shall also comply with the relevant requirements of local competent authorities.

1.1.2 Scope of application

1.1.2.1 The Guidelines apply to riser systems connected to offshore floating installations/ single point mooring installations in offshore oil and gas development. These systems functionally comprise risers for permanent operations (such as production, export, import, injection) and risers for temporary operations (such as drilling, completion, workover). For other risers for non-oil and gas applications, refer to the relevant requirements applicable in the Guidelines.

1.1.2.2 For low-pressure drilling riser systems in the form of underwater BOPs on mobile offshore platforms/drilling ships, they shall comply with the applicable requirements in the CCS *Guidelines for Survey of Offshore Drilling Plants*. The applicable requirements in the Guidelines may also serve as a reference for relevant analysis methods.

1.1.2.3 Risers used on fixed platforms (e.g., jacket platforms), as auxiliary components in submarine pipeline systems, shall comply with the applicable requirements in the CCS *Rules for Submarine Pipeline Systems* and/or in the rules and standards specified by the owner.

1.1.2.4 Depending on the riser types and materials, the Guidelines apply to steel catenary risers, top tensioned risers, flexible risers and hybrid risers. Applicable pipe types include steel pipes and non-bonded flexible pipes with steel armor layers. For specific requirements about non-bonded flexible pipes, please refer to API Spec 17J and API RP 17B. Risers made of special materials such as titanium alloys and composite materials shall meet applicable technical requirements in the recognized standards specified by the owner.

1.1.2.5 The Guidelines apply to construction of new riser systems, modification of existing riser systems and reapplication of existing riser systems in different floating installations or operation areas.

1.1.2.6 The applicable requirements in the Guidelines may also serve as a reference for the global analysis of the dynamic umbilical cable and the structural design of its internal steel hydraulic pipes.

1.1.3 Equivalent and exemption

1.1.3.1 Design provisions inconsistent with the requirements of the Guidelines (including the requirements in accepted standards) may be accepted as substitutions for the corresponding requirements herein, provided that they are demonstrated through documentary evidence to attain at least an equivalent level of safety, and are agreed upon by the parties to the contract and China Classification Society (CCS).

1.1.3.2 Any riser system which embodies structure and features of a novel kind may be exempted from any requirement of the Guidelines if the application of which might seriously impede the incorporation of its features or its service, subject to the agreement of CCS.

1.1.4 Application of risk assessment

1.1.4.1 If the owner, operator, designer or other organization intends to design, manufacture or operate the riser system based on risk assessment, the risk control plan and measures used in the risk assessment can replace all or part of the provisions of the Guidelines after CCS reviews and approves the submitted risk assessment documents.

Section 2 Definitions

1.2.1 Definitions

1.2.1.1 The terms used in the Guidelines are defined as follows:

(1) Floating structure

It refers to a structure that relies on buoyancy to support its full load weight.

(2) Offshore floating installation

It refers to offshore installations that float on the water and are moored at sea for oil and gas processing, storage, loading and offloading and other operation purposes for a long time.

(3) Single point mooring installation

It refers to a mooring and transfer device, which provides a connection between submarine pipelines and floating structures (offshore floating installation, oil tanker, etc.) and can be used to transport fluid goods when necessary. Floating structures can be tied to it and can rotate around mooring points under environmental loads.

(4) Marine (offshore / subsea) riser

It refers to the pipeline connecting production or drilling equipment on floating structures with submarine pipelines and underwater facilities, hereinafter referred to as risers. Risers functionally include production/export/ import/injection risers for permanent operations and drilling/workover/completion risers for temporary operations. For drilling/workover/completion risers, they are also called drilling/workover/completion marine risers.

(5) Riser system

It refers to the system integrated by the riser and related components.

(6) Riser component

It refers to the components that constitute the riser, which is any part of the riser system that may be subjected to internal fluid pressure, including the riser main tube (riser pipe), flange, connector, stress joint, flex joint, ball joint, tension joint, telescopic joint (slip joint), valve, etc.

(7) Component

It refers to the components that constitute the riser system. Typically, the following types of components may be included:

① Components for fluid delivery:

a. Riser pipe sections, such as standard riser joint, pup joint, stress joint, flex joint, tension joint, keel joint and flexible pipe;

b. Mechanical connectors, such as coupling, end-connector and end fittings;

c. Valves, such as ball valve, gate valve, non-return valve and injection valve;

② Components for support and external load control:

a. Riser tensioner system;

b. Top basket structure;

c. Supplementary buoyancy devices, such as buoyancy module and buoyancy tank;

d. Flexure control devices, such as flex joint, ball joint, stress joint, keel joint, bending stiffener and bending restrictor;

e. Structural supporting members installed on the riser, such as riser tensioner ring and bracket;

f. Devices for regulating hydrodynamic loads, such as VIV suppression devices;

③ Riser disconnection devices, such as quick disconnect coupling, riser lower assembly and flexible pipe quick disconnect system;

④ Riser monitoring system:

a. Monitoring system, such as riser position, angle, tension, strain, vibration monitoring systems;

b. Control system, such as the control system for adjusting the top tension or position of the riser and the control system for underwater actuator;

⑤ Fairlead, such as riser guide arm, guide wire and guide structure (guide bases or wellhead base plates);

⑥ Components related to the prevention or removal of marine growth, such as anti-fouling coating and movable decontamination equipment;

⑦ Mechanical damage protection devices such as protective nets and structural frames;

⑧ Materials related to thermal insulation;

⑨ Materials related to anti-corrosion, such as coating and sacrificial anode.

(8) Pressure-containing component/part

It refers to components that will cause fluid leakage into the environment in case of possible function failure, such as standard pipe, stress joint, flex joint, connector, surface wellhead and other riser components.

(9) Primary load-carrying component/part

It refers to components that will compromise the integrity of the riser string in case of possible function failure, such as tensioner, buoyancy tank, top assembly, riser base and riser component.

(10) Production riser

It refers to the riser that transports fluid produced by a reservoir from the underwater wellhead, submarine pipeline or other underwater structures (such as PLET and PLEM) to the floating structure. Production risers can also be used for workover, completion, injection and other purposes.

(11) Injection riser

It refers to the riser that transports fluid from the floating structure to the underwater wellhead, submarine pipeline or other underwater structures (such as PLET and PLEM) to maintain reservoir pressure or realize other production purposes.

(12) Export riser

It refers to the riser that transports fluid (oil, gas, water or a mixture of them) after oil and gas processing from the floating structure to other downstream facilities (such as platforms or submarine pipelines).

(13) Import riser

It refers to the riser that transports fluid (oil, gas, water or a mixture of them) after oil and gas processing from other facilities (such as platforms or submarine pipelines) to the floating structure.

(14) Drilling riser

It refers to the riser used in drilling and workover operations. The main functions of the drilling riser include providing a fluid transfer channel from the floating structure to the wellbore, supporting auxiliary lines/guide tools/drill strings, running and retrieving the BOP, etc. It can also be used for completion and logging operations.

(15) Workover riser

It refers to the riser used for workover operations.

(16) Completion riser

It refers to the riser used for completion operations.

(17) Permanent riser

It refers to the riser that remains in place for many years after installation until subsequent recovery, such as the production riser, injection riser, export riser, import riser, and drilling/workover riser not allowed to be disconnected under extreme conditions (such as drilling/workover risers on TLP and SPAR).

(18) Temporary riser

It refers to the riser used intermittently for limited operating time and can be recovered under harsh environmental conditions.

(19) Steel catenary riser

It refers to the steel riser connected to the floating installation in a catenary configuration, which can be regarded as an extension of the submarine pipeline. The steel catenary riser can be used for production, export, import and injection purposes.

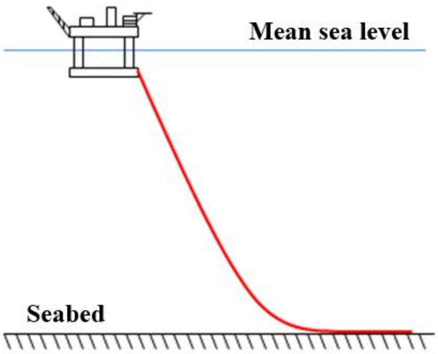

Figure 1.2.1.1-1 Schematic Diagram of Typical Steel Catenary Riser Configuration

(20) Top tensioned riser

It refers to the riser that is maintained in a vertical or near-vertical position by top tension. It allows for relative vertical motion between the riser and the floating structure while constraining relative horizontal movement. The top tensioned riser can be used for production, export, import, injection, drilling, workover and completion purposes.

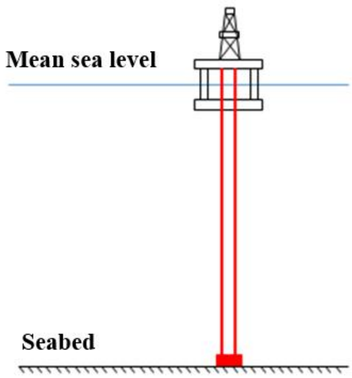

Figure 1.2.1.1-2 Schematic Diagram of Typical Top Tensioned Riser Configuration

(21) Flexible riser

It refers to the riser consisting of a flexible pipe and connecting the floating installation to the submarine pipeline/submarine facility. The flexible riser can be used for production, export, import and injection purposes.

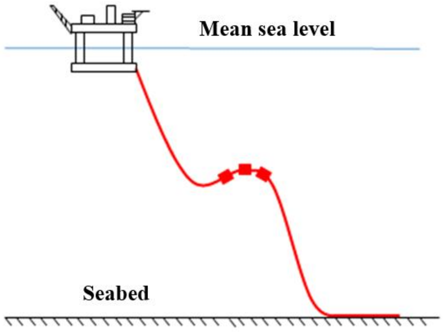

Figure 1.2.1.1-3 Schematic Diagram of Typical Flexible Riser Configuration

(22) Hybrid riser

It refers to the riser consisting of a steel riser section with top tension provided by the buoyancy tank and a flexible jumper connecting this section of the riser to the floating installation. The steel riser section can be vertically tensioned, with the bottom anchored to the seabed through a pile foundation. Alternatively, it can be deployed as a catenary, with the bottom directly connected to the submarine pipeline or other submarine facilities. The hybrid riser can be used for production, export, import and injection purposes. The hybrid riser with the steel riser section vertically tensioned is also known as a free-standing hybrid riser.

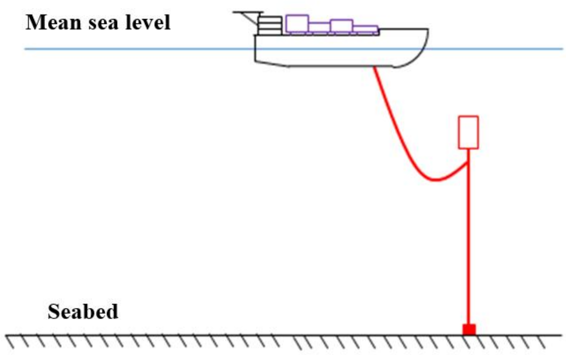

Figure 1.2.1.1-4 Schematic Diagram of Typical Hybrid Riser Configuration

(23) Top tensioned riser system

The top tensioned riser system generally includes the riser tensioner system, standard riser joint, pup joint, stress joint, tension joint, buoyancy module, tie-back connector, fairlead, anti-corrosion system, monitoring system, etc.

(24) Steel catenary riser system

The steel catenary riser system generally includes all components from the basket structure of the top joint of the riser down to its subsea connection point with the submarine pipeline, PLET, or PLEM.

(25) Flexible riser system

The flexible riser system generally includes all components from the Type I pipe down to its subsea connectors with the submarine pipeline/PLET/PLEM, such as the flexible pipe body, end fittings, bending restrictor, bending stiffener, bell mouth, buoyancy module, underwater buoyancy tank and its tendons/foundations, cathodic protection and monitoring system.

(26) Hybrid riser system

Hybrid riser systems can generally be classified by their configuration into types such as free-standing hybrid risers, hybrid riser towers, buoyancy-supported risers and hybrid catenary risers. Each type of hybrid riser system has different components, as described in 5.4.2 of the Guidelines.

(27) Riser main tube (riser pipe)

It refers to the pipe that constitutes the main channel of a riser joint.

(28) Tubing

It refers to the pipe used in a well to guide fluid from the production formation of the well to an underwater or above-water Christmas tree.

(29) Annulus

It refers to the space between the outer pipe and the inner pipe.

(30) Riser joint

It refers to a single section of the riser string that comprises the riser main tube, male/female connectors installed at both ends, auxiliary lines, and their supporting structures.

(31) Standard riser joint

It refers to a riser joint of standard length, depending on the size of the equipment for placing the riser joint on the floating installation and the capability of the riser handling equipment.

(32) Pup joint

It refers to a riser joint that is shorter than a standard riser joint.

(33) Slick joint

It refers to a riser joint of standard length without the buoyancy module installed.

(34) Buoyancy joint

It refers to a riser joint of standard length with the buoyancy module installed.

(35) Tension joint

It refers to a special riser joint that connects the vertical riser to the tensioner system on the floating structure.

(36) Riser tensioner ring

It refers to the connection point between the tension joint and the tensioner.

(37) Telescopic joint (slip joint)

It refers to a special riser joint with an inner barrel and an outer barrel, where a sealing mechanism is fitted between the two barrels. When the floating structure moves, the relative displacement between the inner and outer barrels of the telescopic joint compensates for the length of the riser string.

(38) Keel joint

It refers to a special riser joint designed to withstand contact between the riser and the bottom of the moon pool.

(39) Stress joint

It refers to a special riser joint designed with a tapered cross-section to control curvature and reduce local bending stresses.

(40) Flex joint

It refers to an assembly made of steel and synthetic rubber that allows a certain degree of relative rotation to reduce the bending moment at the end of the riser.

(41) Ball joint

It refers to a ball and socket assembly that can be installed on the riser string to reduce local bending stresses.

(42) Hold collar

It refers to the hanging flange used for riser installation/repair, usually located at locations such as flex joint extensions.

(43) Connector

It refers to the machinery installation used to connect adjacent components of the riser. The connectors include the couplings joining two riser joints, the riser top connector, and the riser bottom connector. The common types of connectors typically include threaded, flanged, clamp and collet types.

(44) Coupling

It refers to the machinery installation that joins the ends of two riser pipe sections. Couplings may also be designed to provide support for choke/kill lines, auxiliary lines, buoyancy modules.

(45) End-connector

It refers to the top connector used to connect the riser to above-water equipment (e.g., above-water Christmas tree) and the bottom connector used to connect the riser to submarine equipment (such as an underwater wellhead). Of them, the bottom connector usually has a replaceable sealing assembly and locking device, which can be assembled on the seabed by remote control.

(46) Tie-back connector

It refers to an underwater connector that provides a metal-to-metal seal by hydraulic operation.

(47) Riser string

It refers to the assembly of all riser joints deployed.

(48) Auxiliary line

It refers to rigid pipelines (excluding choke/kill lines) installed inside or outside the riser main tube, such as the hydraulic control line, drilling fluid pressurized line and buoyancy control line.

(49) Riser tensioner system

It refers to the device that provides top tension for the riser string and heave compensation between the riser and the floating structure. Main components include the hydraulic cylinder, accumulator, centralizing/guide roller assembly, control panel and instruments.

(50) Centralizing/guide rollers

It refers to the centralizing device located near the top of a top tensioned riser, which restrains lateral displacement while allowing axial displacement of the riser so as to maintain a proper riser spacing during motion of the floating structure and which is a part of the riser tensioner system.

(51) Riser tensioner stroke

It refers to the maximum vertical movement distance of the riser relative to the floating structure.

(52) Buoyancy tank (air tank / air can)

It refers to a buoyancy structure located below or at the water surface and filled with gas or low-density liquid, connected to the riser or installed on the outside of the riser, providing a constant or variable upward tension to the riser string. The buoyancy tank can be sealed at the top, and the bottom can be left open, in which case the internal gas pressure equals the ambient pressure. Alternatively, the bottom can be sealed, resulting in an internal gas pressure that differs from the ambient pressure.

(53) Buoyancy module (foam buoyancy)

It refers to a device of low-density material, usually foamed polymers strapped or clamped to the exterior of riser joints, to reduce the submerged weight of the riser.

(54) Guideline system

It refers to the guideline system used to guide and align the top tensioned riser to the underwater wellhead. The guideline system generally includes components such as the guide structure (e.g., guide base or wellhead base plate), guide post receptacle, guide post, guide wire anchor, guide wire, guide arm, winch, guide sheave and back-out sheave.

(55) Pipe joint

It refers to a complete pipe joint formed by welding two steel pipes. It is commonly used for in steel catenary risers and vertical steel pipe sections welded in hybrid risers.

(56) Riser porch structure

It refers to the porch structure welded to a pontoon or similar floating structure. It is used to connect the basket structure of steel catenary riser and to transfer riser loads to the outermost structural part of the floating structure.

(57) Basket (receptacle) structure

It refers to the receiving structure of the flex joint at the top of the steel catenary riser, usually welded to the riser porch structure on the floating structure.

(58) Bulkhead

It refers to a device that connects the inner and outer pipes of the pipe-in-pipe at regular intervals, separates the annulus into parts, and limits the relative axial expansion deformation between the inner and outer pipes.

(59) Pipe spacer (centralizer)

It refers to a device installed on the inner pipe of the pipe-in-pipe at a certain interval, so that the inner and outer pipes maintain concentricity and allow axial relative sliding between the inner and outer pipes.

(60) Field joint coating

It refers to the single-layer or multi-layer coating applied for the protection of girth welds. The field joint coating may be applied offshore on-site or pre-applied in a factory.

(61) Gooseneck assembly

It refers to the assembly structure used to connect the top riser assembly and the top flexible jumper in the hybrid riser system. The gooseneck assembly may include the bend, flexible jumper stiffener and underwater connector.

(62) Top riser assembly

It refers to the assembly structure used to connect the tether chain/flex joint, top flexible jumper and upper stress joint in the hybrid riser system, including the gooseneck assembly.

(63) Bottom riser assembly

It refers to the assembly structure used to connect the riser string, riser base jumper and pile foundation.

(64) Tether chain

It refers to a structure used to connect the buoyancy tank and the top riser assembly in the hybrid riser system.

(65) Top flexible jumper

It refers to the flexible pipe used to connect the floating structure and top riser assembly in the hybrid riser system.

(66) Riser base jumper

It refers to a short section of flexible or rigid pipe used to connect the bottom of the riser to the submarine pipeline terminal/submarine manifold in the hybrid riser system.

(67) Upper tapered stress joint

It refers to a section of variable cross-section stress joint used to connect the top riser assembly and the standard riser pipe in the hybrid riser system, usually a forging.

(68) Lower tapered stress joint

It refers to a section of variable cross-section stress joint used to connect the bottom riser assembly and the standard riser pipe in the hybrid riser system, usually a forging.

(69) Stem pipe (central pipe / core supporting pipe)

It refers to a large steel pipe in the center of a buoyancy tank that transfers the riser weight to each compartment of the buoyancy tank. The stem pipe (central pipe / core supporting pipe) may also refer to a section of pipe installed at the bottom of the top riser assembly or at the top of the bottom riser assembly (as part of the top/bottom riser assembly).

(70) Riser base

It refers to the structure fixed to the seabed and used to connect the riser stress joint and the hydraulic connector, providing resistance to tension, bending moment and lateral load for the riser. The riser base may include an independent pile foundation.

(71) Maximum operating condition

It refers to the maximum allowable operating environment conditions of the system specified by the operator.

(72) Extreme condition

It refers to the environmental conditions with a return period of 100 years or an annual exceedance probability of 1%.

(73) Reduced extreme condition

It refers to the environmental conditions with a return period of less than 100 years and combined with rare events caused by other accidental loads.

(74) Survival condition

It refers to the environmental conditions with a return period between 100 and 10,000 years.

(75) Normal operation

It refers to the state of equipment or systems used as planned, including steady flow conditions and scheduled shutdowns that may occur during daily operations.

(76) Incidental operation

It refers to various states other than normal operation of the equipment or systems, such as water hammer caused by sudden closing of the gate, failure of the pressure regulating system and activation of the pressure safety system.

(77) Design pressure

It refers to the maximum pressure difference experienced by all cross-sections of the riser during normal operation.

(78) Maximum operating pressure

It refers to the maximum pressure difference that the riser is subjected to during normal operation at the reference point. The maximum operating pressure shall not exceed the design pressure of any riser component, including pipes, valves, flanges, connectors, etc.

Note: For risers with an average density of the media in the pipe lower than that of seawater, the height of the top of the riser is generally taken as the reference point. For risers with an average density of the media in the pipe greater than that of seawater, the height of the bottom of the riser is generally taken as the reference point.

(79) Operating pressure

It refers to the pressure difference of the riser within the normal operation range at the reference point. The operating pressure is less than or equal to the maximum operating pressure.

(80) Extreme (incidental) pressure

It refers to the maximum pressure difference experienced by all cross-sections of the riser during incidental operation, including water hammer pressure, emergency shutdown pressure, etc.

(81) Hydrostatic test pressure

It refers to the pressure difference used in the pressure test of the riser system. Usually, the hydrostatic test pressure shall not be less than 1.25 times the design pressure.

Section 3 Abbreviations and Symbols

1.3.1 Abbreviations

Abbreviations	**Full name in English**
BOP	Blowout Preventer
BRA	Bottom Riser Assembly
BS&W	Bottom Sediment and Water
BT	Buoyancy Tank
CD	Chart Datum
CFD	Computational Fluid Dynamics
CP	Cathodic Protection
CRA	Corrosion-Resisting Alloy
CTOD	Crack Tip Opening Displacement
CVN	Charpy V-notch
DWT	Drop Weight Tear
DBM	Distributed Buoyancy Module
ECA	Engineering Critical Assessment
ESD	Emergency Shut-Down
FAT	Factory Acceptance Test
FJ	Flexible Jumper
FMEA	Failure Mode Effect Analysis
FR	Flexible Riser
FSHR	Free Standing Hybrid Riser
HAZOP	Hazard and Operability Study
HCR	Hybrid Catenary Riser
HR	Hybrid Riser
HRT	Hybrid Riser Tower
ITP	Inspect and Test Plan
LRFD	Load and Resistance Factor Design
LTSJ	Lower Taper Stress Joint
MBR	Minimum Bending Radius
MOP	Maximum Operating Pressure
MPS	Manufacturing Procedure Specification
MSL	Mean Sea (Still) Level
MT	Magnetic Particle Testing
MWL	Mean Water Level
NDE	Non-Destructive Examination
OP	Operating Pressure
PIP	Pipe-in-Pipe
PLEM	Pipeline End Manifold
PLET	Pipeline End Termination
PT	Penetrant Testing
QA/QC	Quality Assurance/Quality Control

Abbreviations	**Full name in English**
RAO	Response Amplitude Operator
RBJ	Riser Base Jumper
ROV	Remotely Operated Vehicle
RT	Radiographic Testing
SAF	Stress Amplification Factor
SCF	Stress Concentration Factor
SCR	Steel Catenary Riser
SIT	System Integration Test
SLHR	Single Line Hybrid Riser
SMYS	Specified Minimum Yield Strength
SMTS	Specified Minimum Tensile Strength
STC	Stress Transfer Coefficient
TLR	Tension Leg Riser
TRA	Top Riser Assembly
TSJ	Tapered Stress Joint
TTF	Top Tension Factor
TTR	Top Tension Riser
UT	Ultrasonic Testing
UTSJ	Upper Tapered Stress Joint
VIM	Vortex Induced Motion
VIV	Vortex Induced Vibration
WPS	Welding Procedure Specification
WSD	Working Stress Design

1.3.2 Symbols

Symbols	Definitions of symbols
A	Cross-sectional area of pipe
a	Cross-sectional area of pipe wall
b	Strain reduction factor
C_a	Allowable stress coefficient
C_f	Design factor
D	Nominal outer diameter
D_{ins}	Fatigue damage during installation
D_{max}	Maximum outer diameter
D_{min}	Minimum outer diameter
D_{wave}	Wave-induced fatigue damage
D_{VIM}	VIM-induced fatigue damage
D_{VIV}	VIV fatigue damage
E	Modulus of elasticity
F_b	Pressure-containing (rupture) design factor
F_c	Design factor
f	Out-of-roundness function
G	Unit weight of seawater
g	Defect function
H	Water depth
I	Moment of inertia of a pipe section
k	Coefficient accounting for mechanical properties and wall thickness dimensions
N_{tot}	Total number of cyclic stresses during the service life or survey cycle
N_{cg}	Number of stress cycles required for initial crack growth to critical size
P_b	Specified minimum burst pressure
P_c	Collapse pressure of a steel pipe under pure external pressure
P_e	External pressure
P_{el}	Elastic collapse pressure
P_i	Internal pressure
P_{net}	Net external pressure
P_o	Collapse pressure of a steel pipe under external pressure, axial force and bending load
P_p	Plastic collapse pressure
P_r	Collapse propagation pressure
P_y	Yield collapse pressure
p	Ratio of plastic to elastic collapse pressure
R_i	Distribution of response variables at the i^{th} node
S_a	Average axial stress
SF	Fatigue safety factor
SF_{VIM}	VIM-induced fatigue safety factor
SF_{VIV}	VIV fatigue safety factor
SF_{wave}	Wave-induced fatigue safety factor
STC_i	Stress transfer coefficient at the i^{th} node

Symbols	Definitions of symbols
s	Bending strain
s_0	Critical bending strain
T_e	Effective axial force
T_{min}	Minimum service temperature
t_{corr}	Corrosion, wear and erosion allowances
t_{min}	Nominal wall thickness minus the corrosion, wear and erosion thickness considered
t_{nom}	Nominal wall thickness
Y_r	Reduced yield stress
α_{fab}	Fabrication factor
β	Proportion of fatigue damage during installation to total long-term fatigue damage
δ_0	Ovality
$\sigma_i(t)$	Stress distribution
$\sigma_{p\theta}$	Circumferential membrane stress
σ_{pr}	Radial membrane stress
σ_{pz}	Axial membrane stress
σ_u	Specified minimum tensile strength
σ_y	Specified minimum yield strength
$(\sigma_p)_e$	Equivalent stress
υ	Poisson's ratio

Section 4 Accepted Standards

1.4.1 General requirements

1.4.1.1 In addition to meeting the requirements in the Guidelines, the design, manufacture, installation, inspection and test of risers shall also comply with the applicable requirements in international standards, advanced foreign standards, national standards and industry standards recognized by CCS.

1.4.1.2 Alternative standards can be used in place of those accepted in the Guidelines, provided that they are demonstrated to attain at least an equivalent level of safety, and are agreed upon by CCS.

1.4.1.3 Alternative provisions inconsistent with design standards, as well as exemptions from and changes to design standards shall be stated in the design documents and agreed upon by the owner and CCS.

1.4.1.4 The latest version of the standard on the effective date of the design contract shall be adopted. Otherwise, it shall be clearly stipulated in the contract.

1.4.2 Accepted standards

1.4.2.1 The main relevant standards for riser systems accepted by CCS are as follows:

S/N	Standard number	Standard name
1	API RP 2RD	Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms (TLPs)
2	API Std 2RD	Dynamic Risers for Floating Production Systems

S/N	Standard number	Standard name
3	API Std 1104	Welding of Pipelines and Related Facilities
4	API RP 1111	Design, Construction, Operation, and Maintenance of Offshore Hydrocarbon Pipelines (Limit State Design)
5	API RP 17A	Design and Operation of Subsea Production Systems — General Requirements and Recommendations
6	API RP 17B	Recommended Practice for Flexible Pipe
7	API RP 16Q	Design, Selection, Operation, and Maintenance of Marine Drilling Riser Systems
8	API RP 2A-WSD	Planning， Designing and Constructing Fixed Offshore Platforms — Working Stress Design
9	API RP 2GEO	Geotechnical and Foundation Design Considerations
10	API RP 2SK	Design and Analysis of Stationkeeping Systems for Floating Structures
11	API Spec 5L	Specification for Line Pipe
12	API Spec 5LC	CRA Line Pipe
13	API Spec 5LD	CRA Clad or Lined Steel Pipe
14	API Spec 5CT	Specification for Casing and Tubing
15	API Spec 16F	Specification for Marine Drilling Riser Equipment
16	API Spec 16R	Specification For Marine Drilling Riser Couplings
17	API Spec 17D	Design and Operation of Subsea Production Systems — Subsea Wellhead and Tree Equipment
18	API Spec 17E	Specification for Subsea Umbilicals
19	API Spec 17J	Specification for Unbonded Flexible Pipe
20	API Spec 6A	Specification for Wellhead and Christmas Tree Equipment
21	API Spec Q1	Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry
22	API Spec 2H	Specification for Carbon Manganese Steel Plate for Offshore Structures
23	API Spec 2W	Steel Plates Produced by Thermo-mechanically Controlled Processing for Offshore Structures
24	API Spec 2Y	Specification for Steel Plates, Quenched-and-Tempered, for Offshore Structures
25	ISO 13628-7	Petroleum and Natural Gas Industries — Design and Operation of Subsea Production Systems — Part 7: Completion/Workover Riser Systems
26	ISO 15589-2	Petroleum, Petrochemical and Natural Gas Industries — Cathodic Protection of Pipeline Transportation Systems — Part 2: Offshore Pipelines
27	ISO 2394	General Principles on Reliability for Structure
28	ISO 6507-1	Metallic Materials — Vickers Hardness — Part 1:Test Method
29	ISO 9712	Non-destructive Testing — Qualification and Certification of NDT Personnel
30	ASME B31.4	Pipeline Transportation Systems for Hydrocarbon and Other Liquids
31	ASME B31.8	Gas Transmissions and Distribution Piping Systems
32	ASME BPVC	ASME Boiler and Pressure Vessel Code
33	BS 7448	Fracture Mechanics Toughness Tests
34	BS 7608	Code of Practice for Fatigue Design and Assessment of Steel Structures
35	BS 7910	Guide to Methods for Assessing the Acceptability of Flaws in Metallic Structures
36	NACE SP0169	Control of External Corrosion on Underground or Submerged Metallic Piping

S/N	Standard number	Standard name
		Systems
37	NACE MR0175 / ISO 15156-1	Petroleum and Natural Gas Industries — Materials for Use in H_2S-containing Environments in Oil and Gas Production — Part1 General Principles for Selection of Cracking-resistant Materials
38	ASTM A36	Standard Specification for Carbon Structural Steel
39	ASTM A194	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature, or Both
40	ASTM A320	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service
41	ASTM A516	Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
42	ASTM A537	Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel
43	ASNT SNT-TC-1A	Personnel Qualification and Certification in Nondestructive Testing
44	AWS D1.1	Structural Welding Code — Steel

Chapter 2 Survey and Certification

Section 1 General Provisions

2.1.1 General requirements

2.1.1.1 This Chapter specifies the specific requirements for CCS to conduct surveys on production, export, import and injection riser systems used in offshore floating installations/single-point installations. The types of surveys include classification surveys, certification surveys and verification surveys. The drilling/workover/completion riser systems used for offshore floating installations shall follow the applicable requirements for survey and certification of drilling/workover/completion riser systems in the CCS *Rules for Classification of Offshore Floating Installations*, *Guidelines for Survey of Offshore Drilling Plants* and *Guidelines for Certification of Subsea Production System*.

2.1.1.2 To ensure smooth and timely survey of the riser system, the applicant shall provide appropriate survey conditions, including transportation to the survey site and other arrangements.

2.1.1.3 If significant modifications to the riser system are necessary following the survey in accordance with the provisions of the Guidelines, the applicant shall promptly notify CCS and obtain corresponding approval.

2.1.2 Classification surveys

2.1.2.1 Upon application by the owner/operator or their agents, a CCS-class offshore installation may be awarded the class notation "RISERS" provided that the riser system installed on it complies with the provisions of the Guidelines and its design, manufacture, installation and test have been surveyed by and to the satisfaction of CCS.

2.1.2.2 Conditions for maintaining classification class notations:

(1) Various surveys shall be carried out in accordance with the provisions in the Guidelines to verify continuous compliance of their technical conditions with the provisions for the classification class notations granted;

(2) Operators shall abide by the operating procedures of the riser system, and riser operations shall be limited to the specified design range;

(3) In the event of any significant defect in the riser system that does not comply with the requirements in the Guidelines, the applicant or operator shall report it to CCS and make necessary rectifications;

(4) Where any damage, alteration, repair, or significant replacement occurs to the riser system, or where there is a change in the conveyed medium or a significant change in the conveying conditions, an application shall be made to CCS for survey.

2.1.3 Certification surveys

2.1.3.1 Upon application by the owner/operator or their agents, CCS, as the certification survey party, shall conduct a certification survey (including design review and on-site survey) of the riser system in accordance with the Guidelines and/or applicable rules and standards. For riser systems that meet the above survey basis, CCS will issue corresponding certificates and necessary documents.

2.1.3.2 Conditions for maintaining validity of the certificate of compliance:

(1) Various surveys shall be carried out in accordance with the provisions in the Guidelines to verify continuous compliance of their technical conditions with relevant provisions in the Guidelines;

(2) Operators shall abide by the operating procedures of the riser system, and riser operations shall be limited to the specified design range;

(3) In the event of any significant defect in the riser system that does not comply with the requirements in the Guidelines, the applicant or operator shall report it to CCS and make necessary rectifications;

(4) Where any damage, alteration, repair, or significant replacement occurs to the riser system, or where there is a change in the conveyed medium or a significant change in the conveying conditions, an application shall be made to CCS for survey.

2.1.4 Verification surveys

2.1.4.1 Upon application by the client, CCS may conduct a verification survey of the riser system in accordance with the provisions in the Guidelines or the standards specified by the client. After confirmation of compliance, CCS will issue the corresponding survey certification documents.

Section 2 Design Review

2.2.1 General requirements

2.2.1.1 Prior to commencement of construction, the applicant shall submit the plans and documents specified in this section to the marine engineering plan approval department of CCS for review. CCS may, if necessary, require the submission of additional plans and documents.

2.2.1.2 Where any substantial modifications or additions have been made to the approved design documents, the applicants are to submit such modifications or additions to the original plan approval location(s) for reexamination.

2.2.2 List of design documents to be submitted

2.2.2.1 For various types of riser systems, the riser system plans and documents to be submitted include but are not limited to:

(1) Specifications

① Process specifications of the riser system;

② Design basis of the riser system;

③ Specifications of the riser connector (including connectors between riser joints and at the ends of risers);

④ Insulation specifications (if any);

⑤ Specifications of anti-corrosion coating;

⑥ Specifications of field joint coating (if any);

⑦ Specifications of cathodic protection;

⑧ Specifications of the VIV suppression device (if any);

⑨ Specifications of riser system accessories such as flanges, tees and bulkheads (if any);

⑩ Specifications of the counterweight layer of horizontal pipe section (if any);

⑪ Specifications of welding and NDE (if any);

⑫ Specifications of girth weld fatigue test (if any);

⑬ Installation specifications;

⑭ Pre-commissioning specifications;

⑮ Specifications of the riser monitoring system (if any);

⑯ Specifications of requirements for riser inspection, maintenance, repair and monitoring;

⑰ Commissioning program.

(2) Drawings

① General arrangement plan of the riser system;

② Riser configuration diagram and cross-sectional details;

③ Diagram of VIV suppression device;

④ Anode arrangement plan and detailed drawing;

⑤ Installation flow chart of riser (if any);

⑥ General arrangement plan of the riser monitoring system (if any).

(3) Reports

① Analysis report on flow guarantee (including hydraulic and thermal calculations);

② Riser wall thickness selection report;

③ Riser interference analysis report;

④ Riser strength analysis report;

⑤ Riser fatigue analysis report;

⑥ Riser installation analysis report;

⑦ Sensitivity analysis report (if any);

⑧ Cathodic protection analysis report.

2.2.2.2 For the top tensioned riser system, in addition to those specified in 2.2.2.1, the following plans and documents shall be submitted:

(1) Specifications

① Specifications of riser joints (including various special riser joints, e.g., stress joints);

② Specifications of the tensioner system;

③ Specifications of the centralizing device (if any);

④ Specifications of the guidance system;

⑤ Specifications of the buoyancy tank (if any);

⑥ Specifications of the buoyancy module (if any);

⑦ Launch/recovery specifications.

(2) Drawings

① Arrangement plan of wellhead;

② Design drawings of riser joints (including stress joints, tension joints and other special riser joints);

③ Launch/recovery flow chart.

(3) Reports

① Riser wear analysis report (if any).

2.2.2.3 For the steel catenary riser system, in addition to those specified in 2.2.2.1, the following plans and documents shall be submitted:

(1) Specifications

① Specifications of steel pipes;

② Specifications of the riser top joint basket;

③ Specifications of the riser porch assembly;

④ Specifications of the flowline section at the seabed;

(2) Drawings

① Diagram of riser-floating structure interface;

② General arrangement plan of the riser porch assembly;

③ Drawing of the riser porch assembly;

④ Diagram of the riser top joint basket.

(3) Reports

① Weld ECA report;

② Design, strength and fatigue analysis report of the riser porch assembly;

③ Design, strength and fatigue analysis report of the riser basket structure;

④ Analysis report of the flowline section at the seabed.

2.2.2.4 For the flexible riser system, in addition to those specified in 2.2.2.1, the following plans and documents shall be submitted:

(1) Specifications

① Specifications of flexible pipes;

② Specifications of the bending stiffener;

③ Specifications of the bending limiter;

④ Specifications of the buoyancy module, buoyancy tank or buoyancy support system.

(2) Drawings

① Arrangement plan of riser-floating structure interface;

② Diagram of the bending stiffener;

③ Diagram of the bending limiter;

④ Diagram of the buoyancy module, buoyancy tank or buoyancy support system;

⑤ Diagram of flexible pipe body;

⑥ Diagram of end fittings;

⑦ Arrangement plan of riser protection pipe.

(3) Reports

① Connector selection report.

2.2.2.5 For the hybrid riser system, in addition to those specified in 2.2.2.1, the following plans and documents shall be submitted:

(1) Specifications

① Specifications of the riser joint/steel pipe;

② Specifications of the top flexible jumper;

③ Specifications of the buoyancy tank;

④ Specifications of the tether chain/flex joint;

⑤ Specifications of the riser top assembly;

⑥ Specification of the riser stress joint;

⑦ Specifications of the riser bottom assembly;

⑧ Specifications of connectors;

⑨ Specifications of the bending stiffener (if any);

⑩ Specifications of the riser base;

⑪ Specifications of the riser support system (if any);

⑫ Specifications of the riser bottom jumper;

⑬ Specifications of full-scale riser pipe fatigue test.

(2) Drawings

① Diagram of riser-floating structure interface;

② Detailed drawing of buoyancy tank;

③ Diagram of riser base;

④ Diagram of top flexible jumper;

⑤ Diagram of permanent structural components of the riser system (including top riser assembly, bottom riser assembly, stress joint and other permanent structures);

⑥ Diagram of riser bottom jumper;

⑦ Diagram of bending stiffener.

(3) Reports

① Overall configuration design report of riser;

② Design, strength and fatigue analysis report of top flexible jumper;

③ Design and analysis report of buoyancy tank;

④ Design, strength and fatigue analysis report of permanent structural components of the riser system (including top riser assembly, bottom riser assembly, stress joint and other permanent structures);

⑤ Design and analysis report of riser base;

⑥ Design, strength and fatigue analysis report of riser bottom jumper;

⑦ Weld ECA report (if any).

2.2.2.6 Other plans and documents for information:

(1) Reports

① Marine environment report;

② Field investigation report.

Section 3 Product Inspections

2.3.1 General requirements

2.3.1.1 Components of the marine riser system shall be inspected to verify their compliance with the requirements of classification, certification and client.

2.3.1.2 The product manufacturer shall apply to CCS headquarters or the product plan approval unit and survey organization designated by CCS for the plan approval and on-site inspections of the product.

2.3.1.3 If no technical requirements are specified for the products covered by the Guidelines, they may be designed, manufactured, tested and inspected as per the standards recognized by CCS.

2.3.2 Inspection and certificate classification

2.3.2.1 The products are inspected as per the following three types, namely, A, B, and C:

(1) Type-A products

① The design documents shall be submitted to CCS for review;

② The relevant construction documents shall be submitted to CCS for review, and construction may commence only after they are approved;

③ Before commencement, a kick-off meeting shall be held with the participation of the riser system owner or his agent, the CCS surveyor and the manufacturer;

④ Inspection shall be applied according to the quality assurance plan during manufacturing;

⑤ Function tests, pressure tests and load tests shall be reported for inspection;

⑥ Manufacturing records shall be submitted to CCS for review.

In the manufacturing survey of Type-A products, CCS shall review the manufacturer's QA/QC system. Before commencement, CCS shall review the manufacturer's quality assurance plan, and specify the quality control points and inspection activity categories based on the plan.

(2) Type-B products

① Safety-related design documents shall be submitted to CCS for review;

② Function tests, pressure tests and load tests shall be reported for inspection;

③ Manufacturing records shall be submitted to CCS for review.

In the manufacturing survey of Type-B products, CCS shall review the manufacturer's QA/QC system. Before commencement, CCS shall review the manufacturer's quality assurance plan, and specify the quality control points and inspection activity categories based on the plan.

(3) Type-C products

Such products shall be manufactured in accordance with recognized standards, specifications and according to recognized manufacturing methods.

2.3.2.2 The product inspection and certificate classification shall comply with the provisions in Table 2.3.2.2. C/E stands for product certificate/equivalent document issued by CCS, and W stands for certificate issued by the manufacturer.

2.3.2.3 For general products not specified in Table 2.3.2.2, the above-water portion shall comply with the requirements in the specifications used for installations, and the underwater portion shall meet the corresponding requirements in the CCS *Guidelines for Certification of Subsea Production System* and *Rules for Submarine Pipeline Systems*.

Product Inspection and Certificate Classification Table 2.3.2.2

S/N	Product name	Inspection type			Certificate type	
		A	B	C	C/E	W
1	**Steel catenary riser system**					
1.1	Riser pipe		×		×	
1.2	Flex joint/ball joint		×		×	
1.3	Special riser joint		×		×	
1.4	Sacrificial anode		×		×	
1.5	VIV suppression device		×		×	
1.6	Riser basket structure		×		×	
1.7	Riser monitoring system		×		×	
1.8	Connector		×		×	
2	**Top tensioned riser system**					
2.1	Riser tensioner system		×		×	
2.2	Standard riser joint		×		×	
2.3	Pup joint		×		×	
2.4	Telescopic joint		×		×	
2.5	Flex joint/ball joint		×		×	
2.6	Tension joint		×		×	
2.7	Riser tensioner ring		×		×	
2.8	Tapered stress joint		×		×	
2.9	Keel joint		×		×	

S/N	Product name	Inspection type			Certificate type	
		A	B	C	C/E	W
2.10	Other special riser joint		×		×	
2.11	Buoyancy module		×		×	
2.12	Buoyancy tank		×		×	
2.13	Centralizer		×		×	
2.14	Sacrificial anode		×		×	
2.15	VIV suppression device		×		×	
2.16	Guidance system			×		×
2.17	Riser monitoring system		×		×	
2.18	Connector		×		×	
3	**Flexible riser system**					
3.1	Flexible pipe (including end fittings)		×		×	
3.2	Buoyancy module		×		×	
3.3	Buoyancy tank		×		×	
3.4	Bending restrictor			×		×
3.5	Bending stiffener			×		×
3.6	Connector		×		×	
3.7	Sacrificial anode		×		×	
3.8	Riser monitoring system		×		×	
4	**Hybrid riser system**					
4.1	Top flexible jumper (including end fittings)		×		×	
4.2	Buoyancy module		×		×	
4.3	Buoyancy tank		×		×	
4.4	Bending restrictor			×		×
4.5	Bending stiffener			×		×
4.6	Standard riser joint		×		×	
4.7	Pup joint (if applicable)		×		×	
4.8	Flex joint/ball joint		×		×	
4.9	Other special riser joint		×		×	
4.10	Centralizer			×		×
4.11	Riser base	×			×	
4.12	Top stress joint		×		×	
4.13	Bottom stress joint		×		×	
4.14	Bottom jumper		×		×	
4.15	Tether chain		×		×	
4.16	Bottom riser assembly		×		×	
4.17	Top riser assembly		×		×	
4.18	Gooseneck assembly		×		×	
4.19	Sacrificial anode		×		×	
4.20	VIV suppression device		×		×	
4.21	Guidance system			×		×
4.22	Riser monitoring system		×		×	

S/N	Product name	Inspection type			Certificate type	
		A	B	C	C/E	W
4.23	Connector		×		×	

2.3.3 Product design review

2.3.3.1 The applicant shall submit the design documents for the following certified products to CCS for review:

(1) Applicable technical standards for products;

(2) General product instructions;

(3) Product design drawings and/or production drawings, including component drawings and list of parts and materials;

(4) Design calculations (including design calculations for pressure-containing/load-carrying components, if applicable);

(5) Prototype and/or type test report (if any);

(6) Product inspection and test plan and/or test program and acceptance criteria;

(7) Other documents required by CCS.

2.3.3.2 CCS will review the submitted design documents to confirm that the product is designed in accordance with the provisions in the Guidelines or the accepted standards of the Guidelines. After the design review is completed, CCS will issue a design review approval notice to the applicant, mark the approval status on the technical documents submitted for review, and return the approved design documents.

2.3.3.3 For products approved by CCS, their design documents do not need to be submitted for review provided that there are no changes affecting their function or performance. If the above changes occur, the product design documents shall be submitted for review as a whole.

2.3.4 Product manufacturing surveys

2.3.4.1 In addition to conducting specific product inspection according to the product drawing approved, the surveyor shall understand the operating principle of the whole riser system, the function of the product inspected in the system, and the specific requirements of the product specifications.

2.3.4.2 The surveyor shall conduct product inspections according to the approved drawings and product specifications.

2.3.4.3 Manufacturing surveys include surveys during manufacturing and pre-delivery surveys and tests.

2.3.4.4 Before commencement, the following plans and documents shall be submitted to the CCS attending surveyor for review:

(1) Main manufacturing process documents;

(2) Quality plan/scheme;

(3) Inspection and test plan;

(4) Personnel qualification, including welders and NDE personnel.

2.3.4.5 The product inspection by CCS surveyors at the manufacturer includes but is not limited to the following items:

(1) Confirm that the product manufacturing and processing have a continuously effective quality control plan which includes design, procurement, processing and testing and meets the technical standards applicable to their products;

(2) Check the certificates or documents of materials;

(3) Check the main weldments before assembly;

(4) Check the final welded product;

(5) Witness the NDE of welds and review NDE records;

(6) Check the PWHT records, especially the pressure-containing structures with acid media shall comply with the requirements in relevant standards;

(7) Check that the dimensions are consistent with the approved drawings;

(8) Check that the installation dimensions and alignment of each component and part meet relevant standards and technical requirements;

(9) Check that all control, monitoring and instrumentation equipment is consistent with the approved drawings;

(10) Witness the prototype and/or type test of products in accordance with applicable standard requirements. For products of molded design, the surveyor shall check their prototype and/or type test documents;

(11) Witness the delivery test of products according to product specifications;

(12) Check other items agreed upon by all parties in advance;

(13) Review and approve the final manufacturing data book and the issued final survey report.

2.3.5 Product certification

2.3.5.1 After the product passes the inspection, relevant certificates and/or other survey certification documents will be issued to the applicant.

Section 4 Surveys During Construction

2.4.1 General requirements

2.4.1.1 The surveys during construction of the riser system mainly cover those at stages such as onshore prefabrication and assembly, offshore installation and completion test.

2.4.1.2 When applying for surveys by CCS during construction of a riser system, the applicant shall submit a written application to either CCS headquarters or its on-site survey agency, prior to the commencement of construction.

2.4.1.3 When a builder for the first time applies for building a riser system, the surveyor is to carry out evaluation for the production capacity of the builder, including production locations and facilities and quality assurance system of builder, general qualification of construction personnel and subcontractors.

2.4.1.4 Prior to the commencement of construction, the surveyor is to examine and confirm the preparations of the builder for construction, e.g., plan of preparations for construction, building/welding procedure, qualifications of welders/NDE personnel, list of certification requirements for marine products, welding specifications, NDE diagrams, list of survey/test items, materials used in construction, manufacturing tolerance standards, subcontractors (if applicable) and technical documents required before the commencement of construction.

2.4.1.5 The attending surveyor shall review and approve the construction drawings, construction processes, and test programs to confirm that they comply with the requirements in the design documents approved by the CCS plan approval department and CCS rules, and then surveys shall be carried out in accordance with the approved construction drawings, construction processes, and test programs.

2.4.2 Surveys at the onshore prefabrication and assembly stage

2.4.2.1 The following documents and materials at the onshore prefabrication and assembly stage of the riser system shall be submitted to CCS for approval:

(1) Welding Procedure Specification;

(2) NDE procedures;

(3) Heat treatment procedures;

(4) Hydrostatic test procedures for assembled pipe sections;

(5) Construction procedures of anti-corrosion coating;

(6) Construction procedures of the counterweight layer (if any);

(6) Installation procedures of sacrificial anode;

(7) Qualification certificates of welding and NDE personnel;

(8) Procedures for storage, loading and offloading, transportation of assembled pipe sections and temporary control measures for pipe corrosion;

(9) Inspection and test plan;

(10) Other documents and materials required by CCS.

2.4.2.2 At the onshore prefabrication stage of the riser system, the surveyor will survey the following items:

(1) Onshore prefabrication of pipe sections and manufacturing of main accessories;

(2) Check of the material certificates of pipes and components;

(3) Qualification review of welding and NDE personnel;

(4) Welding quality control and survey;

(5) Coating quality control and survey;

(6) Gauging and pigging tests;

(7) Hydrostatic test witness of assembled pipe sections;

(8) Other survey items required by CCS.

2.4.3 Surveys at the offshore installation stage

2.4.3.1 The following documents and materials at the offshore installation stage of the riser system shall be submitted to CCS for approval:

(1) Description of pipe laying methods and procedures;

(2) Welding Procedure Specification, NDE, painting construction and other technical procedures;

(3) Description of riser installation methods and procedures;

(4) Description of methods and procedures for connection between riser and submarine pipeline;

(5) Description of special workboats and equipment used for laying and installation;

(6) Qualification certificates of welding and NDE personnel engaged in offshore installation;

(7) Inspection and test plan;

(8) Other documents and materials required by CCS.

2.4.3.2 At the offshore installation stage of the riser system, the surveyor will survey the following items:

(1) Arrival inspection of riser system components;

(2) Check of the material certificates of pipes and components;

(3) Welding quality control and survey during offshore installation;

(4) Coating quality control and survey during offshore installation;

(5) Positioning of laying route;

(6) Installation and docking of risers with submarine pipelines and floating structures;

(7) Equipment installation and test;

(8) Various tests;

(9) Other survey items deemed necessary.

2.4.4 Surveys at final inspection and completion test stage

2.4.4.1 The following documents and materials at final inspection and completion test stage of the riser system shall be submitted to CCS for approval:

(1) Description of the completion test status, including the completion status diagram of the riser system, the deviation between the completion status and the original design, and the identified damage conditions and locations of the risers;

(2) NDE reports;

(3) Performance report on the anti-corrosion system;

(4) Report on the riser protection;

(5) Completion test program;

(6) Report on final inspection and completion test results;

(7) Other documents and materials required by CCS.

2.4.4.2 Final inspection and completion test of the riser system usually includes the following activities:

(1) Inspection of compliance of the riser configuration and routing location with the design tolerance, and inspection of the location of adjacent structures or obstacles;

(2) Inspection of compliance of the riser system components installed with the approved technical documents and the tolerance requirements;

(3) External inspection of important components, including coatings, sacrificial anodes, VIV

suppression devices, flex joints, monitoring systems, etc.;

(4) Inspection for local buckling using a gauging pig;

(5) Inspection of safety system;

(6) System pressure test, etc.

Section 5 Surveys for Maintaining Validity of Certificate

2.5.1 General requirements

2.5.1.1 This section specifies the survey requirements for maintaining the validity of the riser system certificate (classification or certification surveys).

2.5.1.2 Surveys after construction of the riser system for maintaining the validity of the certificate include annual surveys, renewal surveys and occasional surveys.

2.5.1.3 To ensure the safety of the riser system during operations, various surveys specified in this section shall be performed. CCS surveyors may expand the scope of surveys based on their professional judgment during the survey. The owner or operator shall provide corresponding survey conditions and make appropriate arrangements.

2.5.1.4 The owner or operator shall promptly submit to CCS the applications for various surveys to maintain the validity of the certificate, and prepare for the survey items and provide safety measures for the surveys in accordance with the requirements of the rules.

2.5.1.5 If, during survey, any damage or imperfection detrimental to the validity of the certificate is found and is deemed to require immediate corrective action, the surveyor shall notify the applicant of the required actions. Should these actions not be implemented, the surveyor shall promptly report the situation to the CCS headquarters.

2.5.1.6 Surveys of the riser system during operation may be carried out in accordance with the provisions of this section, or risk-based surveys may be carried out based on the results of risk analysis for the specific system.

2.5.1.7 A certificate may be reinstated within six months after its expiration, provided that a survey equivalent to the overdue survey is completed. If the certificate has been expired for more than six months, reinstatement requires completion of a survey equivalent to a renewal survey.

2.5.2 Annual surveys

2.5.2.1 Annual surveys are to be carried out on all riser systems. Annual surveys shall be carried out within 3 months before or after each anniversary date of the initial issuance or the most recent endorsement of the Certificate of Survey. The annual survey can be replaced by the renewal survey.

2.5.2.2 The annual surveys include:

(1) Check the implementation of external inspection items for that year according to the survey items and survey intervals specified in Table 4.16.2.4;

(2) Check the monitoring records of riser operating status, including:

① The temperature, pressure, flow rate, current speed and water dew point of the pipeline inlet and outlet;

② Density, pH and BS&W, etc.;

(3) Check the corrosion monitoring data of risers, including:

① Regular disassembly and corrosion trend analysis for risers with corrosion coupons;

② Regular monitoring data reading and corrosion trend analysis for risers with resistance probes or field fingerprint devices;

③ Regular disassembly and corrosion trend analysis for risers with bypass monitoring;

④ Recording of corrosion inhibitor injection amount for risers with corrosion inhibitors; Irregular detection of saprophytes, sulfate-reducing bacteria and Fe2+;

(4) Check composition analysis data, including oil, natural gas, water, pigging products, etc.;

(5) Check the assessment data of chemical agent effect;

(6) Check the inspection and maintenance records of the riser system;

(7) Verify whether a comprehensive inspection of the riser is required in that year and its implementation according to the requirements of the inspection interval;

(8) The comprehensive inspection shall meet the following requirements:

① Generally, the riser undergoes a comprehensive inspection for the first time within three years of initial operation. Subsequent inspection intervals shall be determined based on its fitness-for-service assessment results, but shall not exceed five years;

② The comprehensive inspection methods include internal inspection, hydrostatic test and direct assessment;

③ For risers that are suitable for internal inspection, an internal inspection tool should be used to conduct a comprehensive inspection of both internal/external corrosion and the geometric shape;

④ For risers not suitable for internal inspection, a comprehensive inspection can be carried out by a hydrostatic test. The hydrostatic test shall comply with the requirements in the corresponding national standards, industry standards and riser design standards;

⑤ If supporting documents demonstrate that the riser is not suitable for methods such as internal inspection or hydrostatic test, the comprehensive inspection may be conducted using the direct assessment method;

⑥ A fitness-for-service assessment shall be performed, with its results submitted to CCS for review, if an internal inspection or a direct assessment has been conducted on the riser within that annual period. The fitness-for-service assessment shall meet the following requirements:

a. When the internal inspection method is used, the fitness-for-service assessment report shall at least include information such as defect location, defect depth, defect development speed, residual strength of the riser, remaining service life of the riser, operational restrictions of the riser, and the cycle of the next internal inspection or direct assessment;

b. When the direct assessment method is used, the fitness-for-service assessment shall include process flow guarantee analysis, internal (external) corrosion analysis and structural integrity analysis. The fitness-for-service assessment report shall at least include information such as the location and area of corrosion, corrosion rate, corrosion depth, residual strength of the riser, remaining service life of the riser, operational restrictions of the riser, and the cycle of the next internal inspection or direct assessment.

2.5.2.3 Conclusion of annual surveys

After completion of field annual surveys, the surveyor shall make the following conclusions based on the survey results:

(1) The survey results meet the specified requirements, and an endorsement is made on the annual survey certificate;

(2) Non-conforming items exceeding the limits specified in the relevant technical safety regulations are identified during the survey, and appropriate operational restrictions shall be imposed based on the assessment results;

(3) Where practicable, the operator should enter the annual survey and its conclusions into the submarine pipeline management system and manage them using information technology.

2.5.3 Renewal surveys (or special surveys)

2.5.3.1 Renewal surveys are to be carried out on all riser systems. Renewal surveys shall be conducted within each 5-year interval to allow for the renewal of the Certificate of Survey. The first renewal survey shall be completed within 5 years from the date of first issuance of the Certificate of Survey, and subsequent renewal surveys shall be completed within 5 years from the last renewal survey.

2.5.3.2 The renewal survey items shall be carried out in accordance with annual survey items in 2.5.2 of this Chapter to confirm that the riser system meets the requirements in the Guidelines and has a corresponding level of safety. However, depending on the specific situation of the system, CCS may require additional survey items and tests.

2.5.4 Occasional surveys

2.5.4.1 Where any damage to the riser system may affect its safety, or where any alteration, repair, or significant replacement occurs to the riser system, or where there is a change in the conveyed medium or a significant change in the conveying conditions, the operator shall promptly apply to CCS for occasional surveys of the riser system. Related drawings and schemes shall be submitted to CCS for review, and surveys and tests shall be to the surveyor's satisfaction.

Section 6 Initial Surveys After Construction

2.6.1 General provisions

2.6.1.1 For riser systems that apply for our RISERS class notation or certification survey after construction, the owner/operator or their agents shall apply for initial surveys.

2.6.1.2 For riser systems not constructed under the supervision of CCS, the initial surveys include:

(1) Review the design, manufacture, installation, completion test and other relevant information of the riser system, including the product certificates and manufacturer's quality certification documents of the riser system components;

(2) Check the status information, monitoring data, test data, etc. of the riser system after it is put into operation. For specific survey items, please refer to the requirements in Section 2.5.2 of this Chapter.

2.6.1.3 For riser systems constructed under the supervision of CCS, the initial surveys include:

(1) Check the status information, monitoring data, test data, etc. of the riser system after it is put into operation. For specific survey items, please refer to the requirements in Section 2.5.2 of this Chapter.

Chapter 3 Design Basis Data

Section 1 General Provisions

3.1.1 General requirements

3.1.1.1 In the initial stage of riser system structural design, the designer shall prepare basic design documents of riser system. The basic design documents shall include a basic description of the floating structure and riser system, in addition to environmental condition data, internal fluid data, floating structure data, riser system data, design requirements, analysis requirements, etc.

3.1.1.2 In the event of any changes in the design basis data during the design process, the basic design documents of the riser system shall be updated in a timely manner, and the final riser system design shall be based on the final design basis data.

Section 2 Environmental Data

3.2.1 General requirements

3.2.1.1 The operator/designer shall specify environmental condition data for the riser system.

3.2.1.2 The riser system design shall take into account various factors that may affect the environmental conditions of the system under both installation and in-position conditions. General environmental conditions include: water depth, seawater data (such as temperature and density), air temperature, wind, waves, ocean currents, internal waves, tides, ice regimes, earthquakes, marine growth (attachments), seabed geology, seabed topography, seabed obstacles, subsea shallow-layer characteristics (such as shallow faults, subsidence, etc.) and seabed stability.

3.2.1.3 The environmental data shall be representative of the geographical area where the riser system is located. Where sufficient data for the specific location is not available, a reasonable and conservative estimate can be made based on the data of other relevant locations.

3.2.1.4 Environmental parameters of random nature (such as wind and waves) shall be quantitatively described by characteristic parameters obtained from long-term observation data using mathematical statistics methods. Characteristic parameters shall be determined using recognized statistical methods.

3.2.1.5 The main environmental condition data used in the riser design shall be consistent with those used in the floating structure design.

3.2.1.6 Based on its intended purpose, environmental condition data can generally be divided into the following categories:

(1) Extreme value data, mainly used for strength check and short-term fatigue check of individual events;

(2) Long-term distribution data, mainly used for long-term fatigue check;

(3) Normal environmental condition data, mainly used for verification of normal operating conditions and temporary operations (such as transportation and installation).

3.2.2 Water depth and level

3.2.2.1 The water depth from the mudline to the chart datum / mean still water level in the area where the base of each riser in the riser system is located shall be provided.

3.2.2.2 The water depth at any location includes the water depth at the mean still water level of that location plus the water level variation due to tides. When water depth is an important parameter, the effects of tides shall be considered, such as calculation of riser wave loads and determination of maximum or minimum external water pressure.

3.2.2.3 The mean still water level is the average level of the highest and lowest astronomical tides. The design maximum still water level includes the highest astronomical tide and positive storm surge. The design lowest still water level includes the lowest astronomical tide and negative storm surge.

3.2.3. Winds

3.2.3.1 Wind data is mainly used to calculate the motion of the floating structure induced by wind load, including the average offset and average inclination angle of the floating structure caused by steady mean wind speed and the low-frequency slow drift motion of the floating structure caused by gust wind speed, so as to determine the indirect effects of wind on the riser.

3.2.3.2 The mean wind speed is a function of time and location. Generally, the mean wind speed at 10m above the still water level over a certain period of time (usually 1 hour) is taken. The wind speed at other locations is converted based on the wind speed of this reference point.

3.2.3.3 The gust wind speed shall be selected to best represent the wind spectrum (such as API spectrum and NPD spectrum) in the area where the floating structure is located.

3.2.3.4 Mean wind speed data required for riser analysis shall include the main extreme values, conditional extreme values and directional extreme values of wind speed in each return period under typhoon conditions and non-typhoon conditions, and wind speed data corresponding to each short-term sea state in the wave scatter diagram.

3.2.4. Waves

3.2.4.1 Wave data is used to calculate the motion of floating structure induced by waves and the dynamic load effect of waves on the riser part in the near-surface area.

3.2.4.2 Waves shall be described by a wave spectrum representative of the sea area where the floating structure is located. Typically, the P-M spectrum/Bretschneider spectrum is used for fully developed sea areas, and the Jonswap spectrum is used for underdeveloped sea areas. If appropriate, they can also be described using the traditional regular wave method.

3.2.4.3 Wave statistical data usually includes different wave heights, periods, directions and probability of occurrence in the sea area.

3.2.4.4 Wave data shall include the main extreme values, conditional extreme values, directional extreme values and corresponding peak periods (or mean zero-crossing periods) of significant wave heights in each return period under typhoon conditions and non-typhoon conditions. Each significant wave height, peak period (or mean zero-crossing period) and joint probability of occurrence in all directions are given in the wave scatter diagram.

3.2.5 Currents

3.2.5.1 Consideration shall be given to the load effect of the currents on the floating structure connected to the riser and the direct effect of the currents on the riser part below the still water level. These effects include the effects of drag force, lift force and vortex shedding induced by currents.

3.2.5.2 Currents shall include currents induced by changes in wind and air pressure, currents induced by astronomical tides, circulation currents (related to ocean circulation patterns) and solitary currents (currents induced by internal waves resulting from density differences).

3.2.5.3 In the riser design, the current speed can be considered as steady. The ocean current data required for riser design shall usually include surface current speed in each direction (relative to a specific reference water depth position, e.g., 1m below the still water level) and current profile coefficients varying along the water depth for each return period under typhoon conditions and non-typhoon conditions, annual current profile speed distribution for riser VIV analysis, and surface current speed distribution for floating structure VIM analysis.

3.2.6 Marine growth

3.2.6.1 For permanent riser sections without anti-fouling coating, consideration shall be given to the effect of attached marine growth on the weight, diameter (including buoyancy diameter and hydrodynamic diameter) and hydrodynamic coefficient of the riser. The hydrodynamic coefficient is determined based on the roughness of marine growth.

3.2.6.2 The data on attached marine growth shall include the density of marine growth and the thickness that varies along the water depth.

3.2.7 Seabed geology

3.2.7.1 The seabed geological data is used to calculate the soil resistance of the riser base and underwater wellhead and analyze the riser-soil interaction in the touchdown zone of the SCR.

3.2.8 Earthquake

3.2.8.1 Consideration shall be given to the effects of seismic loads on the riser system if seismic activity is present in the area where the riser is installed.

3.2.8.2 When considering the effects of seismic loads, it is generally not necessary to combine other environmental conditions (such as winds, waves and currents).

3.2.9 Subsidence

3.2.9.1 If seabed subsidence is anticipated during the design life of the riser, consideration shall be given to its impact on the tensioner stroke design of the TTR.

3.2.10 Sea ice

3.2.10.1 If the riser system is located in an ice-covered sea area, consideration shall be given to the impact of sea ice on the riser system.

3.2.10.2 The collision analysis of ice loads on risers requires considering the impact of large-mass ice floes driven by currents and winds, as well as the impact of small-mass ice pieces driven by waves. The collision analysis requires data on the mass, additional mass, shape, speed, direction and physical and mechanical properties of ice.

3.2.11 Seabed stability

3.2.11.1 Riser installation, changes in riser operating conditions, wave pressure, soil weight, earthquakes and other factors may cause seabed movement. Areas of potential seabed instability need to be identified during geological surveys and avoided in the routing of risers and submarine pipelines.

Section 3 Internal Fluid Data

3.3.1 General requirements

3.3.1.1 The operator/designer shall specify the internal fluid data for the riser system.

3.3.1.2 The internal fluid data shall include the data on the type, composition, acidity, density, pressure (reference height position) and temperature of the fluid medium under various conditions during the installation, pressure test and operation of the riser.

3.3.1.3 For flexible pipes in riser systems, the internal fluid data required for their designs shall also comply with the applicable requirements in API Spec 17J and API RP 17B.

Section 4 Floating Structure Data

3.4.1 General requirements

3.4.1.1 According to the overall motion response analysis of the floating structure-mooring-riser system, the floating structure motion data of the conditions required for the riser design are given, including the corresponding conditions of the riser strength analysis, interference analysis, wave-induced fatigue analysis, and riser fatigue analysis induced by vortex-induced motions of floating structure.

3.4.1.2 The motion of a floating structure usually includes the following parts:

(1) Draft;

(2) Static offset;

(3) Subsidence;

(4) Wave-frequency motion;

(5) Low-frequency motion.

3.4.1.3 Depending on the analysis methods used, floating structure motion data can be provided in the following ways:

(1) Time history data of the six-degree-of-freedom motion of the floating structure under various conditions;

(2) The static position of the floating structure under various conditions and the transfer function of the floating structure motion based on the floating structure-mooring-riser system;

(3) Load transfer function of the floating structure and relevant data for calculation of load and resistance of the floating structure.

Section 5 Riser System Data

3.5.1 General requirements

3.5.1.1 The designer shall provide relevant data of the riser system in the design basis, including riser function and quantity, design life, riser location and configuration, operation mode, riser pipe and component data, coating and cathodic protection, VIV suppression device, interface connection, hydrodynamic coefficient, S-N curve, empirical coefficient used by the model, tolerance, etc.

3.5.1.2 The design life of risers used for production, export, injection and import shall generally not be shorter than that of the connected floating installation or single point mooring system. The design life of risers used for drilling, workover and completion shall be determined based on the actual use requirements of a specific project.

3.5.1.3 The design basis shall give data such as component dimension, weight, stiffness and hydrodynamic coefficient for riser analysis. Where experience-based assumed data are employed for important design parameters, the conservatism of these parameters shall be proved through sensitivity analysis or testing.

3.5.1.4 Allowances and tolerances to be considered in the riser design usually include corrosion allowance, wear allowance (if applicable), pipe thickness/dimensional manufacturing tolerance, weight tolerance, installation tolerance (position, angle), etc.

Section 6 Other Requirements

3.6.1 General requirements

3.6.1.1 Design requirements for the riser system, generally include design principles, applicable rules and standards, acceptance criteria, design limitations, etc.

3.6.1.2 Analysis requirements for the riser system, generally include analysis types, analysis methods, calculation software, working conditions, verification of analysis results, etc.

3.6.1.3 Acceptance criteria for the riser system, generally include the requirements for pressure bearing, collapse, combined load stress, interference, fatigue, deformation, corrosion, wear (if applicable), axial pressure, fracture, in-position stability, etc. and safety factors used in various types of design cases.

3.6.1.4 Operation plan is required for riser analysis, e.g., drilling plan for wear analysis.

Chapter 4 Riser System Design

Section 1 General Provisions

4.1.1 Safety goals

4.1.1.1 The overall safety goal of the riser system design is to control the failure probability (i.e., the probability of exceeding the limit state) of various failure modes below the specified value.

4.1.2 Design principles

4.1.2.1 The riser system shall be designed based on the following principles:

(1) Meet the requirements in the design specifications of the riser system;

(2) Meet the requirements in the design criteria such as riser strength and life;

(3) Use the "fail-safe" design for mechanical components (e.g., valves) of the riser system wherever practicable, or take measures for early failure detection and/or ensure sufficient redundancy for main components;

(4) Support simple and reliable installation and recovery, and robustness for operation;

(5) Provide access for inspection, maintenance, repair or replacement;

(6) Facilitate monitoring of the riser system, such as tension, stress, angle, vibration, fatigue cracks, wear and corrosion;

(7) Base on recognized manufacturing technical standards for the design of riser joint and other components;

(8) Avoid the escalation of an unforeseen event into an accident that far exceeds the scale of the original event.

4.1.3 Design methods

4.1.3.1 Design methods of riser structures include the working stress design (WSD) method, load and resistance factor design (LRFD) method, reliability-based method and test-based design method.

4.1.3.2 The WSD method is a common method for riser design. One safety factor or utilization factor is used to reflect the safety allowance of the structure under each limit state. The WSD method can be generally expressed as:

$$S_d(S) \leq \eta R_k \tag{4-1}$$

Where,

S_d is the total load effect;

R_k is the total resistance;

η is the safety factor, which is related to the failure mode and type of working conditions.

4.1.3.3 The LRFD method is to ensure that the design value of the load effect under any limit state does not exceed the design value of the structural resistance. The partial safety factors used include load effect factors and resistance factors. The load effect factors are determined based on the load category and limit state category, and the resistance factors are determined based on the safety class and limit state category. The safety class is determined based on factors such as the type, location, and operating status of the medium inside the riser. The LRFD method can be generally expressed as:

$$S_d(S_p; \gamma_F \cdot S_F; \gamma_E \cdot S_E; \gamma_A \cdot S_A) \leqslant \frac{R_k}{\gamma_{sc} \cdot \gamma_m \cdot \gamma_c} \tag{4-2}$$

Where,

S_p is the pressure load effect;

S_F is the functional load effect;

S_E is the environmental load effect;

S_A is the accidental load effect;

γ_F is the functional load effect factor;

γ_E is the environmental load effect factor;

γ_A is the accidental load effect factor;

γ_{sc} is the resistance factor to account for the safety class;

γ_m is the resistance factor to account for the material;

γ_c is the resistance factor to account for special conditions;

4.1.3.4 In the LRFD method, the limit states of the riser can be divided into the following four categories, and the corresponding partial safety factors are used based on the category of the analyzed conditions:

(1) Serviceability limit state;

(2) Ultimate limit state;

(3) Accidental limit state;

(4) Fatigue limit state.

4.1.3.5 In addition to the design methods specified in the Guidelines, the probabilistic design method based on recognized structural reliability analysis may also be used provided that it satisfies the following conditions and is approved by both the owner and CCS:

(1) This method is used to calibrate the limit states that may occur outside the scope specified in the Guidelines;

(2) This method complies with ISO 2394 or other recognized standards;

(3) It can be proved that the results obtained when this method is used in existing cases are safe enough.

4.1.3.6 Full-scale or model tests may be used to determine or verify the load effects, structural resistance and resistance of the riser system when material properties are reduced. All relevant discrepancies between the model test and the actual conditions shall be accounted for, including but not limited to:

(1) Size effects;

(2) Simplification of models/tests and their uncertainties;

(3) Simplification of data acquisition and processing and their uncertainties;

(4) Uncertainty of long-term effects and failure modes.

4.1.4 Design content and process

4.1.4.1 The riser system design is a cyclic design process related to floating structure design, operating requirements, etc. The design content and process of a typical riser system are shown in the figure below.

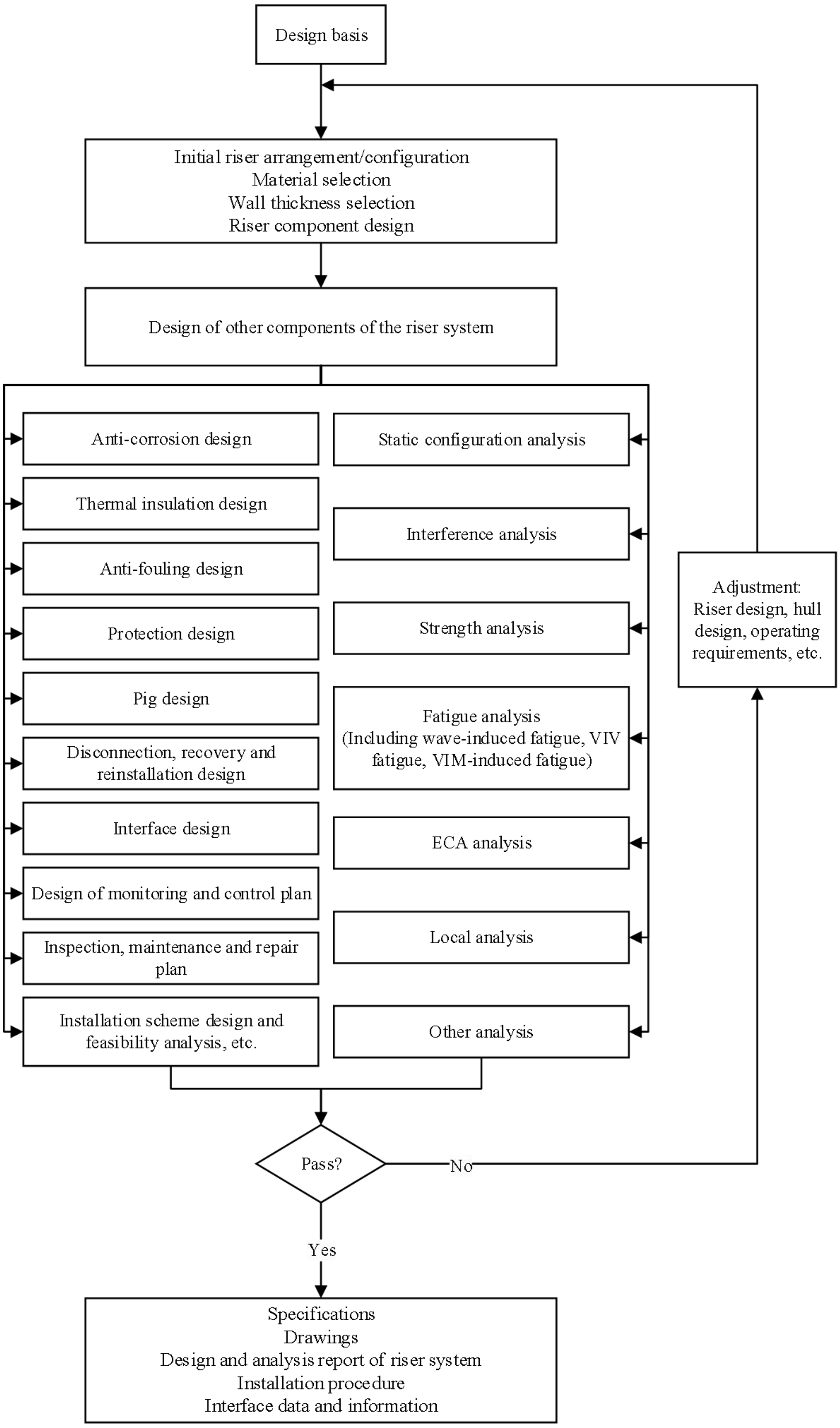

Figure 4.1.4.1 Design Content and Process of a Typical Riser System

Section 2 Loads and Load Cases

4.2.1 Loads

4.2.1.1 The loads acting on a riser can be categorized into pressure loads, functional loads, environmental loads and accidental loads.

4.2.1.2 Pressure loads generally include internal pressure, external hydrostatic pressure, and pressure induced by changes in water level. The local internal pressure of a specific riser section is calculated based on the height difference between the actual position and the reference point and based on the reference point for the riser design pressure.

4.2.1.3 Functional loads are loads arising from the physical properties of the system itself and loads generated by system operation, excluding environmental loads or accidental loads. Functional loads generally include:

(1) Weight and buoyancy of the riser, coating, marine growth, anode, buoyancy module, medium, auxiliary components, etc.;

(2) Nominal tension at the top of the riser;

(3) Installation induced residual loads;

(4) Prestress on the connector;

(5) Temperature load;

(6) Riser-soil interaction at the seabed;

(7) Installation load;

(8) In-line pigging, etc.

4.2.1.4 Environmental loads are those in the marine environment applied directly or indirectly to the risers. Environmental loads generally include:

(1) Wave load;

(2) Internal wave load and other effects caused by differences in seawater density;

(3) Ocean current load;

(4) Seismic load;

(5) Ice load;

(6) Motion of a floating structure caused by winds, waves and currents, etc.

4.2.1.5 Accidental loads generally include:

(1) Impact load of falling objects;

(2) Collision load between risers;

(3) Load due to breaking of floating structure mooring line;

(4) Load due to flooding of the floating structure/buoyancy tank space;

(5) Load due to failure of floating structure DP system;

(6) Load due to failure of tensioning device, etc.

4.2.2 Load cases

4.2.2.1 A load case is defined as a combination of pressure, functional, environmental, and accidental loads acting on the riser under specific conditions. This condition usually includes the riser operating conditions, environmental conditions, integrity of the floating structure compartment/mooring system/tensioner, and presence or absence of compensation.

4.2.2.2 The operator/designer shall specify the riser design conditions, including at least the following most dangerous situations:

(1) Maximum stress;

(2) Maximum rotation or bending;

(3) Hydrostatic collapse;

(4) Maximum load acting on a specific component;

(5) Fatigue.

4.2.2.3 For the WSD method, riser conditions are typically classified into:

(1) Operating conditions;

(2) Extreme conditions;

(3) Survival conditions;

(4) Installation conditions;

(5) Test conditions;

(6) Fatigue conditions.

The safety factor for each load case is determined based on the type of the case.

4.2.2.4 For the LRFD method, the safety factor for each load case is determined based on the type of the limit state.

4.2.2.5 Typical conditions for riser strength analysis are shown in Table 4.2.2.5:

Typical Conditions for Riser Strength Analysis **Table 4.2.2.5**

Working conditions	**Types of working conditions**	**Environmental conditions**	**Pressure**	**Compartment damage/tension loss/ mooring line breakage**	C_f
1	Operating conditions	Maximum operating conditions	Design pressure	No	1.0
2	Extreme conditions	Extreme conditions	Design pressure	No	1.2
3	Extreme conditions	Maximum operating conditions	Design pressure	Yes	1.2
4	Extreme conditions	Maximum operating conditions	Extreme pressure	No	1.2
5	Installation conditions	Erection conditions	Corresponding pressure	No	1.2
6	Test conditions	Maximum operating conditions	Hydrostatic test pressure	No	1.35
7	Survival conditions	Survival conditions	Corresponding pressure	No	1.5
8	Survival conditions	Extreme conditions	Corresponding pressure	Yes	1.5

4.2.2.6 Typical conditions for riser interference analysis are shown in Table 4.2.2.6:

Typical Conditions for Riser Interference Analysis Table 4.2.2.6

Working conditions	Types of working conditions	Environmental conditions	Density of medium inside upstream riser	Density of medium inside downstream riser	Compartment damage /tension loss/ mooring line breakage	Any compensation?
Flow-induced interference						
1	Extreme conditions	Extreme conditions (ocean currents)	Minimum	Maximum	No	No
2	Survival conditions	Survival conditions (ocean currents)	Minimum	Maximum	No	No
3	Survival conditions	Extreme conditions (ocean currents)	Minimum	Maximum	Yes	No
Wave-induced interference						
4	Extreme conditions	Extreme conditions (storms)	Minimum	Maximum	No	No
5	Survival conditions	Survival conditions (storms)	Minimum	Maximum	No	No
6	Survival conditions	Extreme conditions (storms)	Minimum	Maximum	Yes	No

4.2.2.7 Typical conditions for riser fatigue analysis are shown in Table 4.2.2.7. During the in-position period, it includes environmental conditions in the wave scatter diagram and flow loads (VIV and VIM). Extreme conditions for separate short-term fatigue include extreme storm conditions and extreme ocean current conditions.

Typical Conditions for Riser Fatigue Analysis Table 4.2.2.7

Working conditions	Types of working conditions	Environmental conditions	Pressure	Compartment damage/tension loss/mooring line breakage	Any compensation?
1	Long-term wave-induced fatigue conditions	Wave scatter diagram	Operating pressure	No	No
2	Short-term wave-induced fatigue conditions	Extreme conditions (storms)	Corresponding pressure	No	No

Working conditions	Types of working conditions	Environmental conditions	Pressure	Compartment damage/tension loss/mooring line breakage	Any compensation?
3	Long-term VIV fatigue conditions	Long-term ocean current profile	Operating pressure	No	No
4	Short-term VIV fatigue conditions	Ocean current profile under extreme conditions	Corresponding pressure	No	No
5	Long-term VIM-induced fatigue conditions	Ocean currents with joint probability distribution	Operating pressure	No	No
6	Short-term VIM-induced fatigue conditions	Ocean current profile under extreme conditions	Corresponding pressure	No	No
7	Installation fatigue conditions	Temporary conditions	Corresponding pressure	No	No

Section 3 Structural Design Criteria

4.3.1 General requirements

4.3.1.1 This section provides the common design criteria for dynamic steel risers. If required by the operator, the design criteria in other riser standards accepted in the Guidelines can also be used.

4.3.1.2 Non-steel risers and other components of the riser system shall comply with the relevant requirements in the corresponding standards adopted by the operator.

4.3.1.3 The static section of the flat-laid riser at the seabed shall comply with the relevant requirements in the CCS *Rules for Submarine Pipeline Systems* or other recognized submarine pipeline system rules specified by the owner.

4.3.1.4 In the riser design, appropriate allowances shall be given to the design allowances for corrosion, wear and erosion, as well as manufacturing (thickness, size, weight) tolerances and installation tolerances according to the actual conditions in each case. The actual deviations in manufacturing and installation shall meet the tolerance requirements adopted during design.

4.3.1.5 This section provides the main design criteria based on the WSD method. Other design criteria specified by the owner or based on the LRFD method shall comply with the requirements in API RP 2RD, API Std 2RD or other recognized riser standards.

4.3.2 Pressure-containing (rupture)

4.3.2.1 The riser shall comply with the requirements of withstanding the internal pressure under various conditions without rupture failure. According to the operator's requirements, the following design criteria can usually be used for riser pressure verification.

4.3.2.2 The internal pressure of the pipeline shall meet the following requirements:

$$P_i - P_e \leq F_b P_b \tag{4-3}$$

Where,

P_e is the external pressure, in MPa;

P_i is the internal pressure, in MPa;

F_b is the design factor, and its values for different internal pressures or pressure differences are as follows:

$$F_b=\begin{cases}0.81 & \textit{Casing internal pressure during oil pipe leakage}\\ 0.81 & \textit{Extreme pressure of drilling risers}\\ 0.90 & \textit{Hydrostatic test pressure}\\ 0.67 & \textit{Extreme pressure}\\ 0.60 & \textit{Maximum operating pressure}\end{cases} \tag{4-4}$$

P_b is the specified minimum burst pressure, in MPa, which can be calculated according to the following formula:

$$P_b=k(\sigma_y+\sigma_u)\ln\left(\frac{D}{D\text{-}2t_{min}}\right) \tag{4-5}$$

Where,

k is the coefficient with mechanical properties and wall thickness dimensional changes considered, taken as 0.45 for steel pipes in API Spec 5L or API Spec 5CT;

t_{min} is the nominal wall thickness minus the corrosion, wear and erosion thickness considered, in mm;

D is the nominal outer diameter of the pipe, in mm;

σ_y is the specified minimum yield strength of the riser, in MPa;

σ_u is the specified minimum tensile strength of the riser, in MPa.

4.3.2.3 For risers connected to submarine pipelines (e.g., SCR), the requirements in API RP 1111 may also be used.

4.3.3 Hydrostatic collapse

4.3.3.1 The riser shall comply with the requirements of withstanding the external pressure under various conditions without collapse failure. According to the operator's requirements, the following design criteria can usually be used for collapse verification.

4.3.3.2 For situations where the external pressure on the riser exceeds the internal pressure (such as offshore installation of an empty riser and loss of mud in the annulus of drilling risers), the following requirements shall be met:

$$P_e\text{-}P_i \leqslant F_c P_c \tag{4-6}$$

Where,

P_e is the external pressure, in MPa;

P_i is the internal pressure, in MPa;

F_c is the design factor, and its values corresponding to different internal pressures are as follows:

$$F_o=\begin{cases}0.6 & \textit{Cold expansion tube (such as DSAW)}\\ 0.7 & \textit{Seamless steel pipe or ERW pipe}\end{cases} \tag{4-7}$$

For cold-expanded pipes that are heat treated (at least 233°C) to restore yield strength, F_c may be increased from 0.6 to a maximum of 0.7.

P_c is the collapse pressure under pure external pressure. When the steel pipe is a round pipe, it can be calculated as follows:

$$P_c=\frac{P_y P_{el}}{\sqrt{P_y^2+P_{el}^2}} \quad \text{MPa} \tag{4-8}$$

P_y is the yield collapse pressure of the pipe, which can be calculated as follows:

$$P_y=2\sigma_y\left(\frac{t_{min}}{D}\right) \quad \text{MPa} \tag{4-9}$$

P_{el} is the elastic collapse pressure of the pipe, which can be calculated as follows:

$$P_{el}=\frac{2E(t_{min}/D)^3}{1-v^2} \quad \text{MPa} \tag{4-10}$$

σ_y is the specified minimum yield strength, in MPa;

E is modulus of elasticity, in MPa;

v is Poisson's ratio.

In cases where the ovality of the steel pipe is accounted for, the collapse pressure P_c may be calculated using the following formula:

$$\left(P_{\circ}-P_{el}\right)\left(P_c^2-P_{el}^2\right)=2P_cP_{el}P_p\delta_0\frac{D}{t_{min}} \tag{4-11}$$

Where,

δ_0 is the initial ovality, which can be calculated as follows:

$$\delta_0=\frac{D_{max}-D_{min}}{D_{max}+D_{min}} \tag{4-12}$$

The initial ovality shall not exceed 0.25%. This value does not include ovality caused at the installation stage, nor does it include ovality caused by external pressure or bending moment during service;

P_p is the plastic collapse pressure of the riser, which can be calculated as follows:

$$P_p=2\frac{t_{min}}{D}\sigma_y\alpha_{fab} \quad \text{MPa} \tag{4-13}$$

α_{fab} is the fabrication factor, which is taken as follows:

$$\alpha_{fab}=\begin{cases}1.000 & \textit{Seamless steel pipe}\\ 0.850 & \textit{UOE pipe}\\ 0.925 & \text{UO/TRB pipe}\end{cases} \tag{4-14}$$

4.3.4 Buckling

4.3.4.1 The riser shall meet the buckling requirements during installation and operation. The analysis shall take into account the simultaneous action of loads (such as external pressure, axial load and bending load) as well as variations in the riser (such as ovality, material anisotropy and residual stress).

4.3.4.2 For the case where the external pressure on the riser exceeds the internal pressure, the following requirements shall be met:

$$P_e-P_i\leqslant F_oP_o \tag{4-15}$$

Where,

P_e is the external pressure on the riser, in MPa;

P_i is the internal pressure on the riser, in MPa;

F_o is the design factor, and its values corresponding to different internal pressures are as follows:

$$F_o=\begin{cases}0.60 & \text{Cold-expanded pipe (such as DSAW)}\\ 0.75 & \textit{Seamless steel pipe or ERW pipe}\end{cases} \tag{4-16}$$

For a pipe exhibiting ovality and subjected to combined bending and axial loads, the minimum collapse pressure is:

$$P_\circ=P'_\circ\left(g\text{-}s/s_\circ\right) \qquad \text{MPa} \tag{4-17}$$

Where,

$P'_\circ$ is the collapse pressure of the round pipe under external pressure and axial load, which can be calculated as follows:

$$P'_o=\frac{P'_yP_{el}}{\sqrt{P_{el}^2+P_y'^2}} \qquad \text{MPa} \tag{4-18}$$

P'_y is the yield pressure of the pipe under axial load, which can be calculated as follows:

$$P'_y=2Y_r\left(\frac{t_{min}}{D}\right) \qquad \text{MPa} \tag{4-19}$$

P_{el} is the elastic collapse pressure of the pipe, which can be calculated as follows:

$$P_{el}=\frac{2E(t_{min}/D)^3}{1\text{-}v^2} \qquad \text{MPa} \tag{4-20}$$

D is the nominal outer diameter of the pipe structure, in mm;

$t_{\min}$ is the nominal wall thickness of the pipe minus the corrosion, wear and erosion allowances, in mm;

E is modulus of elasticity, in MPa;

v is Poisson's ratio;

g is the defect function, which can be calculated as follows:

$$g=\frac{(1+p^2)^{1/2}}{(p^2+f^2)^{1/2}} \tag{4-21}$$

p is the ratio of plasticity to elasticity, which can be calculated as follows:

$$p=P'_y/P_{el} \tag{4-22}$$

f is the out-of-roundness function, which can be calculated as follows:

$$f=[1+(\delta_0\cdot D/t_{min})^2]^{1/2}\text{-}\delta_0\cdot D/t_{min} \tag{4-23}$$

s is the bending strain of the pipe;

S_0 is the critical bending strain, which can be calculated as follows:

$$S_o=t_{min}/(2b\cdot D) \tag{4-24}$$

b is the strain reduction factor, which is 1.5 for API pipes;

δ_0 is the initial ovality, which can be calculated as follows:

$$\delta_0=\frac{D_{max}\text{-}D_{min}}{D_{max}+D_{min}} \tag{4-25}$$

Y_r is the reduced yield stress, which can be calculated as follows:

$$Y_r=\sigma_y\left\{\left[1-3\left(\frac{S_a}{2\sigma_y}\right)^2\right]^{1/2}-\frac{S_a}{2\sigma_y}\right\} \qquad \text{MPa} \tag{4-26}$$

σ_y is the specified minimum yield strength, in MPa;

S_a is the average axial stress, which can be calculated as follows:

$$S_a=(T_e-P_{net}A)/a-P_i \qquad \text{MPa} \tag{4-27}$$

T_e is the effective axial force of the pipe, in N;

P_{net} is the net external pressure, which can be calculated as follows:

$$P_{net}=GH-P_i \qquad \text{MPa} \tag{4-28}$$

A is the cross-sectional area of the pipe, which can be calculated as follows:

$$A=\pi D^2/4 \qquad \text{mm}^2 \tag{4-29}$$

a is the cross-sectional area of the pipe wall, which can be calculated as follows:

$$a=\pi[D^2-(D-2t_{min})^2]/4 \qquad \text{mm}^2 \tag{4-30}$$

P_i is the internal pressure of the pipe, in MPa;

G is the unit weight of seawater, in N/mm3;

H is the water depth of the pipe, in mm.

4.3.5 Collapse propagation

4.3.5.1 For a riser design that meets hydrostatic collapse requirements, collapse may still initiate and propagate under lower pressure if the pipe is damaged (e.g., by impact from accidental loads) or if excessive bending moment occurs due to tensioner failure until the external pressure is small enough to reach the expansion pressure or expand to the buckle arrestor. The collapse propagation pressure can be calculated by the following formula:

$$P_p=24\sigma_y(t/D)^{2.4} \qquad \text{MPa} \tag{4-31}$$

4.3.5.2 In the riser design, consideration shall be given to the consequences of collapse propagation (e.g., the number of damaged pipe sections) and feasible methods for replacement and repair. The buckle arrestor, if equipped for the riser, shall meet the corresponding requirements in API 1111. If the buckle arrestor is positioned at a location critical for riser fatigue, the associated stress concentration effects induced by the buckle arrestor shall be accounted for in the riser fatigue analysis.

4.3.6 Combined load

4.3.6.1 For the dynamic strength analysis of the riser, the equivalent stress shall meet the following requirements:

$$\left(\sigma_p\right)_e\leqslant C_aC_f\sigma_y \tag{4-32}$$

Where,

σ_y is the yield strength of material, in MPa;

C_a taken as 2/3;

C_f value taken as per the requirements in 4.2.2.

For ordinary steel round pipes, when both the transverse shear force and torsion load are neglected, the equivalent stress of the membrane stress is:

$$\left(\sigma_p\right)_e=Max\frac{1}{\sqrt{2}}\sqrt{\left(\sigma_{pr}-\sigma_{p\theta}\right)^2+\left(\sigma_{p\theta}-\sigma_{pz}\right)^2+\left(\sigma_{pz}-\sigma_{pr}\right)^2} \quad \text{MPa} \tag{4-33}$$

Where,

The radial membrane stress can be calculated as follows:

$$\sigma_{pr}=-\frac{P_o\cdot D+P_i\cdot D_i}{D+D_i} \quad \text{MPa} \tag{4-34}$$

The circumferential membrane stress can be calculated as follows:

$$\sigma_{p\theta}=\left(P_i-P_{\circ}\right)\frac{D}{2t_{min}}-P_i \quad \text{MPa} \tag{4-35}$$

The axial membrane stress can be calculated as follows:

$$\sigma_{pz}=\frac{T_w}{A}\pm\frac{M}{2I}\left(D-t_{nom}\right) \quad \text{MPa} \tag{4-36}$$

The cross-sectional area of pipe wall can be calculated as follows:

$$A=\frac{\pi}{4}\left(D^2-D_i^2\right) \quad \text{mm}^2 \tag{4-37}$$

The moment of inertia of the pipe section can be calculated as follows:

$$I=\frac{\pi}{64}\left(D^4-D_i^4\right) \quad \text{mm}^4 \tag{4-38}$$

The nominal wall thickness of the pipe can be calculated as follows:

$$t_{nom}=\frac{D-D_i}{2} \quad \text{mm} \tag{4-39}$$

The minimum wall thickness can be calculated as follows:

$$t_{min}=t_{nom}-t_{corr} \quad \text{mm} \tag{4-40}$$

4.3.6.2 If agreed by the owner, the combined load verification criteria from API Std 2RD may also be adopted for the strength criteria of the riser under combined loads.

4.3.6.3 The riser strain shall not exceed the limit requirements of the base material and welds. If the total nominal strain in any direction (excluding strain concentration) due to installation and operations exceeds 0.5% at the OD surface, consideration shall be given to both strain-based design and the additional material requirements in Section 7.7 of API Std 2RD.

4.3.7 Fatigue life based on S-N curve

4.3.7.1 The fatigue life assessment of the riser design should be carried out using the S-N curve and the Palmgren-Miner linear cumulative damage theory.

4.3.7.2 In the fatigue life assessment of the riser, all cyclic loads that may cause fatigue damage throughout the life cycle of the riser shall be taken into account, including fatigue damage generated during installation, fatigue damage caused by wave loads (wave-frequency and low-frequency) during the in-position period, VIV fatigue damage caused by currents, and fatigue damage caused by vortex-induced motion of floating structure.

4.3.7.3 In the fatigue life assessment of the riser, it is required to separately verify the total long-term fatigue damage of the riser caused by various cyclic loads and the short-term fatigue damage caused by individual extreme/survival events.

4.3.7.4 The total long-term fatigue damage of the riser includes long-term wave-induced fatigue damage, long-term VIV fatigue damage and long-term VIM-induced fatigue damage and fatigue damage during installation, and it shall meet the following requirements:

$$(1\text{-}\beta)/\big((SF_{wave}\times D_{wave})+(SF_{VIM}\times D_{VIM})+(SF_{VIV}\times D_{VIV})\big)>Design\ life \tag{4-41}$$

Where,

D_{wave} is the annual wave-induced fatigue damage (including wave-frequency and low-frequency effects);

D_{VIM} is the annual VIM fatigue damage;

D_{VIV} is the annual VIV-induced fatigue damage;

β is the proportion of fatigue damage during installation to total long-term fatigue damage;

SF_{wave}, SF_{VIM} and SF_{VIV} are the corresponding fatigue safety factors, and their values shall at least meet the following requirements:

$$SF=\begin{cases} 3 & Locations\ for\ in\text{-}service\ inspection\ or\ low\text{-}risk\ locations \\ 10 & Locations\ not\ in\text{-}service\ inspection\ or\ high\text{-}risk\ locations \end{cases} \tag{4-42}$$

4.3.7.5 For calculation of the total long-term fatigue damage of the riser, the expected fatigue damage during riser installation (e.g., fatigue damage during SCR laying and recovery stages) shall be specified. The installation analysis results shall meet the expected fatigue damage requirements.

4.3.7.6 When applicable, fatigue caused by the following factors should be considered:

(1) Stress cycles in the riser caused by shutdown and startup operations;

(2) Temperature fluctuations;

(3) Impact of reel-lay on the weld fatigue life;

(4) Circular riser-soil interaction.

4.3.7.7 The short-term fatigue damage from individual extreme/survival events shall not be accumulated with the long-term fatigue damage. Separate verification is required for each event. The safety factor for short-term fatigue damage assessment of individual extreme events shall not be less than 10. If required by the owner, a robustness analysis of short-term fatigue damage for individual survival events can be performed with a safety factor of not less than 1. The duration of an individual extreme/survival event shall be determined based on the conditions within the area where the event occurs.

4.3.7.8 Fatigue damage assessment shall be carried out for all critical locations of the riser where cracks are anticipated (typically at welds and stress concentration points).

4.3.8 Fatigue life based on fracture mechanics

4.3.8.1 For initial cracks detected in riser components or welds, engineering critical assessment methods based on fracture mechanics can be used to calculate the remaining fatigue life of these cracks, establish acceptance criteria for NDE of risers during manufacturing/installation/in-service and survey intervals during service, or predict appropriate S-N curves for welded joints that lack applicable S-N curves.

4.3.8.2 The growth life of fatigue cracks shall meet the following requirements:

$$\frac{N_{tot}}{N_{cg}} \cdot SF \leq 1 \tag{4-43}$$

Where,

N_{tot} is the total number of cyclic stresses during the service life or survey cycle;

N_{cg} is the number of stress cycles required for initial crack growth to critical size;

SF is the fatigue safety factor.

4.3.9 Interference

4.3.9.1 Acceptance criteria for riser interference analysis:

(1) In extreme conditions, risers must not come into contact with each other. Typically, the distance between the outer surfaces of adjacent risers shall be at least twice the average outer diameter;

(2) In survival conditions, collision is permissible, provided that the assessment demonstrates that the riser will not suffer further collapse.

4.3.9.2 The clearances for other components in the riser system, such as the spacing between the riser and the floating structure, the spacing between the flexible jumper /umbilical cable of the TTR system at the top and the adjacent equipment/structure, and the spacing between the Christmas tree at the top of the TTR and the adjacent equipment/structure, shall comply with the requirements in the design specifications.

4.3.10 Allowable deformation/rotation

4.3.10.1 Riser deformation shall be controlled to avoid unacceptable bending stresses and curvature radii (e.g., for flexible pipes) and unacceptable stresses on tubing or other pipelines fixed to the riser.

4.3.10.2 For components with relative motion restrictions such as the tensioner, flex joint, telescopic joint and jumper hose in the riser system, their maximum stroke/rotation angles shall comply with the requirements in the design specifications during the analysis of extreme conditions and accidental conditions of the riser.

4.3.11 Axial load

4.3.11.1 For displacement-controlled cases (e.g., riser motion following the floating structure), it is acceptable if the axial negative tension in the riser does not lead to other failures, such as stress or curvature. Axial buckling of the riser caused by load control (e.g., loss of buoyancy of the buoyancy tank) is unacceptable.

4.3.11.2 For top tensioned risers (including steel riser sections in top tensioned risers and hybrid risers), the minimum tension requirements in the design specifications shall be met to avoid excessive bending stresses at locations with small or negative effective tensions caused by small changes in effective tension at the top of the riser.

Section 4 Material Selection

4.4.1 General requirements

4.4.1.1 The material selection of the riser system shall follow the following principles:

(1) The materials shall meet the functional performance requirements and demonstrate compatibility with the expected internal and external environment conditions (such as medium composition and temperature);

(2) The materials shall meet all requirements applicable to various expected dynamic responses, including dynamic load generated by the motion with the floating structure, vortex-induced vibration, interaction between the riser and the seabed, production operation, transportation, loading and offloading, and storage;

(3) The materials shall have mechanical properties that meet design requirements, including strength, hardness, toughness, fatigue performance, etc.;

(4) The materials shall fit the intended manufacturing and installation methods, such as welding, processing and reel-lay;

(5) The materials shall be able to avoid electro-corrosion and interaction with heterogeneous materials;

(6) The materials shall be able to maintain adequate material properties throughout the design life;

(7) The materials shall have sufficient resistance to wear or mechanical damage.

4.4.1.2 Riser components designed to withstand high stresses (such as stress joints) may be made of titanium or other high-strength materials.

4.4.1.3 Metal castings shall not be used for pressure-containing components and for components directly welded onto pressure-containing components.

4.4.1.4 Non-metallic sealing materials selected should meet the following requirements:

(1) They shall have adequate physical and mechanical properties for all intended operations;

(2) They shall be resistant to extrusion or creep under high pressure;

(3) They shall be resistant to thermal cycles and dynamic loads;

(4) They shall be resistant to rapid decompression of the gas in the pipe;

(5) Performance degradation during the design life shall not exceed the limit.

Section 5 General Arrangement

4.5.1 General requirements

4.5.1.1 The riser shall be located as far as possible from residential areas and critical safety areas, and its layout shall avoid damage from fire, explosions, or other hazards. To prevent small-scale fires from escalating to casualties or equipment failure, fire prevention measures shall be taken for risers, riser supporting structures, and tensioning equipment.

4.5.1.2 The spacing between risers shall comply with the requirements of riser interference.

Section 6 Anti-corrosion Design

4.6.1 General requirements

4.6.1.1 All components of the riser system shall be made of materials suitable for the anticipated corrosive environment, or shall be protected with appropriate anti-corrosion measures to prevent both internal and external corrosion of the riser.

4.6.1.2 The corrosion of the riser system is divided into external corrosion and internal corrosion. External anti-corrosion measures usually include anti-corrosion coatings (for example, spraying aluminum) and cathodic protection methods. Internal anti-corrosion measures usually include material selection, injection of corrosion inhibitors, wall thickness corrosion allowance, internal anti-corrosion coating (including CRA lining) and other methods.

4.6.2 External anti-corrosion coating

4.6.2.1 The riser system design shall incorporate the most suitable external anti-corrosion coating. The coating system selected shall:

(1) Be able to withstand the loads during operation and installation, including hydrostatic pressure, thermal expansion, lifting/installation load, fatigue load, impact load in a splash zone, damage to assembled threaded connectors, wear with other components, etc.;

(2) Be resistant to damage caused by temporary contact with the internal medium during connector assembly or in the event of thread damage;

(3) Be resistant to damage such as peeling, cracking and embrittlement;

(4) Be resistant to electro-corrosion at the joints of different materials;

(5) Be resistant to the attached marine growth (including both flora and fauna);

(6) Be capable of enhancing protection in areas where cathodic protection is insufficient (such as risers covered by VIV suppression devices and risers in splash zones);

(7) Be maintainable and repairable;

(8) Be fireproof;

(9) Be resistant to UV aging.

4.6.2.2 The environment in splash zones accelerates metal corrosion, and appropriate anti-corrosion coatings shall be taken into account for these zones.

4.6.3 Cathodic protection

4.6.3.1 Cathodic protection is typically accomplished using sacrificial anodes, or using impressed current or a combination of both. In design, the following factors shall be taken into account:

(1) Surface area of riser;

(2) Environmental conditions;

(3) Adaptability of sacrificial anode to specific marine environment;

(4) Design life of sacrificial anode;

(5) Physical damage protection of sacrificial anode;

(6) The influence of current interference from nearby structures;

(7) The need to install insulated joints for the electrically isolated parts of the system;

(8) Survey requirements for rectifiers or other external power supplies.

4.6.3.2 The sacrificial anode used for cathodic protection of the riser should be located on the static section of the riser at the seabed or on the hull structure and underwater structure connected to the riser. It should not be located in the dynamic section of the riser to avoid stress concentration and coating damage.

4.6.3.3 If the sacrificial anode is installed on the dynamic section, the effects of the riser's dynamic response (especially bending deformation) shall be considered in the design. The welding procedure used during installation may influence the material properties of the riser, potentially leading to stress concentration and excessive hardness. Therefore, special attention should also be given to the welding procedure.

4.6.3.4 Direct electrical contact shall be designed between the various components of the riser system using cathodic protection. For locations where coatings or rubber may impede electrical contact, appropriate measures shall be implemented to ensure electrical continuity.

4.6.3.5 The design of the cathodic protection system for the riser system shall be coordinated with the adjacent hull/underwater structure. The risers shall maintain electrical continuity with sacrificial anodes installed on the hull/underwater structure to provide cathodic protection for risers.

4.6.3.6 If cathodic protection is used for riser materials susceptible to hydrogen embrittlement (such as high-strength steel, duplex stainless steel and buttering), effective intervention methods (such as coating and welding procedure) shall be implemented to prevent potential failure.

4.6.3.7 Cathodic protection design and calculations for risers shall comply with the requirements in ISO 15589-2 or other recognized standards specified by the owner. The cathodic protection design of other auxiliary components in the riser system shall comply with the requirements in relevant recognized standards.

4.6.4 Corrosion allowance

4.6.4.1 For steel risers, the corrosion allowance shall be assessed, taking into account the anticipated corrosion occurring throughout all stages, including manufacturing, transportation, storage and operation.

4.6.4.2 The corrosion allowance shall be determined, taking into account the following factors: the anti-corrosion method applied, the corrosion resistance of the material, the chemical composition of the media in the pipe and seawater, the position on the riser, etc. For splash areas, additional corrosion allowances may be added.

4.6.4.3 If the riser is adequately protected against corrosion, a corrosion allowance may not be necessary.

Section 7 Anti-fouling Design

4.7.1 General requirements

4.7.1.1 The riser can be designed to clean marine growth by moving the anti-fouling equipment along the riser. In such a case, the riser surface shall be resistant to the loads imposed by the anti-fouling equipment.

4.7.1.2 The riser may be applied with anti-fouling coatings to reduce or eliminate specific types of marine growth. For anti-fouling coatings that release toxic substances, their application must comply with local regulations.

Section 8 Wear and Erosion

4.8.1 General requirements

4.8.1.1 For anticipated wear and erosion on the internal or external surfaces of the riser, or between riser components, the estimated material loss shall be less than the design allowance, or adequate measures shall be implemented to prevent excessive wear of the riser.

4.8.1.2 For the SCR, consideration shall be given to the wear caused by the motion of the riser in the touchdown zone. The anti-corrosion or counterweight coating, if also designed to resist wear, shall have a thickness and material composition appropriate for effective wear resistance.

Section 9 Thermal Insulation Design

4.9.1 General requirements

4.9.1.1 The thermal insulation design of the riser shall meet the medium transportation temperature requirements required for flow guarantee.

4.9.1.2 To reduce heat loss during medium transportation, the riser can be designed with thermal insulation measures, which usually include:

(1) Fill the annulus of a pipe-in-pipe with still water or gas;

(2) Use thick protective coating for thermal insulation;

(3) Use a single-purpose thermal insulation coating;

(4) Reduce the number of heat radiation components connected to the riser;

(5) Take active heating measures, etc.

Section 10 Mechanical Damage Protection

4.10.1 General requirements

4.10.1.1 If possible, the riser shall be protected from mechanical damage such as collision, either by positioning it appropriately within the floating structure or by providing it with suitable protection measures. Protection measures for the riser may include protective nets, bumpers, frames, buoyancy foam wrapping, etc.

4.10.1.2 Valves or other underwater structures in the riser shall be properly protected to prevent damage from fishing gear, anchors, etc.

Section 11 Diameter Requirements

4.11.1 General requirements

4.11.1.1 Depending on the type of riser, the following operations may need to be conducted through its inner bore from the floating installation:

(1) Drilling;

(2) Workover and completion;

(3) Through-tubing;

(4) Coiled tubing;

(5) Flushing;

(6) Pipeline pigging, riser internal maintenance, etc.

4.11.1.2 If the riser design requires the aforementioned operations through the inner bore, the inner diameter, tolerance, material, bending curvature and other factors of the riser shall be designed to comply with the requirements for the passage of relevant operating equipment.

Section 12 ROV Compatibility

4.12.1 General requirements

4.12.1.1 The corresponding component of the riser system shall be designed with an interface for the remotely operated vehicle (ROV), if to be used, in the installation and maintenance of the riser system. The ROV interfaces shall comply with the relevant requirements in ISO 13628-8.

Section 13 System Interface

4.13.1 General requirements

4.13.1.1 For specific projects, the interfaces between the riser system and the upper floating structures and submarine structures/submarine pipelines, etc. shall be determined by the operator/designer.

4.13.1.2 In addition to the design requirements for the riser string in Section 3 of this Chapter, the structures/equipment at the top and bottom of the riser system shall meet all necessary interface requirements.

4.13.2 Structural requirements

4.13.2.1 The components at the top and bottom of the riser system shall be designed to withstand the load/motion of the riser and maintain sealing and pressure bearing capability.

4.13.2.2 For the riser porch structure used to connect the riser basket structure on the floating structure, it shall be designed to meet the size and load requirements of the riser. If the porch structure needs to support risers of different weights, an appropriate amplification factor can be used for the load during design to ensure fitness-for-purpose of the porch structure for different risers.

4.13.3 Functional requirements

4.13.3.1 The interfaces at the top and bottom of the riser system shall be designed to comply with the requirements for fluid transfer, umbilical cables for monitoring systems and operating requirements (e.g., drilling/workover/completion). The relevant components shall comply with the requirements for necessary connection, installation, maintenance, release, etc.

Section 14 Operation Limits and Emergency Operations

4.14.1 General requirements

4.14.1.1 Risers may be designed to remain connected or to be disconnected in an emergency under extreme conditions. For risers designed to remain connected under extreme conditions, their interference, strength and fatigue shall comply with the requirements of the corresponding design criteria. For risers designed to be disconnectable, they shall support emergency operations (e.g., disconnection) when environmental conditions exceed normal operation limits and support reconnection once conditions are restored.

4.14.1.2 The disconnection of the riser can be categorized as: (1) normal or scheduled disconnection; (2) rapid or emergency disconnection. In a scheduled disconnection, hydrocarbons are typically cleared from the riser and displaced by seawater using surface or underwater equipment, such as the Christmas tree, prior to riser disconnection. In an emergency disconnection, surface or underwater equipment, such as the Christmas tree, typically isolates the hydrocarbons within the riser and prevents additional hydrocarbon ingress, thereby minimizing hydrocarbon loss upon riser disconnection.

4.14.1.3 For the riser system designed to allow emergency disconnection, emergency operations may include riser disconnection, temporary free standing, deployment to the seabed, suspending, recovery and reinstallation.

4.14.1.4 For a top-disconnected riser, it may be designed to be temporarily deployed to the seabed or configured for temporary free-standing in an acceptable vertical configuration. For a bottom-disconnected riser, it may be designed to be temporarily recovered to the water surface or suspended on a floating unit.

4.14.2 Operation limits

4.14.2.1 For the riser system designed to allow emergency disconnection, corresponding operation limits shall be established for both normal operation while connected and for each emergency operation procedure designed. These limits can be illustrated using a relationship diagram between the maximum allowable riser offset and sea state parameters. Normal operations with the riser in a connected state shall be limited within the permissible contour.

4.14.2.2 The following factors are usually considered when determining the offset limit of the riser in the connected state and each emergency operation mode:

(1) The distance between the riser and the moon pool;

(2) Rotation limit of the bottom flex joint;

(3) Rotation limit of the top flex joint;

(4) Riser tension;

(5) Length of flexible jumper, etc.

4.14.3 Disconnection

4.14.3.1 Rapid or emergency disconnection can be designed for emergencies in the floating structure or well system, failure of the floating structure positioning system, and situations where environmental conditions suddenly exceed the operating threshold of the riser. The components for quick or emergency disconnection include the quick disconnect coupling between the riser and the floating structure, the riser bottom assembly of the riser, etc.

4.14.3.2 Prior to disconnection at the riser bottom, its top tension is typically reduced first to prevent recoil. In the riser design, the minimum tension requirement to ensure the riser stability in this case shall be determined.

4.14.3.3 Riser disconnection shall be designed to avoid collision with adjacent wellheads or risers.

4.14.3.4 The following aspects shall be considered for the rapid or emergency disconnection procedure:

(1) Production shutdown of all oil and gas processing equipment;

(2) Closure of all underwater and riser valves;

(3) Emergency unlocking of risers. If necessary, a disconnection safety system may be designed to close all underwater valves and bring the production system to a fully safe shutdown state.

(4) Monitoring of the riser bottom angle to ensure no greater than the maximum allowable rotation angle;

(5) Riser tension greater than the minimum tension determined by the design.

4.14.4 Temporary free standing

4.14.4.1 For a top-disconnected riser in a temporary free-standing configuration, a safe connection point shall be designed for the riser bottom connector, and the riser shall maintain adequate clearance from critical equipment. Sufficient buoyancy shall be provided at the riser top to avoid damage to other equipment or to the riser itself while in its temporary emergency position.

4.14.5 Suspending

4.14.5.1 The suspending limits of the riser shall be determined based on the range of anticipated environmental conditions (such as wave height and current), the floating structure profile, etc. The collision between the riser and the floating structure is a governing criterion for the suspending mode.

4.14.6 Recovery and reinstallation

4.14.6.1 The following aspects are generally considered for the riser recovery procedures:

(1) Appropriate reverse installation procedures for riser recovery;

(2) Required floating structure ballast;

(3) Recoil and tension adjustment after disconnection;

(4) Guidance system that may be required;

(5) Potential need for control of the floating structure offset.

4.14.6.2 For risers to be reinstalled after disconnection, in addition to the initial installation considerations, the spacing and interaction with adjacent existing risers shall be taken into account.

Section 15 Monitoring and Control

4.15.1 General requirements

4.15.1.1 This section specifies the monitoring and control requirements for riser systems used for permanent operations. Riser systems used for temporary operations shall meet the monitoring and control requirements in the CCS *Guidelines for Survey of Offshore Drilling Systems* or other applicable rules and standards.

4.15.1.2 The riser system shall be monitored and controlled as required from the main production processing system control station, main control station, or other designated locations of the floating structure so as to determine whether its operating conditions exceed its design conditions and allow for appropriate adjustments to be made.

4.15.1.3 The marine environment monitoring and floating structure motion monitoring related to the riser system shall meet relevant requirements in the CCS *Rules for Classification of Offshore Floating Installations* or other applicable standards.

4.15.2 Monitoring system

4.15.2.1 The riser system monitoring includes internal medium status monitoring, riser corrosion monitoring and riser structure monitoring. Internal medium status monitoring usually covers the medium composition, temperature, pressure, etc. Corrosion inside the riser can be monitored using metal test piece method. Riser structure monitoring may include riser tension, stress, angle, stroke, spacing, etc.

4.15.2.2 The internal medium status monitoring shall comply with the relevant laws and regulations of coastal states and the relevant provisions of oil and gas processing systems. An alarm shall be triggered upon the riser reaches its operation limits.

4.15.2.3 Riser structure monitoring can be used to maintain accurate riser tension during operation, monitor riser dynamic response, evaluate riser fatigue life, assist in floating structure dynamic positioning control, and verify design methods and tools. Riser structure monitoring shall be designed according to the operator's requirements, but it is not a mandatory requirement.

4.15.2.4 Based on the recording and transmission methods of monitoring data, riser structure monitoring methods can be classified into offline standalone monitoring, cable wired real-time monitoring, optical fiber wired real-time monitoring and acoustic real-time monitoring. If real-time recording of data peaks is required to support decision-making, online monitoring is typically employed. In contrast, offline monitoring is more suitable for long-term objectives, such as service life assessment.

4.15.2.5 The location, spacing and number of monitoring points can be determined based on the overall riser analysis results. The design can follow the principles below:

(1) If multiple risers are installed, it is not necessary to monitor all of them. The riser(s) to be monitored shall be selected based on their utilization rate and failure consequences;
(2) The local response at the most critical locations shall be monitored, such as the location of maximum stress/maximum fatigue damage or key components;
(3) Monitoring points shall be positioned to capture the overall response of the riser, either by distributing them throughout the structure or concentrating them in critical areas;
(4) The number of monitoring points shall be sufficient to achieve the required accuracy level in the monitoring results;
(5) Monitoring points shall be positioned to allow for easy installation and replacement of monitoring instruments.
(6) Redundancy design.

4.15.3 Control system

4.15.3.1 The riser system shall be equipped with a control system for the internal fluid medium, such as:
(1) Emergency shutdown;
(2) Pressure protection device;
(3) Pressure, temperature and flow control devices;
(4) Release device.

4.15.3.2 The control system may also be designed to adjust riser structure response parameters, control wellhead connectors, etc. by changing the riser top tension or position.

Section 16 Inspection, Maintenance and Repair

4.16.1 General requirements

4.16.1.1 This section specifies the principle requirements for in-service inspection, maintenance and repair that should be considered in the riser system design.

4.16.2 Inspection

4.16.2.1 The inspection principles of the riser system shall be considered as part of the riser system design, combined with the criticality and inspection difficulty of the components. The designer shall ensure that the riser system allows for all necessary inspections.

4.16.2.2 The external inspection of the riser system generally covers above-water components (e.g., tensioners), underwater key components (e.g., flex joints), VIV suppression devices, external damage to the riser, overall configuration of the riser, torsion, external corrosion, coating, sacrificial anodes, attached marine growth, SCR touchdown zone and seabed conditions, slippage of the buoyancy module, position of underwater buoyancy tank, flexible pipe bending restrictor/stiffener, etc. The external inspection of its underwater portion is primarily conducted using the ROV.

4.16.2.3 The internal inspection plan of the riser system shall be determined based on the operator's inspection principles and the operational risks of the riser system.

4.16.2.4 Generally, permanent riser systems should be visually inspected after completion tests and one year of operation. The inspection intervals during in-service shall comply with the relevant provisions in Section 5, Chapter 2 of the Guidelines and should generally not exceed the following requirements unless experience or engineering analysis justifies a longer interval.

Recommended Inspection Methods and Intervals Table 4.16.2.4

Components	Inspection method	Intervals
Above-water components	Visual inspection	1 year
Underwater components	Visual inspection	3-5 years
All components	NDE	As required
Sacrificial anodes	Visual inspection or potential testing	3-5 years
Areas of known or suspected damage	Applicable methods	After occurrence of the design event
Components that can be recovered out of the water	As recommended by the manufacturer	After disconnection

4.16.3 Maintenance

4.16.3.1 The purpose of scheduled maintenance is to ensure the function and performance of the riser system and reduce the possible subsequent repair costs, particularly for sections located in underwater areas inaccessible to divers.

4.16.3.2 The designer shall consider all key maintenance items, maintenance time and cycle of the riser system.

4.16.3.3 It is necessary to remove part or all of attached marine growth when it exceeds the design allowance. Removal methods usually include water flushing, mechanical brushes or scrapers. Removal procedures shall be compatible with the cathodic protection system.

4.16.4 Repair/replacement

4.16.4.1 The riser system shall be designed so that for minor local damage that does not cause leakage, it can be repaired or replaced without emergency shutdown (such as repair to corrosion coating and repair to cathodic protection). For major damage that will cause leakage, it can be recovered, repaired or replaced after the riser is shut down and depressurized.

Section 17 Tests

4.17.1 General requirements

4.17.1.1 For key design parameters of risers that require test data or verification of assumed data, corresponding tests shall be designed and carried out, such as the weld fatigue test, material performance test, CTOD test and model test required for special components.

Section 18 Installation Scheme Design

4.18.1 General requirements

4.18.1.1 This section specifies installation considerations for the riser system design. The designer shall determine the preliminary installation procedure and conduct an installation feasibility analysis based on the intended installation method and the ship on which the riser will be installed to verify compliance of the riser with the design criteria such as strength and fatigue requirements during installation.

4.18.1.2 The final detailed installation design and calculation shall be formulated by the installation contractor and submitted to the operator and CCS for approval. The final installation design shall also comply with the relevant requirements in this section.

4.18.1.3 This section specifies general considerations for the installation design of riser systems for production, export, injection, import, drilling, workover and completion. For special considerations of riser systems used for drilling, workover and completion, please refer to the relevant requirements in API RP 16Q and API RP 17G. For special considerations of flexible and hybrid risers, please refer to the relevant requirements in API RP 2RD and API RP 17B.

4.18.1.4 The installation specifications shall specify the scope of onshore fabrication by the installation contractor. The installation contractor shall develop a fabrication procedure and submit it to the owner and CCS for review before starting onshore fabrication.

4.18.2 Installation methods

4.18.2.1 Depending on its type, a riser system can be installed either from a floating installation or from an installation vessel. If installed from an installation vessel, installation methods include S-lay, J-lay, reel-lay, and tow-in.

4.18.2.2 When the S-lay method is used, the riser is usually pre-laid by a pipe-laying vessel. After the floating installation is in place, the riser is lifted by a dedicated vessel from the seabed to the predetermined position. Subsequently, the riser pull-in system on the floating installation is used to install the riser into its final position. When the J-lay method is used, the riser is usually laid by the pipe-laying vessel after the floating installation is in place.

4.18.2.3 The installation method for the riser system shall be selected to ensure sufficient weather windows to complete the installation.

4.18.2.4 The installation scheme shall be selected with careful consideration of its effects on the design of underwater structures (e.g., PLET).

4.18.3 Transportation and lifting

4.18.3.1 The lifting device of the riser system shall have the required lifting capacity according to the riser installation method. The structural design of the lifting device and rigging shall comply with the relevant provisions in API RP 2A.

4.18.3.2 Appropriate protection measures such as protective covers and end caps shall be taken for the shipping and lifting of the riser system.

4.18.3.3 Riser components shall be so stored and secured during transportation that they are protected against mechanical damage and corrosion. Riser components shall be secured, with consideration given to the impact of ship motions.

4.18.4 Offshore installation procedures

4.18.4.1 The installation procedure for the riser system shall take into account the following factors:

(1) Clearance requirements: To meet the total length requirement of the riser between the top and bottom connection points, a special pup joint may be used in the riser string to meet the length requirements of the remaining clearance;

(2) Appurtenances to be installed for riser running, such as buoyancy modules and VIV suppression devices;

(3) Guidance methods for riser installation (such as riser running guidance and riser tie-back guidance). For multiple risers on floating installations, different guidance methods may be required at different stages of installation;

(4) Dynamic positioning of the floating structure that may be used during installation;

(5) Interference between the riser and other risers, mooring lines or other obstacles during installation;

(6) Motion compensation requirements for riser installation;

(7) Supporting ships;

(8) Emergency plans, including those in case of dynamic positioning failure and chain cable failure;

(9) Dry lay or wet lay method;

(10) Requirements for installation accuracy.

4.18.4.2 The installation procedure for the riser system shall be designed to allow the operation to be halted at any time, enabling the risers to be safely recovered and discarded as necessary.

4.18.4.3 The installation procedure for the riser system shall allow pigging (if applicable) and hydrostatic tests after installation.

Section 19 Component Design

4.19.1 General requirements

4.19.1.1 The component design documents (including specifications, main drawings and reports) of the riser system shall be submitted to CCS for review, including at least main components such as flex joints, VIV suppression devices and tensioners. The requirements for the ultimate capacity of components shall be specified in the specifications of the riser system. These documents shall state that the ultimate capacity of components meets the requirements specified in the riser system design.

4.19.1.2 Riser system components, as products, shall comply with the requirements of the relevant recognized acceptance criteria.

4.19.1.3 The pressure-containing components and primary load-carrying components in the riser system shall comply with the requirements of strength criteria and fatigue criteria.

4.19.1.4 This section provides corresponding design requirements for some common components in the riser system. Design requirements for components specific to other types of riser systems are specified in Chapter 5 of the Guidelines.

4.19.2 Connectors

4.19.2.1 Riser connectors are used to connect and disconnect the riser joint or equipment, usually including threaded connectors, flange connectors and other mechanical connectors.

4.19.2.2 The riser connector design shall meet the sealing, strength and fatigue requirements under all conditions, and shall not be inferior to the corresponding requirements for the pipe or weld. The loads on the connector include assembly/disassembly loads, internal/external pressures, bending and tension loads, cyclic loads, temperature loads, etc. Where applicable, accidental loads such as fire and impact shall also be considered.

4.19.2.3 Riser connectors primarily use metallic seals. Non-metallic seals shall only be used as backup seals.

4.19.2.4 Riser connectors shall have sufficient design redundancy to prevent a failure at a single position from causing major failure of the riser system.

4.19.3 VIV suppression devices

4.19.3.1 VIV suppression devices are used to reduce the vortex-induced vibration of the riser. These devices include helical strakes and deflectors, and an appropriate type should be selected for use based on installation method and fitness-for-purpose.

4.19.3.2 Their design shall satisfy the specified requirements for minimum suppression efficiency and maximum drag coefficient at the amplitude across the range of current conditions applicable to the riser design.

4.19.3.3 Their size and coverage can be determined by riser VIV fatigue analysis. Their effects on parameters such as riser weight, drag diameter and drag coefficient shall be verified by recognized test data.

4.19.3.4 Their design shall meet the load requirements at the installation, in-position and recovery stages.

4.19.3.5 They are installed before the riser is lowered into the seawater and are typically designed to be removable and re-installable subsea using an ROV.

4.19.3.6 They are typically applied with anti-fouling coating to mitigate the impact of marine growth on the effectiveness of VIV suppression.

4.19.3.7 They shall be designed to minimize their adverse impact on the effectiveness of cathodic protection.

4.19.4 Valves

4.19.4.1 The valves in the riser system shall meet the corresponding standard requirements based on their locations. For example, valves located on underwater submarine pipelines shall generally comply with the requirements in API SPEC 6DSS, and those located on the top of the riser and on the hull shall generally comply with the requirements in standards such as API SPEC 6D and ASME B16.34.

Chapter 5 Special Requirements for Various Riser Systems

Section 1 Special Design Requirements for Steel Catenary Riser Systems

5.1.1 General requirements

5.1.1.1 The steel catenary riser (SCR) is mainly used for medium transportation, and its end at the seabed is welded to a PLET or a submarine pipeline, which can be regarded as an extension of the submarine pipeline to the floating installation.

5.1.1.2 The individual pipes of the SCR are generally connected using welded joints.

5.1.1.3 In addition to the Guidelines and API RP 2RD and API Std 2RD, the SCR may also be designed based on the applicable requirements in API RP 1111, ASME B31.4 or ASME B31.8.

5.1.2 Top assembly

5.1.2.1 According to design requirements, the top assembly of SCR can use flex joints or stress joints. Consideration should be given to the potential performance degradation of flexible units in a medium environment for flex joints and to the large bending moment loads exerted on the basket and porch structures for stress joints.

5.1.2.2 Flex joints can be categorized into bellowsless and bellowed types. Bellowsless flex joints usually consist of the main body, connection flange, extension section, flexible unit (including elastomer and reinforcing gasket). Of them, the flexible unit is the core component of the flex joint. It is bonded between the main body and the extension section, bears the internal pressure within the riser, and allows the extension section to rotate relative to the main body. Generally, a metal sealing ring is used between the flange and the main body of flex joint. If it is necessary to prevent damage to the flexible unit due to specific medium composition or rapid pressure drop, bellowed flex joints can be used to isolate the flexible unit from the internal medium.

5.1.2.3 The design of flex joints shall generally meet the following requirements:

(1) Pressure-containing requirements;

(2) Strength and fatigue requirements;

(3) Maintenance requirements during the service life, generally designed to be maintenance-free;

(4) Alternative design requirements;

(5) Fail-safe design requirements, e.g., reinforcing gasket stack to prevent the riser from falling off in the event of failure of elastomer in the flexible unit;

(6) Rotational stiffness and size requirements required for the riser design, enabling the riser to comply with the requirements for interference, strength and fatigue;

(7) Pigging requirements.

5.1.2.4 Materials for flex joints include metallic and elastomeric materials. The metallic materials used for the main body, flange and extension section of the flex joint are usually high-strength low-carbon steel, e.g., ASTM A707. The reinforcing materials in the elastic unit shall meet the strength and fatigue requirements in service conditions, and the elastomeric materials shall either be compatible with the medium or properly isolated from it. The flex joint materials shall have sufficient fracture toughness, and fracture toughness tests and fracture mechanics analysis shall be carried out. CTOD tests shall be carried out on all welds and other base materials at specified locations.

5.1.2.5 Where required, the flex joint design may include the following auxiliary components or equipment:

(1) Flex joint running tool;

(2) Flex joint shroud;

(3) Hold collar;

(4) Flex joint mock-up.

5.1.2.6 The flex joint shall have a strength design to ensure that it is not used as a weak link in the riser. Under various extreme cases, its stress utilization factor shall be lower than that of the riser pipe to ensure no damage to or leakage at the main body, flexible unit, extension section or connection flange of the flex joint in the event of excessive bending or tension in the riser. In fatigue life assessment, the effects of long-term creep of elastomers under static and dynamic loads shall be taken into account.

5.1.2.7 The data about bending moment or rotational stiffness of the flex joint at each angle to the maximum rotation angle at the design temperature shall be submitted to the riser system designer. For the riser design, sensitivity analysis should be carried out to study the influence of flex joint stiffness deviation on riser response, as well as the influence of internal pressure and temperature changes during operation on flex joint stiffness and riser response.

5.1.3 Basket structure of top joint

5.1.3.1 The basket structure of top joint shall generally meet the following requirements:

(1) The basket structure shall meet the strength and fatigue criteria in the corresponding load cases at the installation and in-position stages;

(2) The angle of the basket structure shall meet the overall configuration design requirements of the riser;

(3) The design of the basket structure shall take into account the influence of manufacturing and installation tolerances;

(4) The fracture toughness and welding procedure of the materials shall comply with the requirements for fatigue life;

(5) The connection between the basket structure and the porch structure is generally accomplished using full-penetration welds.

5.1.4 Touchdown zones

5.1.4.1 The SCR design shall account for the influence of soil parameters in the touchdown zone on the strength and fatigue performance of the riser. The soil parameters used in the riser design shall be representative of the soil conditions in the touchdown zone.

5.1.4.2 For the external anti-corrosion coating of SCR in the touchdown zone, the requirements for wear resistance shall apply.

5.1.4.3 The flowline section of SCR at the seabed shall meet the in-position stability requirements for the submarine pipeline at installation and in-position stages.

5.1.5 Pipe-in-pipe

5.1.5.1 Where thermal insulation is required, the SCR can be in a pipe-in-pipe configuration, with pipe spacers set at equal intervals between the inner and outer pipes. The inner pipe of the SCR is also a part of the riser system and shall comply with the relevant requirements of the riser design.

5.1.5.2 For the pipe-in-pipe structure, the anti-collapse design of the inner pipe shall account for external pressure loads in the event of an outer pipe leakage and water ingress, and the pressure-containing design of the outer pipe shall account for the internal pressure following an inner pipe leakage. The strength check of the pipe-in-pipe can take into account the total stiffness contribution of the inner and outer pipes to the riser motion response.

5.1.5.3 In addition to meeting the above-mentioned riser design requirements, at least the following factors should be considered in the pipe-in-pipe design:

(1) Spacing of pipe spacers;

(2) Axial relative motion of the inner and outer pipes;

(3) Axial force and buckling of the inner pipe caused by thermal expansion and internal pressure;

(4) The force of pipe spacers on the inner and outer pipes;

(5) Residual curvature and residual stress of the inner pipe caused by installation, and residual axial load between the inner and outer pipes.

5.1.6 Installation scheme design

5.1.6.1 The main offshore installation procedure for the SCR system includes the laying stage, recovery stage (if any) and pull-in stage.

5.1.6.2 The SCR may be either pre-laid or laid after the floating structure is in place. The offshore laying methods can be S-lay, J-lay and reel-lay. For the offshore laying process, at least the following aspects shall be considered:

(1) Stress and strain control at the initiation, normal laying and end stages of pipe laying;

(2) Welding and NDE;

(3) Installation of VIV suppression devices;

(4) Application of field joint coatings;

(5) Installation of sacrificial anodes;

(6) Installation of pup joints, flex joints, etc.;

(7) Connection of the flowline section end of the riser with the submarine pipeline/PLET;

(8) Temporary abandonment or recovery (if any), etc.

5.1.6.3 For SCRs using the pre-laid method, the recovery stage generally includes three processes:

(1) Before the recovery operation, the SCR is laid flat on the seabed and the end is connected to the lifting cable on the engineering ship;

(2) During the recovery operation, the engineering ship moves toward the floating structure, and the lifting cable gradually lifts the end of the SCR;

(3) After recovery termination, the engineering ship reaches a position at an appropriate distance from the floating structure, and the SCR is lifted to the target configuration.

5.1.6.4 The pull-in stage of SCR generally includes:

(1) The lifting cable on the floating structure/other auxiliary engineering ship is connected to the top of the SCR;

(2) The main lifting cable on the floating structure gradually pulls the SCR to the predetermined position of the floating structure;

(3) The flex joint of SCR is pulled to the designated suspension position.

5.1.6.5 For the riser structure equipped with a monitoring device, appropriate installation methods shall be selected for the monitoring system.

Section 2 Special Design Requirements for Top Tensioned Riser Systems

5.2.1 General requirements

5.2.1.1 TTRs are suitable for production installations with low heave motion characteristics, such as TLPs, SPARs or fixed platforms, and they can also be used for production installations in mild marine environments or equipped with heave compensation systems.

5.2.1.2 The riser joints of production/export/injection/import risers are usually connected by mechanical connectors, and those of drilling/workover/completion risers are usually connected by flanges. The bottom of the riser is usually connected to the underwater wellhead by a tie-back connector, and the top of the riser is usually connected to other surface equipment by a quick connector or flange. The riser is welded to the connector or flange, etc.

5.2.1.3 In addition to the requirements in the Guidelines and API RP 2RD and API Std 2RD, TTR systems and components shall also comply with the relevant provisions in API Spec 16F, API RP 16Q or API RP 16G applicable to riser systems and components of floating installations.

5.2.2 Riser tensioners

5.2.2.1 Riser tensioners are used to provide vertical tension to TTRs, helping to maintain their stability and control their key parameters such as stress, displacement and bottom angle. TTR tensioners for floating installations are usually located on the production deck.

5.2.2.2 Riser tensioners shall comply with the requirements for nominal tension and up/down stroke of the riser in different operation modes. During operation, inspection and maintenance, they shall be able to meet the minimum tension requirements for the riser in the event of any failure in a single tensioner component.

5.2.2.3 The relationship between the tension and stroke of riser tensioners shall be provided for the global analysis of the riser.

5.2.2.4 The applicable requirements in the CCS *Guidelines for Survey of Offshore Drilling Plants* and API Spec 16F can serve as reference for riser tensioner design, and the electrical design shall comply with the requirements of the floating installation operating area.

5.2.3 Buoyancy tanks

5.2.3.1 The buoyancy tank design of the TTR system shall comply with the applicable requirements in Section 5.4.4 of this Chapter.

5.2.3.2 For cases where the buoyancy tank is designed to provide tension at the top of the riser, upper and lower limits may be designed to limit the vertical movement of the buoyancy tank if necessary, including preventing excessive downward movement of the buoyancy tank from causing buckling of the TTR and preventing excessive upward movement of the buoyancy tank from causing collision with the deck.

5.2.4 Buoyancy modules

5.2.4.1 Buoyancy modules shall be capable of sustaining loads incurred during lifting, transportation, installation, and at maximum allowable water depth. They shall be sized to comply with the requirements for the required lift force, as well as for lifting and installation.

5.2.4.2 They shall be made of lightweight materials of an appropriate density for the specific water depth, accounting for the effects of water absorption, compression under hydrostatic pressure, and manufacturing tolerances.

5.2.4.3 For thrust rings, ties, bolts and other components, they shall meet the anti-corrosion and lift transmission requirements, and avoid structural damage under extreme conditions.

5.2.5 Special riser joints

5.2.5.1 In addition to standard riser joints, the TTR usually also includes other special riser joints, such as tension joints, splash zone pipe joints, keel joints, stress joints, flex joints and ball joints. Special riser joints shall be designed to comply with the requirements for sealing, pressure-containing, strength and fatigue. Please refer to API Spec 16F, API RP 16Q and API RP 16G for the relevant provisions.

5.2.5.2 The bottom tapered stress joint of the riser is designed to resist the bending load at the bottom of the riser caused by floating structure offset. Stress joints are generally forged parts, and their cross-sectional diameters shall meet the design requirements for strength and fatigue as well as the limitations of manufacturing equipment. The bottom stress joint of the TTR can be connected to the underwater wellhead through a tie-back connector integrated at its bottom. The straight pipe section of the stress joint can be connected to a standard riser joint through T&C threads.

5.2.5.3 Splash zone pipe joints are typically designed with a greater wall thickness corrosion allowance than standard riser joints and are also protected with robust anti-corrosion coating.

5.2.5.4 Tension joints are usually forged parts. The bottom can be connected to the lower riser by threads, flanges, etc., and the top can be connected to upper equipment such as tubing heads by quick connectors or flanges. At the tube body of the tension joint, there is a threaded connection interface with the tension ring, which allows adjustment of the tension ring within the specified height.

5.2.6 Launch and recovery

5.2.6.1 The TTR is launched and recovered from the floating installation.

5.2.6.2 The installation process of the TTR system generally includes at least the following steps:

(1) Installation of tensioner system;

(2) Running of guideline system and connection to the underwater wellhead base plate;

(3) Connection between the riser guide arm and the guideline;

(4) Installation of surface equipment such as Christmas tree, BOP and tubing head;

(5) Assembly of riser joint and running of riser string;

(6) Installation of VIV suppression device on riser joint;

(7) Connection between the tensioner and the riser tensioner ring on the tension joint;

(8) Connection of the bottom tie-back connector to the underwater wellhead, etc.

5.2.7 Drilling/workover/completion riser

5.2.7.1 The drilling/workover/completion riser system for a floating installation is usually a high-pressure riser system, with equipment such as BOPs located at the top of the riser and its weight supported by the riser tensioners. In this case, the riser shall be designed to withstand the maximum formation pressure.

5.2.7.2 The drilling/workover/completion riser for a floating installation, usually surrounded by production risers, shall be designed as part of the overall riser system so that each riser meets the corresponding safety and interference requirements.

5.2.7.3 Telescopic joints are usually used for the top connection of TTRs in drilling/workover/completion operations. The stroke of telescopic joints shall meet the minimum stroke requirements of the riser.

5.2.7.4 Installed drilling risers can be fully recovered to the surface and re-lowered at the target wellhead position, or they can be disconnected through the bottom tie-back connector and moved in a suspended state to the target wellhead position for reconnection.

Section 3 Special Design Requirements for Flexible Riser Systems

5.3.1 General requirements

5.3.1.1 Flexible risers, mainly used for medium transportation, shall have excellent corrosion resistance and low bending stiffness, be easy to install offshore, and allow for large displacement between the floating structure and the connection point at the seabed. Flexible risers can be categorized into unbonded and bonded types, with the former type commonly used.

5.3.1.2 Flexible risers can be in multiple configurations, such as free-hanging catenary, lazy-S, steep-S, lazy-wave, steep-wave, and other non-standard configurations.

5.3.1.3 In addition to the applicable requirements in the Guidelines and API RP 2RD, API Std 2RD, unbonded flexible risers shall also comply with the relevant requirements in API Spec 17J and API RP 17B. For general requirements for unbonded flexible risers and static applications, please refer to the relevant provisions in the CCS *Guidelines for Survey of Metal Flexible Pipes for Submarine Pipelines*.

5.3.2 Unbonded flexible risers

5.3.2.1 The unbonded flexible riser is a primary part of a flexible riser system, comprising the riser body and end fittings. Flexible risers shall be designed to meet the load requirements under normal operating conditions, extreme conditions, abnormal conditions, temporary conditions and survival conditions.

5.3.2.2 The cross-sectional design of the riser body shall meet the capacity requirements to withstand internal pressure, external hydrostatic collapse, tensioner mechanical collapse and axial loads. In addition, the flexible riser design shall be verified by global analysis to comply with the requirements for axial load, minimum bend radius and service life during installation and service under various conditions. The configuration and arrangement of flexible risers shall comply with interference criteria with adjacent risers, umbilical cables or structures.

5.3.2.3 During installation and service, axial loads on flexible risers shall be controlled to prevent birdcage buckling of armor layers. Anti-buckling layers may be designed into the flexible riser body as required.

5.3.2.4 The minimum storage bend radius, in addition to meeting all design requirements, shall not be less than 1.1 times the bend radius causing lock-up of the carcass/armor layers. The minimum operating bend radius of the flexible riser shall be 1.5 times the minimum storage bend radius.

5.3.2.5 The wear layer is designed to resist mutual wear of adjacent armor layers during the dynamic response of the riser.

5.3.2.6 Depending on the corrosiveness of the internal liquid, the carcass layer can be made of carbon steel, ferritic stainless steel, high alloy stainless steel and nickel alloy steel. The tensile/compressive armor layer is usually made of carbon steel, but composite materials can also be used instead. The internal pressure sheath, external sheath and intermediate sheath may be manufactured from polymer materials such as high-density polyethylene (HDPE) or cross-linked polyethylene (XLPE).

5.3.3 End fittings

5.3.3.1 End fittings shall comply with the requirements of securing each layer of the riser body, establishing media sealing and withstanding internal/external pressures as well as riser body loads. They shall also comply with the requirements for venting and for maintaining electrical continuity with the armored wire.

5.3.4 Service life

5.3.4.1 The design life of a flexible riser shall, in addition to addressing challenges such as aging and creep in non-metallic materials and corrosion/erosion in metallic materials for static flexible pipes, also satisfy the fatigue life requirements for both the compressive/ tensile armor layers and the carcass layer in the hang-off points and touchdown zones. The predicted fatigue life shall be at least 10 times the service life.

5.3.5 Auxiliary components

5.3.5.1 Bending restrictors generally include bending stiffeners, bending limiters and bell mouths.

5.3.5.2 Bending stiffeners may be designed to prevent excessive bending of flexible risers during installation and service. They are usually made of polymer materials, installed surrounding the flexible pipe and connected to the end fittings. Bending stiffeners shall be designed to comply with the requirements in API Spec 17J.

5.3.5.3 Bending limiters are used to rigidly restrain flexible pipes and are generally used in static applications.

5.3.5.4 Bell mouths are designed to guide the flexible riser through the guide tube to the level of the floating deck to prevent excessive bending of the flexible riser. They shall be designed to comply with the relevant requirements in API RP 17B. In fatigue life assessment of flexible risers, the effects of contact pressure between the bell mouth and the armor layer of the flexible pipe shall be taken into consideration.

5.3.6 Installation scheme design

5.3.6.1 Flexible risers are typically installed using the reel-lay method, which can be classified into vertical reel-lay and horizontal reel-lay. They are laid in an empty condition, and the fitness-for-purpose of the carcass layer to the installation conditions shall be considered.

5.3.6.2 Flexible riser installation can commence either by lowering the riser directly onto the seabed or by first connecting it to the floating structure.

5.3.6.3 Tension and deformation during the laying of flexible risers shall be within permissible limits. The bend radius of the flexible pipe shall be monitored during installation, or the installation method and laying parameters shall be designed to ensure that the bend radius does not exceed the minimum bend radius.

5.3.6.4 The installation process for flexible risers depends on their specific configuration (e.g., lazy-wave) and system components.

5.3.6.5 The installation scheme design for flexible risers shall comply with the relevant requirements in API RP 17B.

Section 4 Special Design Requirements for Hybrid Riser Systems

5.4.1 General requirements

5.4.1.1 Hybrid riser systems, mainly used for medium transportation, are characterized by separation of the steel riser from the floating structure motion through a flexible jumper at the top. In their design, consideration should be given to the design requirements for steel risers, flexible risers, and special components such as the buoyancy tank, riser base, top riser assembly and bottom riser assembly.

5.4.1.2 The overall configuration of the hybrid riser system includes important design parameters such as the length of the top flexible jumper, the underwater depth of the buoyancy tank, and the horizontal distance between the riser base and the floating installation/single point mooring installation.

5.4.1.3 For steel riser sections in a hybrid riser system, individual pipes are usually connected by welded joints and can be connected by mechanical connectors in special cases.

5.4.1.4 This section provides special design requirements for hybrid riser systems. In addition to the relevant requirements in this section, steel riser sections in a hybrid riser system shall also meet applicable requirements in API RP 2RD, API Std 2RD, Chapter 4 of the Guidelines and Sections 1 or 2 of this Chapter, depending on their forms. In addition to the relevant requirements in this section, flexible jumper sections in a hybrid riser system shall also meet applicable requirements in API RP 2RD, API Std 2RD, Chapter 4 of the Guidelines and Section 3 of this Chapter. Special components such as the buoyancy tank, riser base, top riser assembly and bottom riser assembly shall meet the corresponding recognized standards.

5.4.2 Type of hybrid riser system

5.4.2.1 Hybrid risers can generally be classified by their design concepts into types such as free-standing hybrid risers, hybrid riser towers, buoyancy-supported risers and hybrid catenary risers.

5.4.2.2 The vertical steel riser section of a hybrid riser tower is configured as a pipe bundle. It consists of a central pipe and other surrounding pipelines such as production and injection pipelines. The buoyancy module is installed on the central pipe, and the surrounding pipelines can pass through the inside of the buoyancy module or be installed around the buoyancy module. At the top of the vertical riser section, a buoyancy tank is installed to provide top tension, and each steel riser is connected to the floating installation through multiple flexible jumpers. The hybrid riser tower system mainly includes the following components:

(1) Top flexible jumper;

(2) Buoyancy tank;

(3) Top riser assembly (including gooseneck assembly);

(4) Continuous riser bundle;

(5) Bottom riser assembly;

(6) Bottom connector;

(7) Riser tower anchor;

(8) Bottom jumper connected to PLET, etc.

5.4.2.3 The free-standing hybrid riser consists of a vertical steel riser anchored to the seabed through a riser base. The top of the steel riser is lifted by a near-surface buoyancy tank, and a top flexible jumper is connected to the steel riser via a gooseneck assembly. The vertical steel riser section can also be in a pipe-in-pipe configuration. The free-standing hybrid riser system mainly includes the following components:

(1) Top flexible jumper;

(2) Umbilical cable (if any);

(3) Buoyancy tank;

(4) Tether chain/flex joint;

(5) Top riser assembly (including gooseneck assembly);

(6) Top stress joint (if any);

(7) Riser joint, buoyancy module, coating and insulation layer;

(8) Inner pipe and pipe spacer of pipe-in-pipe;

(9) Bottom stress joint (if any);

(10) Bottom riser assembly;

(11) Bottom connector;

(12) Riser base;

(13) Riser bottom jumper connected to PLET, etc.

5.4.3 Top flexible jumper

5.4.3.1 The top flexible jumper shall be designed to be replaceable without recovering the entire riser string or removing the buoyancy tank or any other structure.

5.4.3.2 The interface load and load direction of the flexible jumper may be determined through dynamic analysis of the top flexible jumper under various conditions. Floating installation designers and flexible jumper suppliers shall ensure that all interface components meet strength and fatigue design requirements.

5.4.3.3 In addition to not interfering with adjacent umbilical cables, flexible jumpers or mooring lines, the top flexible jumper shall also avoid interference with the floating structure and its appurtenances.

5.4.3.4 The design service life of the top flexible jumper is usually not less than the service life of the vertical steel riser section.

5.4.4 Buoyancy tank

5.4.4.1 The buoyancy tank may be designed with multiple subdivisions connected to the ballast system to allow adjustment of the buoyancy or in-water position of the buoyancy tank during installation or service.

5.4.4.2 The buoyancy tank design shall generally meet the following requirements:

(1) Support the weight of the hybrid riser (including steel riser section, top flexible jumper, gooseneck and related structures) and provide sufficient top tension for the dynamic response of

the hybrid riser;
(2) Minimize the rotation angle at the riser bottom assembly by limiting the top offset of the riser;
(3) Provide appropriate ballast subdivisions to meet the stability requirements under damage conditions;
(4) Strength requirements;
(5) Fatigue life requirements;
(6) Anti-corrosion requirements;
(7) Requirements for risk analysis.
5.4.4.3 The following factors are usually considered in buoyancy tank design:
(1) Load transfer path between the buoyancy tank and the riser structure;
(2) Stress induced by hydrostatic pressure, ultimate load and sloshing load;
(3) Buoyancy loss resulting from flooding in one or two compartments of the buoyancy tank;
(4) Additional weight and resistance caused by attached marine growth, especially the upper part of the riser;
(5) Additional weight due to riser manufacturing tolerances, etc.;
(6) Fatigue load at the connection between the buoyancy tank and the top riser assembly;
(7) Fatigue caused by pressure changes at structure and pipeline welds (such as waves, tides, currents, in-tank liquid sloshing);
(8) Riser VIV-induced girth weld fatigue at the connection between the riser and the bottom of the buoyancy tank;
(9) ROV collision with the ROV panel or buoyancy tank shell;
(10) Impact from any falling object;
(11) Corrosion inside the buoyancy tank compartment due to residual seawater and oxygen remaining after installation;
(12) Collapse load on the inflated central pipe;
(13) Additional weight due to the failure of the top flexible jumper's connection at one end of the floating installation;
(14) Lifting points and eyes for installing auxiliary buoyancy unit in an emergency.
5.4.4.4 The following ancillary equipment is usually included in the buoyancy tank design:
(1) Pressurization/ballast system;
(2) Tension monitoring system;
(3) ROV connection equipment and control panel;
(4) Transport supporting structure;
(5) Offshore fixed connection equipment;
(6) Lifting equipment during manufacturing/transportation/installation.

5.4.5 Riser base

5.4.5.1 Driven piles or suction piles can be used for the riser base of a hybrid riser system.
5.4.5.2 The riser base shall be designed to account for dynamic loads encountered during its

installation, the installation of the riser system, and throughout service operation.

5.4.5.3 The riser base shall be designed to account for installation tolerances, including position accuracy, orientation and verticality requirements.

5.4.6 Top riser assembly

5.4.6.1 The top riser assembly is used to provide a safe and reliable connection between the top flexible jumper and the top of the vertical riser section.

5.4.6.2 The top riser assembly shall be designed to meet the expected load requirements and interface requirements.

5.4.6.3 The load transfer path from the vertical riser section to the buoyancy tank shall be considered in the top riser assembly design, and each load transfer path shall be analyzed for the expected loads.

5.4.6.4 The top riser assembly shall be designed to facilitate the easy installation and replacement of the top flexible jumper by a diver or ROV, if necessary.

5.4.6.5 The top riser assembly shall be designed to meet the load requirements for the installation guide, winch and supporting structure during installation.

5.4.6.6 If the riser system is designed to be piggable, the pipe bend radius of the top riser assembly shall meet the pigging requirements.

5.4.7 Bottom riser assembly

5.4.7.1 The bottom riser assembly is used to provide a safe and reliable connection between the bottom of the vertical riser section and the riser bottom jumper.

5.4.7.2 If the riser system is designed to be piggable, the pipe bend radius of the bottom riser assembly shall meet the pigging requirements.

5.4.7.3 In deepwater applications, the ovality and wall thickness of the pipe in the bottom riser assembly shall comply with the requirements of the deepwater collapse criteria.

5.4.8 Riser bottom jumper

5.4.8.1 The riser bottom jumper is designed to connect the riser bottom components and PLET/PLEM. Rigid or flexible jumpers can be used.

5.4.8.2 The riser bottom jumper shall be designed with the required adaptability to internal pressure, thermal effects (from submarine pipelines and jumpers), motion of hybrid risers, slug flow loads and other mechanical effects, and shall meet installation tolerance requirements.

5.4.8.3 The riser bottom jumper shall be designed to comply with the requirements of the recommended installation procedure. The riser bottom jumper can be installed before or after the top flexible jumper is connected to the top riser assembly.

5.4.8.4 The riser bottom jumper, usually subjected to high fatigue loads, requires detailed fatigue assessment.

5.4.8.5 For the bottom jumper of production risers, the flow guarantee requirements shall be considered in the thermal insulation design.

5.4.8.6 If the riser system is designed to be piggable, the bend radius of the riser bottom jumper shall meet the pigging requirements.

5.4.9 Connector

5.4.9.1 Connectors for hybrid riser systems are typically used for:

(1) Connection between the top flexible jumper and the gooseneck;

(2) Connection between the top riser assembly and the buoyancy tank;

(3) Connection between the bottom riser assembly and the riser base;

(4) Connection between the bottom riser assembly and the riser bottom jumper;

(5) Connection between the riser bottom jumper and the PLET, etc.

5.4.9.2 For the connection between the top riser assembly and the buoyancy tank, and the connection between the bottom riser assembly and the riser base, emergency measures in the event of load transfer failure shall be considered during design.

5.4.10 Anti-corrosion design

5.4.10.1 Generally, a combination of external anti-corrosion coating and cathodic protection is used for external anti-corrosion purposes of the hybrid riser system. Electrical continuity shall be maintained from the top flexible jumper down to the riser base at the bottom. Sacrificial anodes for protecting the top flexible jumper and vertical steel risers can be installed at the end of the riser (for example, at the top riser assembly or the bottom riser assembly). However, they are usually not installed on the riser string.

5.4.10.2 In the cathodic protection design for each component in a hybrid riser system, the compatibility of cathodic protection with coating on each component, as well as with the floating structure and subsea production system, shall be holistically considered.

5.4.10.3 The cathodic protection design for the buoyancy tank, top riser assembly, bottom riser assembly, pile base or other auxiliary components of hybrid riser systems shall comply with the relevant requirements of recognized standards such as NACE SP0169.

5.4.11 Installation scheme design

5.4.11.1 Steel riser sections and related components of hybrid risers may be installed offshore before or after the floating installation is in place. The top flexible jumper is designed to be installed after the vertical steel riser section is installed offshore. The flexible jumper can be installed after the floating installation is in place, or it can be pre-installed and fixed to the vertical steel riser section by claws and then connected after the floating installation is in place.

5.4.11.2 The installation method of the hybrid riser varies depending on design concepts and component compositions. For example, the riser bundle of the hybrid riser tower is usually prefabricated on land and towed in a floating state to the target sea area for installation. The vertical steel riser section of the free-standing hybrid riser can be laid by the pipe-laying vessel using the J-lay or reel-lay method. Due to the complexity of components in the hybrid riser system, the specific installation method and installation procedure to be used shall be considered in the hybrid riser system design. Additionally, an installation analysis shall be carried out to verify that the vertical steel riser section, top flexible jumper and other main components of the riser system can meet the design criteria requirements under the installation conditions.

5.4.11.3 The installation process for the hybrid riser system usually includes the following steps:

(1) Installation of sea-floor foundation;

(2) Fabrication, launching and offshore towing of steel riser section;

(3) Assembly of buoyancy tank and riser bottom device;

(4) Offshore upending of steel riser section;

(5) Connection between steel riser section and sea-floor foundation;

(6) Tie-back of bottom jumper;

(7) Connection of top flexible jumper, etc.

5.4.11.4 Safe and reliable installation procedures shall be designed for critical installation steps of the hybrid riser system, such as the launching and upending of the hybrid riser, the pull-in of flexible jumper through the turret and the connection of the flexible jumper to the top riser assembly.

5.4.11.5 The buoyancy tank installation process, dictated by its specific installation method, generally includes lifting, suspending, upending, lowering, deballasting, and connecting to the top riser assembly. The corresponding installation analysis shall be carried out for the installation process.

5.4.11.6 The installation procedure of the top flexible jumper shall include protection measures for key collision points to prevent damage to the external sheath during installation and thereby shorten the service life.

Chapter 6 Global Analysis

Section 1 General Provisions

6.1.1 General requirements

6.1.1.1 The purpose of the global analysis of the riser is to verify the riser design, obtain the cross-sectional loads distributed along the length of the riser, check against the design criteria and establish operation limits.

6.1.1.2 The main global analysis of the riser includes interference analysis, strength analysis, fatigue analysis (such as wave-induced fatigue, VIV fatigue, VIM-induced fatigue and installation fatigue) and installation feasibility analysis.

6.1.2 Analysis methods

6.1.2.1 The global analysis method of the riser includes static analysis, eigenvalue analysis (or modal analysis) and dynamic analysis. The static analysis can be used for riser configuration design, initial configuration of dynamic analysis, flow-induced interference analysis, etc. The eigenvalue analysis can be used for modal characteristics required for riser VIV assessment. The dynamic analysis can be used for strength analysis, fatigue analysis, interference analysis, installation analysis, etc.

6.1.2.2 The riser dynamic analysis methods includes frequency domain analysis method and time domain analysis method. The former can be used for riser dynamic analysis when the tension coupling effect is small and there are no other nonlinear effects.

6.1.2.3 The time domain analysis method is typically used to calculate the wave-frequency and low-frequency dynamic responses of the riser. High-frequency response is generally not considered in riser analysis. In addition, it can also be used to analyze transient events or evaluate the accuracy of frequency domain analysis method.

6.1.2.4 For the wave-frequency time domain response analysis of the riser, the response can be calculated using the floating structure displacement RAOs based on the calculation of the average offset and low-frequency motion of the floating structure.

Section 2 Strength Analysis

6.2.1 General requirements

6.2.1.1 The riser strength analysis usually verifies that:

(1) The riser strength meets the requirements of the design criteria, especially in critical areas with high stress (such as the top area and touchdown area of SCR);

(2) The minimum bend radius and maximum tension of the flexible pipe meet the design requirements;

(3) The minimum tension at the bottom of the riser will not damage the structural integrity;

(4) The maximum displacement or deformation of the top of the riser (such as the maximum

stroke of the TTR tensioner and the maximum rotation angle of the SCR flex joint) meets the design requirements for the corresponding components.

6.2.1.2 The riser strength analysis shall provide the interface loads required for local structural analysis, generally including:

(1) Maximum load and its direction of action at the top connection interface;

(2) Maximum load and its direction of action at the connection interface with PLET, underwater wellhead, etc.;

(3) Maximum load and its direction of action at key components as required.

6.2.2 Analysis methods

6.2.2.1 The riser strength analysis includes static configuration analysis and dynamic extreme value response analysis.

6.2.2.2 The static analysis is used to determine the static configuration of the riser under static loads, such as SCR top tension, touchdown point location, suspended length and flowline length. Static analysis results can also be used as initial conditions for dynamic analysis. The loads to be considered in static analysis include at least gravity, buoyancy, hydrostatic pressure inside and outside the pipe, steady-state currents and floating structure average offset.

6.2.2.3 In dynamic analysis, it is to first calculate generally the motion response of the floating structure (including wave-frequency and low-frequency motions) of the floating structure-riser-mooring system under various conditions, and then calculate the dynamic response of the riser based on the floating structure motion and the environmental load and functional load under corresponding conditions.

6.2.2.4 In addition to TTRs, for each sea state, floating structure motion and riser response shall be calculated by taking the environmental load directions as near, transverse and far relative to the riser configuration, respectively. Generally, the motion condition in the far direction results in higher top tension of the riser, whereas that in the near direction induces greater bending stress in the touchdown zone.

6.2.2.5 To determine the extreme value of the riser response under each condition, the extreme value estimation can be performed on the response results of the random process, or multiple random seed numbers (generally not less than five) can be calculated for each condition. The average of the maxima obtained from multiple calculations can be approximated as the extreme value of the riser response. The duration of each sea state is generally not less than three hours.

6.2.2.6 For conservative purposes, the section stiffness and riser weight in the riser analysis may be based on the nominal wall thickness, while the strength check should use the nominal wall thickness minus the corrosion allowance.

Section 3 Wave-Induced Fatigue Analysis

6.3.1 General requirements

6.3.1.1 The riser wave-induced fatigue analysis verifies that:

(1) Short-term wave-induced fatigue damage in extreme sea states shall comply with the requirements for design life;

(2) Long-term wave-induced fatigue damage during the in-position period shall comply with the requirements for design life.

6.3.1.2 The riser wave-induced fatigue analysis is also used to provide the following information:

(1) Long-term wave-induced fatigue damage during the in-position period, used for calculating the total fatigue damage and conducting verification;

(2) Fatigue loads required at the top and bottom interfaces, used for fatigue analysis of top connection structures or submarine structures;

(3) The required fatigue stress histograms (stress amplitude-number of cycles) at key components and welds, used for ECA assessment or component fatigue analysis.

6.3.2 Analysis methods

6.3.2.1 Wave-induced fatigue of risers shall include at least fatigue damage caused by wave-frequency response and low-frequency response. The low-frequency motion of the floating structure may have a significant impact on fatigue damage in the riser touchdown zone. The slowly varying component in the slow drift motion should also be taken into account as it contributes to the total fatigue damage of the riser.

6.3.2.2 The long-term wave-induced fatigue damage of the riser is obtained by calculating its dynamic response under each sea state represented in the wave scatter diagram. The fatigue damage for different sea states is accumulated using the Palmgren-Miner linear accumulation method. The parameters of the sea state spectrum shall be based on observational data, and either JONSWAP or P-M spectrum may be used.

6.3.2.3 In addition to TTRs, the short-term wave-induced fatigue analysis shall account for the directionality of environmental loads relative to the riser configuration, and the fatigue damage caused by floating structure motion and riser response in the near, transverse and far directions shall be verified respectively.

6.3.2.4 Long-term fatigue analysis shall account for the cumulative fatigue damage due to variations in the floating structure's operating draft during the in-position period. Short-term fatigue analysis shall account for the most dangerous draft conditions.

6.3.2.5 For environmental loads in different directions, different positions around the riser cross-sectional circumference should be selected at regular intervals to calculate fatigue damage at the most critical positions. Usually, the maximum cumulative fatigue damage among all positions around the riser cross-sectional circumference shall be taken as the fatigue damage for that specific cross-section along the riser length.

6.3.2.6 In long-term fatigue damage assessment, the wall thickness of a riser shall be reduced over its service life. Usually, half of the corrosion allowance can be taken as a reduction to calculate the fatigue stress of the riser based on the wall thickness after reduction.

6.3.2.7 Fatigue assessment can be based on nominal stress or hot spot stress of the riser. When the nominal stress is used, the stress concentration factor can be determined by appropriate stress analysis or stress concentration factor calculation formula.

6.3.2.8 If a buckle arrestor is installed at the location where the riser is subjected to fatigue load, its influence on stress concentration shall be considered in the analysis.

6.3.2.9 The selected S-N curve shall be applicable to the location of riser components/welds (including weld root and weld toe), service conditions and welding procedure. In the absence of typical riser fatigue resistance data, fatigue tests shall be conducted directly on actual components with due consideration given to the internal and external environmental conditions of the risers.

Section 4 Vortex-Induced Vibration Fatigue Analysis

6.4.1 General requirements

6.4.1.1 The riser VIV fatigue analysis includes verification of the following:

(1) Short-term fatigue damage in extreme sea states shall comply with the requirements for design life;

(2) Long-term VIV fatigue damage during the in-position period shall comply with the requirements for design life.

6.4.1.2 The riser VIV fatigue analysis is also used to provide the following information:

(1) Long-term VIV fatigue damage during the in-position period, used for calculating the total fatigue damage and conducting verification;

(2) Fatigue loads required at the top and bottom interfaces, used for fatigue analysis of top connection structures or submarine structures;

(3) The required fatigue stress histograms at key components and welds, used for ECA assessment or component fatigue analysis.

6.4.1.3 In addition to the requirements in this section, the riser VIV fatigue analysis shall also comply with the relevant requirements in 6.3.2.5-6.3.2.9 of this Chapter.

6.4.2 Analysis methods

6.4.2.1 According to the ocean current and the vibration direction caused, the riser VIV can be mainly classified into:

(1) In-line VIV induced by in-plane flow;

(2) Cross-flow VIV induced by in-plane flow;

(3) In-line VIV induced by out-of-plane flow;

(4) Cross-flow VIV induced by out-of-plane flow.

Among them, the cross-flow VIV is usually greater than the in-line VIV.

6.4.2.2 For long-term VIV fatigue analysis, it can be assumed that all current profiles are in the same direction based on conservative considerations. For VIV fatigue damage of risers in all current profiles and different directions of action, the largest one shall be used to calculate the total long-term cumulative fatigue damage.

6.4.2.3 The long-term VIV fatigue analysis of the riser during its service life shall use ocean currents with a one-year return period in all expected directions, and both uniform flow and shear flow responses shall be considered. The VIV fatigue damage caused by each current profile is multiplied by the coefficient of the corresponding current occurrence probability, and linearly accumulated according to the Palmgren-Miner method to determine the annual VIV fatigue damage.

6.4.2.4 The short-term VIV fatigue analysis of the riser during its service life shall take into account the current profiles with a hundred-year return period in different directions.

6.4.2.5 General process of riser VIV analysis:

(1) Determine cross-flow and, if required, in-line intrinsic frequencies and vibration modes of the riser through modal analysis of the riser model;

(2) Determine the local vortex shedding frequency along the riser;

(3) Compare the vortex shedding frequency with the fundamental intrinsic frequency to determine whether VIV occurs and assess the highest mode of response;

(4) If VIV is likely to occur, use appropriate methods to assess the VIV response;

(5) Calculate the stress amplitude and corresponding fatigue damage based on the VIV response.

6.4.2.6 Recognized methods shall be used for VIV analysis, and sensitivity analysis should be carried out on the relevant parameters of the model to ensure the conservatism of the results. If necessary, the hydrodynamic coefficients of the VIV suppression device used should be verified by tests.

6.4.2.7 The current load of the riser VIV is the current speed component of the vertical riser. The distribution of the current speed component perpendicular to the riser can be calculated based on the angle change of the riser configuration and the current profile determined by static analysis.

6.4.2.8 For riser-soil touchdown zones, the damping effect generated by the seabed shall be considered. The touchdown point of the riser can be simulated by articulated constraints.

6.4.2.9 In simple calculations for fatigue damage caused by VIV, the effects of waves can be ignored, and the current speed is assumed to remain constant.

Section 5 VIM-Induced Fatigue Analysis

6.5.1 General requirements

6.5.1.1 Vortex-induced motion (VIM) of the floating structure or buoyancy tank may occur when the vortex shedding frequency generated by currents passing over the floating structure column or buoyancy tank is close to the intrinsic frequency of the floating structure-mooring system. When the riser system is connected to such a floating structure or buoyancy tank, the VIM-induced fatigue of the riser shall be assessed.

6.5.1.2 VIM-induced fatigue analysis includes verification of the following:

(1) Short-term VIM-induced fatigue damage in extreme sea states shall comply with the requirements for design life;

(2) Long-term VIM-induced fatigue damage during the in-position period shall comply with the

requirements for design life.

6.5.1.3 VIM-induced fatigue analysis is also used to provide the following information:

(1) Long-term VIM-induced fatigue damage during the in-position period, used for calculating the total fatigue damage and conducting verification;

(2) Fatigue loads required at the top and bottom interfaces, used for fatigue analysis of top connection structures or submarine structures;

(3) The required fatigue stress histograms at key components and welds, used for ECA assessment or component fatigue analysis.

6.5.1.4 In addition to the requirements in this section, the riser VIM-induced fatigue analysis shall also comply with the relevant requirements in 6.3.2.5-6.3.2.9 of this Chapter.

6.5.2 Analysis methods

6.5.2.1 VIM response characteristics of the floating structure, such as VIM response amplitude and current reduced velocity curve (A/D curve), can be obtained by model test or CFD simulation. The A/D curve shall take into account the corresponding data for different floating structure drafts and current directions.

6.5.2.2 If the time-domain motion history method of the floating structure is used for riser analysis, the motion time history data of the floating structure can be generated according to the VIM amplitude, direction and frequency of the floating structure under each current profile for riser response analysis.

6.5.2.3 For long-term floating structure VIM response, the current profile that can cause VIM resonance in the joint probability distribution of currents in all directions shall be covered.

6.5.2.4 Long-term VIM-induced fatigue analysis shall account for the cumulative fatigue damage due to variations in the floating structure's operating draft during the in-position period. For conservative considerations, the draft and damping conditions corresponding to the maximum VIM response can be used. Short-term VIM-induced fatigue analysis shall account for the most dangerous draft and damping conditions.

6.5.2.5 The short-term VIM-induced fatigue analysis of the riser shall account for the current profile of the maximum flow condition under extreme conditions in different directions, and the maximum fatigue damage of the riser shall be selected as the most dangerous condition for verification in combination with the specific layout direction of the riser.

Section 6 Interference Analysis

6.6.1 General requirements

6.6.1.1 For riser systems on floating installations, possible interference between the following structures shall be analyzed:

(1) Between different risers, including production risers and other production risers or drilling risers;

(2) Risers and mooring lines;

(3) Risers and umbilical cables;

(4) Risers and floating installations;

(5) Risers and other obstacles.

6.6.1.2 Riser interference analysis usually includes flow-induced interference analysis and wave-induced interference analysis.

6.6.1.3 For TTRs, in addition to the operation phase, interference analysis shall be performed during riser running and when the riser is in a disconnection state to verify that the riser will not collide during this process.

6.6.2 Analysis methods

6.6.2.1 For each group of adjacent risers, the interference analysis shall account for the most dangerous environmental load direction.

6.6.2.2 For each pair analyzed, the upstream riser shall be a riser with lighter weight (e.g., the lightest medium during operation or shutdown), greater drag force (e.g., larger riser diameter) and greater deformation under the same current.

6.6.2.3 For the interference analysis of upstream and downstream risers, the following factors are usually considered:

(1) Differences in drag force caused by differences in weight, medium, size, tension, etc. of adjacent upstream and downstream risers;

(2) Shielding effect in the wake area;

(3) Amplification factor of drag force generated by VIV;

(4) Motion following the floating structure under wave loads.

Section 7 Installation Feasibility Analysis

6.7.1 General requirements

6.7.1.1 The installation feasibility analysis mainly covers:

(1) Check the riser integrity during installation, verify the feasibility of the installation scheme, and determine the installation restrictions (e.g., sea states);

(2) Verify that the installation vessels and equipment (such as the stinger of the S-lay vessel and the tensioner tension of the J-lay vessel) can meet the installation design requirements.

6.7.1.2 The installation feasibility analysis shall take into account factors such as the type of riser system, the specific installation method and installation process used, and the constraints of the installation vessel to ensure that the risers do not suffer excessive strain, buckling, fracture or coating damage under the expected conditions for the most adverse environmental conditions during installation.

6.7.1.3 The installation feasibility analysis includes static and dynamic analyses. Static analysis usually includes the condition analysis of the riser at various positions relative to the floating structure and the seabed.

6.7.1.4 Relevant requirements of other recognized standards may also be used for the design criteria and analysis methods for installation feasibility analysis.

Section 8 Other Analyses

6.8.1 General requirements

6.8.2.1 In addition to the global analysis described in the previous sections of this Chapter, other analyses such as sensitivity analysis and wear analysis may be performed depending on the type of riser and specific needs.

6.8.2 Sensitivity analysis

6.8.2.1 The purpose of the sensitivity analysis is to verify that changes in important parameters in the riser model within the possible range will not have an unacceptable impact on the main analysis results of the riser.

6.8.2.2 The design parameters for sensitivity analysis shall be selected based on the characteristics of the specific riser system. Typical riser design parameters include floating structure draft, riser position and angle (such as TTR underwater wellhead position, SCR top direction angle and angular tolerance of supporting structure), end joints, special riser joint, riser weight tolerance, seabed parameters, mooring pretension, hydrodynamic coefficient, medium parameters in the riser, wave parameters, key parameters for VIV analysis, long-term surface current data for VIM analysis, A/D curve data for VIM analysis, etc.

6.8.2.3 The risers selected for sensitivity analysis shall be fully representative of the different riser types used.

6.8.3 Wear analysis

6.8.3.1 For risers (including drilling risers, production risers, etc.) planned for drilling operations, the contact force of the drill pipe on the riser shall be analyzed based on the drilling plan and corresponding environmental conditions, taking into account installation errors, e.g., that of the wellhead. Corresponding cumulative wear should be estimated combined with the drilling time and wear coefficient.

Chapter 7 Local Analysis

Section 1 General Provisions

7.1.1 General requirements

7.1.1.1 This Chapter includes fracture mechanics evaluation for determining the acceptable size of defects and analysis of local structural components required in the riser system, such as the tensioner, buoyancy tank, riser base, special riser joint, connector, buckle arrestor, top assembly, riser receiving device, VIV suppression device, I/J-shaped pipe, bell mouth and bending stiffener. In this case, it is necessary to use the global analysis results of the riser as input data for local analysis.

7.1.1.2 Detailed structural analysis of components in the riser system is usually carried out using general finite element software. In addition to the requirements in this Chapter, component analysis shall comply with the requirements of specific recognized standards for the corresponding components.

Section 2 Engineering Critical Assessment

7.2.1 General requirements

7.2.1.1 Engineering Critical Assessment (ECA) can be used to determine the allowable initial defect size of girth welds. Based on the ECA results, the installation contractor shall establish acceptance criteria for defect size during NDE based on the dimension error, depth error and detection reliability of the testing technology.

7.2.2 Analysis methods

7.2.2.1 Generally, recognized methods, e.g., CTOD method, are used in ECA, and the assessment method of BS 7910 can also be used. The crack growth time calculated for the girth weld is usually required to meet the requirement of five times the design life.

7.2.2.2 The welds targeted by the ECA shall be located in the most critical areas obtained by fatigue analysis.

7.2.2.3 Fatigue loads for ECAs typically include wave-induced fatigue, VIV fatigue, VIM-induced fatigue and installation fatigue, usually in the form of a histogram of stress range.

7.2.2.4 Local deviations in welding shall be addressed through the application of stress concentration factors or by other appropriate methods.

Section 3 Buoyancy Tank Analysis

7.3.1 General requirements

7.3.1.1 This section specifies the structural analysis requirements for the buoyancy tank of the hybrid riser system, including strength analysis and fatigue analysis.

7.3.2 Strength analysis

7.3.2.1 The strength analysis shall verify that the buoyancy tank can meet the design criteria for stress and buckling at the manufacturing, transportation, installation and in-position stages. The strength analysis of the buoyancy tank can be based on API RP 2A-WSD and ISO 19900 standards.

7.3.2.2 The stress and buckling analysis of the buoyancy tank at the in-position stage shall account for load cases corresponding to its suspended, ascending and descending positions.

7.3.2.3 The hydrostatic test cases at the manufacturing site shall take into account the pressure difference on bulkheads between adjacent water-filled compartments and empty compartments, as well as the hydrostatic head when the buoyancy tank is oriented horizontally or vertically.

7.3.3 Fatigue analysis

7.3.3.1 The fatigue analysis shall verify that the expected fatigue life of the buoyancy tank meets the requirements for design life, and a safety factor of 10 is recommended. The fatigue analysis of the buoyancy tank can be based on API RP 2A-WSD and the CCS *Guidelines for Fatigue Analysis of Marine Engineering Structures*.

7.3.3.2 Cumulative fatigue damage of the buoyancy tank includes:

(1) Fatigue damage of the buoyancy tank under the action of waves, currents and tides during the in-position period. Among them, the changes in hydrostatic pressure on the buoyancy tank caused by waves and tides;

(2) Fatigue damage caused by vortex-induced motion of the buoyancy tank during the in-position period;

(3) Fatigue damage of the buoyancy tank during the in-position period due to sloshing loads generated by free surfaces within compartment;

(4) Fatigue damage during transportation and installation.

7.3.3.3 Based on the global analysis at the installation and in-position stages of the hybrid riser system, a histogram of the loads required for the fatigue analysis of buoyancy tank is obtained.

7.3.4 Risk analysis

7.3.4.1 The following potential accidents of the buoyancy tank should be assessed:

(1) The possibility of objects falling from floating installations or supporting ships and hitting the buoyancy tank;

(2) The possibility of collision between the hull and its appurtenances, underwater robots, etc. and the buoyancy tank;

(3) The possibility of buoyancy loss of the buoyancy tank due to corrosion;

(4) The possibility of buoyancy loss of the buoyancy tank due to cracks.

Section 4 Riser Base Analysis

7.4.1 General requirements

7.4.1.1 This section provides the analysis methods and requirements for suction piles. For the analysis of driven piles, refer to the relevant requirements in API RP 2A-WSD Part IX "Pile

Foundation Design", API RP 2GEO and API RP 2SK.

7.4.1.2 The strength, top displacement and fatigue life of the pile foundation shall comply with the requirements of the design criteria.

7.4.2 Loads

7.4.2.1 The following loads shall be considered in the suction pile analysis:

(1) Anchorage loads due to temperature, environment, riser response: Environmental loads and riser response loads can be obtained based on the global analysis of the hybrid riser, and temperature loads can be obtained based on detailed finite element analysis;

(2) Loads during installation, transportation and lifting: The pile insertion/extraction load can be determined by the pressure obtained from geotechnical analysis.

7.4.2.2 In the bearing capacity analysis of suction piles, vertical and lateral loads and their coupling effects shall be considered.

7.4.3 Geotechnical analysis

7.4.3.1 A geotechnical analysis shall be carried out at the anchorage of the suction piles to ensure sufficient bearing capacity can be provided.

7.4.3.2 The geotechnical analysis results shall meet the corresponding safety factor requirements for insertion and extraction under installation conditions, vertical bearing capacity and lateral bearing capacity under operating/extreme/temporary/survival conditions.

7.4.3.3 The top displacement of the pile foundation shall meet the corresponding requirements of each condition:

(1) The lateral deflection under operating conditions and extreme conditions shall meet the specified tolerance requirements, and the lateral deflection under survival conditions shall not cause overall failure;

(2) The vertical displacement under each condition shall not exceed the service capacity requirements for the hybrid riser. The cumulative cyclic displacement shall be within certain limits to prevent significant loss of uplift resistance.

7.4.4 Structural analysis

7.4.4.1 The overall structural analysis of the pile foundation shall be carried out using the structural finite element method to verify that the pile wall structure and auxiliary structures have sufficient strength in high load areas. The structural analysis of the pile foundation can be based on the WSD method in API RP 2SK and API RP 2A. Under lifting, transportation, pile insertion, pile extraction, operation, extreme and survival conditions, the stress of all structural components shall meet the corresponding requirements specified. API Bulletin 2U and API Bulletin 2V can be used for the analysis of shell structures and flat plate structures respectively, and the safety factors specified in API RP 2SK can be used.

7.4.4.2 Suction piles and their installation appurtenances shall be designed to resist the maximum loads during the lifting, transportation, installation and recovery of suction piles. The loads during installation and recovery shall be calculated based on the specific installation procedures and typical ship motions. All lifting appurtenances and supporting structures shall comply with the relevant requirements in API RP 2A-WSD.

7.4.4.3 For short-term extreme sea states, the short-term fatigue damage of suction piles shall be calculated based on the load history and range at the connection in addition to strength analysis.

Section 5 Analysis of Other Structural Components

7.5.1 General requirements

7.5.1.1 This section provides general analysis requirements for riser structural components such as the top riser assembly, bottom riser assembly, top stress joint, bottom stress joint and tether connection.

7.5.1.2 Analysis of riser structural components typically includes:

(1) Strength analysis during the in-position period;

(2) Fatigue analysis during the in-position period;

(3) Strength analysis and fatigue analysis during transportation;

(4) Strength analysis and fatigue analysis during installation.

7.5.1.3 The analysis of flex joints shall take into account the highly nonlinear characteristics of the flexible unit and the rubber layer therein. Flex joints are usually subject to detailed professional analysis by the supplier.

7.5.2 Strength analysis

7.5.2.1 Pressure-containing components shall be analyzed in accordance with the operating conditions, extreme conditions, survival conditions, test conditions, temporary conditions, etc. specified in API RP 2RD and shall meet the corresponding design criteria requirements. Other non-pressure-containing structural components shall be analyzed for the control conditions of maximum stress determined by the global analysis results of the riser in accordance with the requirements in API RP 2A-WSD. The hot spot stress may be verified based on the relevant requirements in ASME BPVC.

7.5.2.2 The strength analysis process for pressure-containing structural components includes:

(1) Carry out a global time domain response analysis of the riser system and verify the nominal cross-section according to each condition in API RP 2RD;

(2) If necessary, carry out a detailed finite element analysis to determine hot spot stresses at geometric discontinuities in the component. In the detailed finite element analysis, the loads shall be determined based on the maximum values obtained from the first step of the global time domain analysis of the riser, followed by a verification of the local hot spot stress.

7.5.2.3 The strength analysis process for non-pressure-containing structural components includes:

(1) Determine the control conditions based on the stress results of the global analysis of the riser;

(2) Carry out a detailed finite element analysis on components based on the load and boundary conditions obtained under control conditions and verify stress, buckling, etc.;

(3) If necessary, carry out a fine-mesh three-dimensional finite element analysis to verify the local

hot spot stress.

7.5.2.4 In the detailed finite element analysis, three-dimensional solid elements and shell elements should be employed. The element mesh shall be sufficiently refined to capture the hot spot stress.

7.5.3 Fatigue analysis

7.5.3.1 The fatigue analysis of structural components can be carried out using the time domain or frequency domain method. For pressure-containing components, the time domain analysis method should be used.

7.5.3.2 The time domain fatigue analysis method of structural components is used to:

(1) Determine the stress concentration factor by using a detailed finite element model;

(2) Establish a global finite element model of the riser by using beam elements or similar elements, and make time domain fatigue analysis by using appropriate S-N curves and stress concentration factors.

7.5.3.3 The frequency domain fatigue analysis method of structural components is used to determine fatigue damage by performing fatigue analysis on stress histograms at given locations. The stress histogram at a specific location is determined by the response variable histogram and the stress transfer coefficient (STC, the stress change per unit response change), which can be based on the following formula:

$$\sigma_i(t) = STC_i \times R_i \tag{7-1}$$

Where, $\sigma_i(t)$ represents the stress distribution at a given position; STC_i represents the stress transfer coefficient at the i^{th} node; R_i represents the response variable distribution at the i^{th} node. The response variables can be effective tension, torsional moment and shear stress, obtained based on the global analysis. The stress transfer coefficient is defined in the form of hot spot stress.

Chapter 8 Material and Manufacturing Surveys

Section 1 General Provisions

8.1.1 General requirements

8.1.1.1 The materials and manufacturing of components in the riser system shall comply with the requirements of the specifications, the Guidelines or applicable standards.

Section 2 Materials

8.2.1 General requirements

8.2.1.1 Qualification tests shall be carried out on metallic and non-metallic materials and welding of the riser system to verify their compliance with performance requirements in Section 4, Chapter 4 of the Guidelines. For the test methods and acceptance criteria, refer to the corresponding standards.

8.2.2 Fatigue performance of girth weld

8.2.2.1 The welding procedure specification and qualification shall ensure that the fatigue performance of the girth weld can comply with the requirements of the S-N curve selected in the design. The test data shall be able to prove that the S-N curve has a 95% confidence level.

8.2.2.2 The fatigue performance of the weld in the welding procedure qualification shall be verified by full-scale or small-scale fatigue tests.

8.2.2.3 For double-slope S-N curves, sufficient test data shall be available to characterize the change in slope.

8.2.2.4 For girth welds serving in an environment containing H_2S and/or CO_2, the effect of acidic conditions on fatigue performance shall be considered.

8.2.3 Fracture toughness performance

8.2.3.1 Fracture toughness tests shall be carried out on pipe materials in their final delivered condition. For the test type and temperature, refer to Table 8.2.3.1.

Fracture Toughness Tests of Pipe Materials Table 8.2.3.1

Test type	Test temperature requirements	
CVN impact test	Nominal wall thickness (mm)	Test temperature (°C)
	≤20	$\le T_{min}$
	20<t≤40	$\le T_{min}$-10
	>40	$\le T_{min}$-20
CTOD test	$\le T_{min}$-20℃	
DWT test	$\le T_{min}$-28℃	

Note: T_{min} is the minimum service temperature.

8.2.3.2 Fracture toughness tests shall be carried out on pressure-containing forgings/extruded parts. For the test type and temperature, refer to Table 8.2.3.2.

Fracture Toughness Tests of Pressure-containing Forgings/Extruded Parts Table 8.2.3.2

Test type	Test temperature requirements
CVN impact test	≤T_{min}-10℃
CTOD test	≤T_{min}
DWT test	≤T_{min}-28℃

8.2.3.3 Fracture toughness tests of welds shall be included in the welding procedure qualification. For the test type and temperature, refer to Table 8.2.3.3.

Fracture Toughness Tests of Welds Table 8.2.3.3

Location	Test type	Test temperature requirements
Base material	Refer to Table 8.2.3.1.	Refer to Table 8.2.3.1.
Weld	CTOD test	≤T_{min}
	CVN impact test	≤T_{min}-28℃
Fusion line and heat-affected zone	CVN impact test	≤T_{min}-20℃

8.2.3.4 Fracture toughness tests shall be carried out on structural steel sections/steel plates. For the test type and temperature, refer to Table 8.2.3.4.

Fracture Toughness Tests of Structural Steel Sections/Steel Plates Table 8.2.3.4

Test type	Test temperature requirements
CTOD test	≤T_{min}-20℃
DWT test	≤T_{min}-28℃

8.2.3.5 The sampling requirements and test procedures for fracture toughness tests shall comply with the corresponding test procedures in ASTM, API and BS or equivalent standards.

8.2.3.6 Vickers hardness tests shall be carried out in accordance with ISO 6507-1.

8.2.4 NDE

8.2.4.1 The NDE personnel qualifications shall comply with ISO 9712, ASNT SNT-TC-1A or other equivalent standards.

8.2.4.2 Upon completion of the weld, 100% visual inspection and NDE shall be carried out, and NDE shall be carried out after the visual inspection is completed.

8.2.4.3 NDE shall be carried out in the final heat treatment state.

8.2.4.4 All girth welds should be 100% inspected for internal defects through UT and/or RT, and 100% inspected for surface defects through MT or PT.

8.2.4.5 For girth welds subjected to fatigue loads, UT should be used to detect planar defects in the weld root area.

8.2.4.6 The acceptance criteria for NDE shall comply with API 1104 or equivalent standards, and may also be determined based on the results of fracture force analysis.

Section 3 Pipe Materials

8.3.1 General requirements

8.3.1.1 This section applies to the material and manufacturing surveys of riser pipes, and their performance shall meet the design requirements.

8.3.1.2 The manufacturing survey process of riser pipes is as follows:

(1) Document review:

① Specifications;

② Manufacturing procedures;

③ Inspection and test plans;

④ Welding Procedure Specification and qualification reports (if applicable);

⑤ NDE procedures;

⑥ Welder qualifications (if applicable);

⑦ NDE personnel qualifications;

(2) Survey of raw materials;

(3) Manufacturing process qualification;

(4) Production survey:

① Physical and chemical tests;

② Dimension and visual inspection;

③ NDE;

④ Hydrostatic test.

8.3.1.3 Carbon steel pipes shall comply with API Spec 5L or equivalent standards. Corrosion-resistant alloy pipes and pipes with corrosion-resistant lining alloys shall comply with API Spec 5LC, API Spec 5LD or equivalent standards respectively. Tubing and casing shall comply with API Spec 5CT, ISO 13628-7 or equivalent standards. In addition, the brittle fracture resistance of the pipe materials shall also meet the corresponding requirements in Section 2, Chapter 8 of the Guidelines. Flexible pipes and end fittings shall comply with API RP 17B, API Spec 17J or equivalent standards.

8.3.1.4 For risers serving in acidic environment, the steel pipe material shall comply with NACE MR0175 or equivalent standards.

8.3.1.5 After the riser pipes are manufactured, they shall be marked, including information such as manufacturer name, size, material specification and grade, manufacturing process, furnace batch number and pipe number.

8.3.1.6 The completion documents to be submitted at the riser pipe manufacturing stage include but are not limited to:

(1) Material certificates and test reports;

(2) Manufacturing procedures and qualification reports;

(3) Inspection and test plans and reports;

(4) Welding Procedure Specification and qualification reports (if applicable);

(5) NDE procedures and reports;

(6) Welder qualification certificates (if applicable);

(7) Qualification certificates of NDE personnel;

(8) Heat treatment records;

(9) Hydrostatic test reports;

(10) Abnormal item records;

(11) Image and video data.

Section 4 External Coating

8.4.1 General requirements

8.4.1.1 This section applies to the manufacturing survey of the external coating of the riser.

8.4.1.2 The manufacturing survey process of the external coating is as follows:

(1) Document review:

① Specifications;

② Manufacturing procedures;

③ Inspection and test plans;

(2) Survey of raw materials;

(3) Manufacturing process qualification;

(4) Production survey.

8.4.1.3 For the riser system, the external coating process will vary depending on the location (such as pipe body, field joint and splash zone). The specifications, manufacturing procedures and inspection and test plans shall be prepared separately. The pipe body coating and field joint coating shall comply with the requirements of the corresponding standards.

8.4.1.4 If there are thermal insulation performance requirements for the external coating, qualification tests shall be carried out to verify compliance with the design requirements.

8.4.1.5 The completion documents to be submitted for the manufacture of external coatings include:

(1) Procedure documents and inspection and test plans;

(2) Qualification test reports;

(3) Personnel qualifications (if applicable);

(4) List of materials and certificates;

(5) Inspection and test reports during production;

(6) Repair records.

Section 5 Other Components

8.5.1 General requirements

8.5.1.1 Qualification tests shall be carried out on other components of the riser system, such as the connector, VIV suppression device, tensioner, buoyancy module and stress joints in accordance with the specifications and relevant standards.

8.5.1.2 Other components of the riser system shall be subjected to the factory acceptance test (FAT) in accordance with the specifications and relevant standards.

8.5.1.3 For non-pressure-containing structural components of the riser system, such as the buoyancy tank and tensioner, their materials shall comply with corresponding standards such as ASTMA36, ASTM A516, ASTM A537, API 2H, API 2W and API 2Y, their manufacturing shall comply with API RP 2A or equivalent standards, and the welding shall comply with AWS D1.1 or equivalent standards.

8.5.1.4 Qualification tests shall be carried out on the composite buoyancy foam materials in terms of buoyancy performance, buoyancy loss performance and hydrostatic pressure resistance to verify compliance with the design requirements. The composite buoyancy foam materials used on the drilling riser shall comply with API Spec 16F.

8.5.1.5 The pressure-containing forgings of the riser system shall comply with the manufacturing procedures.

8.5.1.6 The relevant requirements in ASTM A320 and ASTM A194 shall serve as reference for bolts and nuts.

8.5.1.7 The manufacture and installation of anodes shall comply with ISO 15589-2 or equivalent standards.

8.5.1.7 The fatigue performance and fracture toughness performance of other components shall also comply with the requirements in Section 2 of this Chapter.

8.5.1.8 Other components serving in acidic environments shall comply with NACE MR0175 or equivalent standards.

Chapter 9 Offshore Installation

Section 1 General Provisions

9.1.1 General requirements

9.1.1.1 This Chapter applies to the design review and on-site survey of production/export/injection/import riser systems at the offshore installation stage. Relevant provisions in the CCS *Guidelines for Survey of Offshore Drilling Plants* shall serve as reference for offshore installation and test of the drilling/workover/completion riser system.

9.1.1.2 All stages of offshore installation shall be carried out in accordance with the specifications, drawings, calculation reports, procedures and inspection and test plans approved by CCS, and the restrictions on each operation shall be clearly specified in the procedures.

9.1.1.3 All construction activities of offshore installation, including welding, NDE, connection and coating, shall be completed by personnel with corresponding qualifications. The relevant certification documents of personnel qualification certificates, equipment and materials shall be kept for information.

Section 2 Installation Design

9.2.1 Installation analysis

9.2.1.1 It is necessary to, based on the specific installation scheme, define the installation and transportation cases, analyze and verify each condition for installation and transportation, and determine the maximum environmental conditions allowed for operation as installation restrictions.

9.2.1.2 The strength analysis shall verify that the stress and strain of the riser during installation and transportation do not exceed the allowable values. The strength analysis shall cover the stages such as lifting, pipe reeling, pipe towing, upending and standing.

9.2.1.3 The fatigue damage to the riser during transportation and installation is calculated through dynamic analysis, taking into account the riser type as well as the specific transportation and installation methods. The predicted fatigue damage shall comply with the requirements of the design specifications.

9.2.2 Risk management plan

9.2.2.1 A risk management plan shall be prepared to identify, describe and assess risk sources, thus minimizing the consequences of risks.

9.2.2.2 The risk management plan shall be tailored to the specific circumstances of the project and reviewed and updated regularly as the management process progresses.

9.2.3 Installation manual

9.2.3.1 The installation contractor shall prepare an installation manual as the basis for offshore installation. The installation manual shall include:

(1) Installation procedures;

(2) Pre-commissioning procedures;
(3) Emergency procedures;
(4) Limiting environmental conditions;
(5) Weather window for completing various operations;
(6) Quality control;
(7) Design and operation limits;
(8) Health, safety and environmental factors;
(9) Responsibilities and communication procedures.

The installation manual shall apply to the installation analysis, personnel qualification and workmanship, installation vessel and equipment capability.

9.2.3.2 If applicable, emergency procedures shall account for:
(1) Weather conditions exceeding the limiting environmental conditions;
(2) Failure or partial failure of the ballast system;
(3) Third-party marine activities;
(4) Riser buckling and water ingress;
(5) Failure of the ship positioning system;
(6) Fault of tensioner system;
(7) ROV failure;
(8) Other emergencies identified in FMEA or HAZOP analysis.

Section 4 Pre-survey

9.4.1 General requirements

9.4.1.1 Before the installation, a pre-survey procedure shall be prepared to survey along the riser and pre-laid section (if any) route to confirm that the water surface, water and seabed conditions meet the operation requirements.

Section 5 Installation Surveys

9.5.1 General requirements

9.5.1.1 The riser system shall be installed in accordance with the installation procedure.

9.5.2 Arrival inspection

9.5.2.1 The surveyor shall inspect the as-received conditions of the riser system components. Any damage to materials, coatings, grooves, etc. shall be recorded and repaired, and replaced if necessary.

9.5.3 Welding surveys

9.5.3.1 Welding at the offshore installation stage shall be carried out in accordance with the Welding Procedure Specification which shall be qualified. The qualification shall include the fatigue performance and fracture toughness performance of the girth weld. For the corresponding requirements, refer to Section 2, Chapter 8 of the Guidelines.

9.5.3.2 Welds at the offshore installation stage shall be subjected to 100% visual inspection and NDE. For the inspection/test methods and acceptance criteria, refer to the corresponding requirements in Section 2, Chapter 8 of the Guidelines.

9.5.3.3 To improve the offshore installation efficiency, pipe sections may also be pre-fabricated and joined by welding onshore. Its welding and inspection shall not be inferior to the corresponding requirements for offshore installation.

9.5.4 Coating surveys

9.5.4.1 Field joint coating, if required, shall be applied according to the qualified coating procedure, and production survey shall be carried out according to the inspection and test plan.

Section 6 Pre-commissioning

9.6.1 General requirements

9.6.1.1 After the offshore installation of the riser system is completed, the entire system shall be pre-commissioned, and the commissioning procedure requires approval from CCS.

9.6.1.2 Pre-commissioning shall include operations such as water-filling, pigging, gauging, pressure testing and dewatering/drying. The construction procedures and results of each operation shall be recorded.

9.6.1.3 The medium used at the pre-commissioning stage shall not cause damage or pollution to the riser structure and internal environment. If it cannot be completely removed, the long-term impact of its residue in the pipe shall be considered.

9.6.1.4 The pressure value used in the system pressure test shall not be less than the specified hydrostatic test pressure, and the pressure holding time shall not be less than 8 hours. The system test pressure of flexible risers shall comply with API RP 17B or equivalent standards.

Section 7 Post-survey

9.7.1 General requirements

9.7.1.1 After the offshore installation of the riser system is completed, a post-survey shall be conducted to confirm that the final state of the riser system meets the requirements of the specifications.

Section 8 Completion Documents

9.8.1 General requirements

9.8.1.1 Completion documents for the offshore installation stage of the riser system include but are not limited to:

(1) Key drawings of the riser system;

(2) All procedure documents and qualification test reports;

(3) Inspection and test plans and reports;

(4) Welding Procedure Specification and records;

(5) NDE procedures and reports;

(6) Qualifications of welders and NDE personnel;

(7) Pre-commissioning reports, including system pressure test report;

(8) Post-survey reports and drawings;

(9) Completion data books;

(10) Abnormal item records.

Chapter 10 Service Beyond Design Life

Section 1 General Provisions

10.1.1 General requirements

10.1.1.1 For existing riser systems that are intended to remain in service beyond their design life, the following surveys shall be carried out:

(1) Review the initial design documents, drawings, structural modification records and survey reports;

(2) Check the operation, monitoring and test data of the riser system;

(3) Review the in-position analysis report based on the above data, which shall specify the key areas that need to be re-tested;

(4) Check the test results of the above key areas;

(5) Check the repair of riser system (if necessary);

(6) Review the subsequent test plan for the riser system.

10.1.1.2 The following documents shall be submitted to CCS for review:

(1) The documents for the use of the riser system beyond the design life generally include:

① Recommended extended service life;

② Recommended conditions of use;

③ Structural state inspected;

④ Records of changes in environmental/geotechnical conditions;

⑤ Corrosion history, predicted corrosion rate and remaining service life;

⑥ Recommended repair and replacement schemes;

⑦ Future survey/monitoring plans, survey intervals and acceptance criteria;

⑧ Recommended test plan, including test pressure and test interval.

(2) The analysis report on the use of the riser system beyond the design life generally includes:

① Strength analysis for each inspection condition;

② Cumulative fatigue damage analysis based on previous operating history;

③ Strength analysis report, for which consideration shall be given to the worst environmental conditions during the recommended service life and the structural state at the end, and to maintenance and replacement factors;

④ Prediction of corrosion and calculation of remaining fatigue life based on the structural state inspected, taking into account repair and replacement.

Section 2 Specific Requirements

10.2.1 Documents of the original riser system

10.2.1.1 The documents of the original riser system shall contain the original riser system data required for the structural integrity assessment of the riser system, including at least specifications, design basis documents, original design reports, completion drawings, and inspection records during manufacturing/installation/in-service.

10.2.1.2 The operator shall ensure that all assumptions are reasonable, the collected data is accurate and can represent the actual situation during the assessment period. If relevant data cannot be provided, a reasonable and conservative assumption shall be determined. Otherwise, actual measurements or tests shall be carried out.

10.2.2 State detection

10.2.2.1 For riser systems used beyond the design life, additional structural detection shall be carried out to assess the actual riser state. The scope of the detection depends on the integrity of the existing detection documents. Any changes, repairs, replacements or equipment installations from the riser installation shall be included in the records. Previous detection and maintenance reports shall be submitted for review.

10.2.2.2 To ensure that the existing sacrificial anodes can support the use of the riser system beyond its design life, the existing anti-corrosion system shall be re-assessed. If necessary, the existing anode needs to be replaced. The riser protective coating in the splash zone shall be repaired.

10.2.2.3 The detection shall include at least the following items:

(1) Inspection of riser splash zone and flexible pipe end fittings;

(2) Inspection of the anti-corrosion system and attached marine growth;

(3) Survey of seabed conditions;

(4) Detection of structural accessories and support systems.

10.2.2.4 The detection location usually includes the following key areas:

(1) High stress areas;

(2) Areas prone to fatigue damage (splash zone and touchdown zone of the riser, girth weld);

(3) Areas with submarine structures, cross-overs and free spans;

(4) Terminations, high-curvature regions and touchdown zones of the riser;

(5) Areas where damage occurs during installation or operation;

(6) Areas that have been repaired, replaced or changed during operation;

(7) Areas where abnormalities were found during the previous detection.

10.2.3 In-position analysis

10.2.3.1 Strength analysis of existing risers shall include measurement results, any structural damage and alterations.

10.2.3.2 For areas where riser design is governed by seismic or ice conditions, corresponding analysis shall also be carried out. The analysis result is used as an indicator for assessing the detection area.

10.2.3.3 Fatigue analysis may be exempted if the following conditions are met:

(1) The original fatigue analysis results show that the fatigue life of the riser meets the

requirements for extended service;

(2) The fatigue environment data used in the original fatigue analysis is still valid or considered to be relatively conservative;

(3) No unacceptable defects were found during the re-detection, and all repairable damages have been fully repaired;

(4) Attached marine growth and corrosion are within the design limits.

10.2.4 Supplementary repair and re-detection

10.2.4.1 The scope of repair or adjustment required shall be determined based on the preliminary riser state detection and structural analysis.

10.2.4.2 High stress areas shown by the structural analysis results may require re-detection. Areas with excessive stress need to be strengthened. Welds with low fatigue life may be improved by reinforcement or grinding. If grinding is used, the grinding procedure shall be submitted to CCS for review. The future detection interval shall be determined based on the remaining fatigue life of the weld.