



GUIDE FOR BUILDING AND CLASSING

SUBSEA RISER SYSTEMS

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**American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862**

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Foreword

This Guide applies to classification of design, construction and installation of subsea production, injection and/or export risers for offshore applications, as well as the periodic surveys required for maintenance of classification. Serviceability of risers is also addressed, but only to the extent that proper functioning of the pipe and its components affects safety. This Guide may also be used for certification or verification of design, construction or installation of subsea production, injection and/or export risers. ABS will certify or verify design, construction and installation of subsea production, injection and/or export risers when requested by the Operator/Owner or mandated by government regulations to verify compliance with this Guide, a set of specific requirements, national standards or other applicable industry standards. If ABS certification or verification is in accordance with this Guide and covers design, construction and installation, then the riser is also eligible for ABS classification.

This Guide has been written for worldwide application, and as such, the satisfaction of individual requirements may require comprehensive data, analyses and plans to demonstrate adequacy. This especially applies for risers located in frontier areas, such as those characterized by relatively great water depth or areas with little or no previous operating experience. Conversely, many provisions of this Guide often can be satisfied merely on a comparative basis of local conditions or past successful practices. ABS acknowledges the wide latitude that exists as to the extent and type of documentation which is required for submission to satisfy this Guide. It is not the intention of this Guide to impose requirements or practices in addition to those that have previously proven satisfactory in similar situations.

Where available, design requirements in this Guide have been posed in terms of existing methodologies and their attendant safety factors, load factors or permissible stresses that are deemed to provide an adequate level of safety. Primarily, ABS's use of such methods and limits in this Guide reflects what is considered to be the current state of practice in subsea riser design. At the same time, it is acknowledged that new materials and methods of design, construction and installation are constantly evolving. The application of this Guide by ABS in no way not seeks to inhibit the use of any technological approach that can be shown to produce an acceptable level of safety.

This Guide becomes effective on the first day of the month of publication.

This Guide is a complete re-write of the previous Guide published in May 2006. Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

Cross Referencing Convention

In this document, cross references are given in the following format:

Example: 1-3/5.6.1ii) signifying Chapter 1-Section 3/Subsection 5.Paragraph 6.Subparagraph 1 (item ii)



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CHAPTER 1 Scope and Conditions of Classification

SECTION 1 Applicability

1 General

This Guide provides criteria for the classification of subsea risers for Floating Production Installations (FPIs). The criteria address the design, fabrication, installation and maintenance of offshore production, injection and/or export risers that are constructed primarily of metallic materials. There is also a section in Chapter 3 addressing flexible risers and an appendix addressing composite risers. The continuance of classification during the service life of a riser is dependent on meeting the criteria contained herein for periodic surveys.

Classification of subsea risers is optional. Upon the request of the Operator/Owner, and where permitted by the cognizant Authority, this Guide can also be used by ABS to provide certification and verification of the riser to satisfy applicable governmental requirements.

3 Scope

The scope of the riser to be classed is to be clearly established in consultation with ABS. The starting and ending points or cross sections of the riser are to be logically selected and referenced to readily identified components; such as valves demarcating the riser's pipes from a seafloor structure and the Floating Installation. Ancillary equipment attached to the riser that is needed to provide the intended functioning of the riser; such as a tensioner, buoyancy tank or jumper hoses are to be included in the scope of the riser. Connections of ancillary equipment to the structure of a Floating Installation or to a seafloor structure are also to be included in the scope. However the structure of the Floating Installation or seafloor structure, supporting these connections may be outside the scope of the riser's classification. Drilling risers are not included in this Guide. Classification of drilling risers is to follow *ABS Guide for the Classification of Drilling Systems*.

5 Classification

The requirements for conditions of classification are contained in the separate, generic *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

Additional requirements specific to subsea riser systems are contained in the following Sections.

7 Minimum Design Service Life

The service life considered in the design of the riser is to be agreed by the designer/manufacturer, owner/operator and ABS. If not specified, the minimum design service life of the riser is considered as 20 years.



CHAPTER 1 Scope and Conditions of Classification

SECTION 2 Classification Symbols and Notations

A listing of Classification Symbols and Notations available to the Operators/Owners of vessels, offshore drilling and production units and other marine structures and systems, “List of ABS Notations and Symbols” is available from the ABS website “<http://www.eagle.org>”.

Application of this Guide is optional. However, compliance with the requirements of this Guide is compulsory when seeking the optional notations offered by this Guide. The following notations are specific to subsea riser systems.

1 Risers Built Under Survey

Risers which have been built, installed, tested and commissioned to the satisfaction of the ABS Surveyors to the full requirements of this Guide or to its equivalent, where approved by the Committee, will be classed and distinguished in the *Record* by:

✕ A1 Offshore Installation – Offshore Risers

3 Risers Not Built Under Survey

Risers which have not been built, installed, tested and commissioned under ABS survey, but which are submitted for classification, will be subjected to a special classification survey. Where found satisfactory, and thereafter approved by the Committee, they will be classed and distinguished in the *Record* in the manner as described in 1-2/1, but the mark ✕ signifying survey during construction will be omitted.

5 Classification Data

Data about the riser will be published in the *Record* (i.e., location, type, dimensions and depth of water at the installation site).



CHAPTER 1 Scope and Conditions of Classification

SECTION 3 Rules for Classification

1 Application

These requirements are applicable to those features that are permanent in nature and that can be verified by plan review, calculation, physical survey or other appropriate means. Any statement in this Guide regarding other features is to be considered as guidance to the designer, builder, Operator/Owner, et al.



CHAPTER 1 Scope and Conditions of Classification

SECTION 4 Documents to be Submitted

1 General

Documentation to be submitted to ABS is to include reports, calculations, drawings and other documentation necessary to demonstrate the adequacy of the design of the risers. Specifically, required documentation is to include the items listed in this Section.

3 Plans and Specifications

Plans and specifications depicting or describing the arrangements and details of the major items of the riser are to be submitted for review or approval in a timely manner. These include:

- Site plan indicating bathymetric features at the proposed site, the location of obstructions to be removed, the location of permanent man-made structures and other important features related to the characteristics of the sea floor
- Structural plans and specifications for risers, their supports and coating
- Schedules of nondestructive testing and quality control procedures
- Flow diagram indicating temperature and pressure profiles
- Specifications and plans for instrumentation and control systems and safety devices

When requested by the Operator/Owner, the Operator/Owner and ABS may jointly establish a schedule for information submittal and plan approval. This schedule, to which ABS will adhere as far as reasonably possible, is to reflect the fabrication and construction schedule and the complexity of the riser systems as they affect the time required for review of the submitted data.

5 Site-specific Conditions

Documents for site-specific conditions are to include environmental condition report and site investigation report.

In the environmental condition report, met-ocean data for normal operating, design (extreme), and survival conditions in terms of wind, waves, current with profile, direction, and associated return of periods are to be included. Other items such as temperature, tide, marine growth, ice conditions, earthquakes and other pertinent phenomena are also to be included if applicable.

In the site investigation report, geotechnical data acquisition and integrated geoscience studies should be included to determine soil properties, soil conditions, and geotechnical hazards and constraints across the site as specified in APR RP 2GEO, if applicable.

Geotechnical data acquisition is to include, logging, sampling, in situ testing, field and onshore laboratory testing, evaluation of geotechnical data, and reporting. The area for soil sampling is to be based on riser type, consideration of the expected variation between final and planned riser position as well as installation tolerance. The soil properties testing should include a suitable combination of in-situ and laboratory testing, seismic, and boring methods. The geotechnical data is to be integrated with geoscience studies (geophysics and geology). The geophysical survey is to identify seabed slopes, gullies, ledges, and the presence of any rocks or obstructions (nature or man-made) that might require removal or avoidance.

Geological modelling and identification of hazards, if applicable, is to determine seismic action due to earthquake, fault planes, sea floor instability, scour and sediment mobility, shallow gas, seabed subsidence, and the possibility that soil properties may be altered due to cyclic loading and the presence of other man-made structures such as pipelines, anchors and wellhead.

Where appropriate, data established for a previous installation in the vicinity of the riser proposed for classification may be utilized, if acceptable to ABS.

7 Material Specifications

Documentation for all materials comprising the major components of risers is to indicate that the materials satisfy the requirements of the pertinent specification including size and weight, material grade and class. Where applicable, procedures for storage and transportation of the riser pipes from the fabrication and coating yards to the offshore destination are to be given.

Material tests, if required, are to be performed to the satisfaction of ABS.

9 Design Data and Calculations

Information is to be submitted for the risers that describes the material data, and methods of analysis and design that were employed in establishing the design. The estimated design life of the risers is to be stated.

Calculations are to be performed to demonstrate that, with respect to the established loads and other influences, the risers, support structures and surrounding soil possess sufficient strength with regard to failure due to the following:

- Stresses
- Fracture
- Fatigue
- Buckling
- Collapse
- Foundation movements

Where applicable, the following analyses reports are to be submitted:

9.1 Flow Assurance Analysis Report

In the flow assurance report, the following studies are typically included based on the flow assurance design basis:

- Production fluid properties indicating the ratio of gas, oil, and water or the phase envelope for a given range of pressure and temperature
- Steady state and transient thermal-hydraulic assessment to determine inner diameter, thermal insulation requirement as well as pressure, temperature, and phase profile along the entire flow passage including riser
- Fluid behavior and solid formation/deposition assessment to develop operating strategies with procedures for control of corrosion, emulsion, and solids such as hydrate, paraffin wax, asphaltenes, and scale during the entire service life
- Slugging assessment if applicable, to determine slug size and slug induced loads
- Sand erosion assessment, if applicable, to determine local thickness requirement at needed locations

9.3 Installation Analysis Report

With regard to installation procedures, calculations and analysis for the installation procedures and limiting weather envelope are to be submitted for review. These calculations are to demonstrate that the anticipated loading from the selected installation procedures and limiting weather window does not jeopardize the strength and integrity of the risers and their foundations.

A riser interference study with already installed riser during installation should also be included in the report. Fatigue damage during installation stage should be calculated in the installation analysis report and is to be combined with calculated riser in-place fatigue damage for riser fatigue damage evaluation.

9.5 In-place Static and Dynamic Strength Analysis Report

The in-place static and dynamic strength analysis reports are to be submitted to demonstrate that stresses in the riser are within allowable limits as specified in this Guide. Loading conditions should include normal operating, extreme and survival conditions. Loads in each loading condition should include functional loads; environmental loads directly acting on the riser; platform static offsets for at least near, far and transverse positions; platform dynamic motions due to waves; as well as internal fluid induced vibration loads due to slugging and pressure surge during system shut down if applicable. Load cases and their corresponding safety factors for each loading condition should be included. Interference study with other risers, mooring lines and adjacent structures should also be included.

9.7 Fatigue Analysis Report

Riser fatigue analysis due to environment and platform (and/or buoy) dynamic motions (including VIM) should be carried out. Fatigue damage should be accumulated together with the VIV induced fatigue damages, installation induced fatigue damage, platform or buoy VIM induced riser fatigue damage, and internal fluid induced fatigue damage including slugging if applicable. In the analysis, stress concentration factors (SCFs) due to geometry discontinuity and misalignment is to be addressed, and S-N curves are to be properly selected.

The vortex induced vibration analysis is to include VIV susceptibility study. If VIV is susceptible, VIV induced fatigue damage is to be included in the analysis. VIV analysis using either frequency or time domain method is acceptable. If fatigue damage exceeds allowable levels, VIV suppression devices and its effect to fatigue damage is to be included in the analysis.

VIV induced additional drag or VIV suppression device induced drag coefficients should also be considered in the in-place strength and interference analysis.

If VIM of riser attached platform (or buoy) is susceptible, VIM analysis and calculations of riser fatigue damage due to platform (or buoy) VIM are to be included in the fatigue analysis report.

9.9 Riser Interference Analysis Report

Interference analyses during riser in-place condition and during installation are to be included in the report to assess the potential of interference under corresponding environment conditions between the risers and the adjacent structures. The effects of wake on drag and lift forces, VIV and dynamics are to be considered in the interference analysis.

9.11 Safety Devices

An analysis of the safety system is to be submitted to demonstrate compliance with API RP 14G. As a minimum, the following safety devices are to be part of the risers:

- For a departing riser, a high-low pressure sensor is required on the floater or platform to shut down the wells, and a check valve is required to avoid backflow.
- For an incoming riser, an automatic shutdown valve is to be connected to the floater or platform's emergency shutdown system, and a check valve is required to avoid backflow.
- For a bi-directional riser, a high-low pressure sensor is required on the floater or platform to shut down the wells, and an automatic shutdown valve is to be connected to the floater or platform's emergency shutdown system.

Shortly after the risers are installed, all safety systems are to be checked in order to verify that each device has been properly installed and calibrated and is operational and performing as prescribed.

In the post-installation phase, the safety devices are to be tested at specified regular intervals and periodically operated so that they do not become fixed by remaining in the same position for extended periods of time.

11 Installation Manual

A manual is to be submitted describing procedures to be employed during the installation of risers to include:

- Procedures to be followed should abandonment and retrieval be necessary
- Repair procedures to be followed should any component of risers be damaged during installation
- Contingency plan

In the installation manual, the following qualifications and procedure are to be included to demonstrate that the methods and equipment used by the installation contractor meet requirements:

- Quality assurance plan and procedures
- Welding procedures and standards
- Welder qualification
- Nondestructive testing procedures
- Repair procedures for field joints, internal and external coating repair, as well as repair of weld defects, including precautions to be taken during repairs to prevent overstressing of the repaired joints
- Qualification of pipe-lay facilities, such as tensioner and winch
- Start and finish procedure
- Laying and tensioning procedures
- Abandonment and retrieval procedures
- Subsea tie-in procedures
- Intervention procedures for crossing design, specification and construction, bagging, permanent and temporary support design, specification and construction, etc.
- Field joint coating and testing procedures
- Drying procedures
- System Pressure Test procedures and acceptance criteria

13 Pressure Test Report

A pressure test report including procedures for and records of the testing of the riser system is to be submitted. The test records are to denote the facility being tested, the pressure gauge readings, the recording gauge charts, and the test medium weight pressure data. Records of pressure tests are also to contain the names of the Operator/Owner and the test contractor, the date, time and test duration, the test medium and its temperature, the weather conditions during the test period.

15 Operations Manual

An operations manual is to be prepared to provide a detailed description of the operating procedures to be followed for expected conditions. The operations manual is to include procedures to be followed during start-up, operations, shutdown conditions and anticipated emergency conditions. This manual is to be submitted to ABS.

17 Maintenance Manual

A maintenance manual providing detailed procedures for the continued operation of the riser system is to be submitted to ABS for record and file.

The manual is to include provisions for the performance of the following items:

- Visual inspection of the riser to verify that no damage has occurred to the system, and that the system is not corroding. Particular attention is to be paid to corrosion in the splash zone of risers
- Evaluation of the cathodic protection system performance by potential measurements
- Detection of dents and buckles by caliper pigging
- Inspection and testing of safety and control devices

Additionally, ABS may require gauging of pipe thickness should it be ascertained that risers are undergoing erosion or corrosion.

Complete records of inspections, maintenance and repairs of risers are to be provided for ABS on board the FPI.

19 Inspection Records

The results of surveys and inspections of the risers are to be provided in a report which is to include the following:

- Description and location of any major damage to a riser and information regarding how such damage was repaired
- The result of the inspections of the riser tie-in to demonstrate compliance with all plans and specifications

As appropriate, results of additional inspections, which may include those for the proper operation of corrosion control systems, buckle detection by caliper pig or other suitable means and the testing of alarms, instrumentation and safety and emergency shutdown systems, are to be included.



CHAPTER 1 Scope and Conditions of Classification

SECTION 5 Survey, Inspection and Testing

1 General

1.1 Scope

This Section pertains to the inspection and survey of risers at different phases, including:

- Fabrication
- Installation
- Post-installation testing

The phases of fabrication and construction covered by this Section include pipe and coating manufacture, fabrication, and assembly and riser pipe pressure test. The phases of installation include route survey of the risers, preparation, transportation, field installation, construction, system pressure test and survey of the as-built installation. The post-installation phase includes survey for continuance of classification, accounting for damage, failure and repair.

1.3 Quality Control and Assurance Program

A quality control and assurance program compatible with the type, size and intended functions of risers is to be developed and submitted to ABS for review. ABS will review and may request modification of this program. The Contractor is to work with ABS to establish the required hold points on the quality control program to form the basis for inspections at the fabrication yard and surveys of the riser. As a minimum, the items specified in the various applicable Subsections below are to be covered by the quality control program. If required, Surveyors may be assigned to monitor the fabrication of risers and check the qualifications of the competent personnel who are carrying out the tests and inspections specified in the quality control program. It is to be noted that the monitoring provided by ABS is a supplement to, and not a replacement for, inspections to be carried out by the Contractor or Operator/Owner.

The quality control program, as appropriate, is to include the following items:

- Material quality and test requirements
- Riser pipe manufacturing procedure specification and qualification
- Welder qualification and records
- Pre-welding inspection
- Welding procedure specifications and qualifications
- Weld inspection
- Tolerances and alignments
- Corrosion control systems
- Nondestructive testing
- Inspection and survey during pipe laying
- Final inspection and system pressure testing
- Pigging operations and tests
- Final as-built condition survey and acceptance

1.5 Access and Notification

During fabrication and construction, ABS Surveyors are to have access to the riser at all reasonable times. ABS is to be notified as to when and where riser pipe and riser components may be examined. If ABS finds occasion to recommend repairs or further inspection, notice will be made to the Contractor or his representatives.

1.7 Identification of Materials

The Contractor is to maintain a data system of material for riser pipe, joints, anodes and coatings. Data concerning place of origin and results of relevant material tests are to be retained and made readily available during all stages of construction.

3 Inspection and Testing in Fabrication Phase

Specifications for quality control programs of inspection during fabrication of riser pipe are provided in this Subsection. Qualification tests are to be conducted to verify that the requirements of the specifications are satisfied.

3.1 Material Quality

The physical properties of the riser pipe material and welding are to be consistent with the specific application and operational requirements of the riser. Suitable allowances are to be added for possible degradation of the physical properties in the subsequent installation and operation activities. Verification of the material quality is to be done by the Surveyor at the manufacturing plant, in accordance with Chapter 2 of this Guide. Alternatively, materials manufactured to the recognized standards or proprietary specifications may be accepted by ABS, provided such standards give acceptable equivalence with the requirements of this Guide.

3.3 Manufacturing Procedure Specification and Qualification

A manufacturing specification and qualification procedure is to be submitted for acceptance before production starts. The manufacturing procedure specification is to state the type and extent of testing, the applicable acceptance criteria for verifying the properties of the materials, and the extent and type of documentation, record and certificate. All main manufacturing steps from control of received raw material to shipment of finished riser pipe, including all examination and checkpoints, are to be described. ABS will survey formed riser pipe and riser components for their compliance with the dimensional tolerances, chemical composition and mechanical properties required by the design.

3.5 Welder Qualification and Records

Welders who are to work on risers are to be qualified in accordance with the welder qualification tests specified in a recognized code, such as API STD 1104 and Section IX of the ASME *Boiler and Pressure Vessel Code*. Certificates of qualification are to be prepared to record evidence of the qualification of each welder qualified by an approved standard/code. In the event that welders have been previously qualified, in accordance with the requirements of a recognized code, and provided that the period of effectiveness of previous testing has not lapsed, these welder qualification tests may be accepted.

3.7 Pre-Welding Inspection

Prior to welding, each pipe is to be inspected for dimensional tolerance, physical damage, coating integrity, interior cleanliness, metallurgical flaws and proper fit-up and edge preparation.

3.9 Welding Procedure Specifications and Qualifications

Welding procedures are to conform to the provisions of a recognized code, such as API STD 1104, or the Operator's/Owner's specifications. A written description of all procedures previously qualified may be employed in the construction, provided it is included in the quality control program and made available to ABS. When it is necessary to qualify a welding procedure, this is to be accomplished by employing the methods specified in the recognized code. All welding is to be based on welding consumables and welding techniques proven to be suitable for the types of material, pipe and fabrication in question. As a minimum, the welding procedure specification is to contain the following items:

- Base metal and thickness range
- Types of electrodes
- Joint design
- Welding consumable and welding process
- Welding parameters and technique
- Welding position
- Preheating
- Interpass temperatures and post weld heat treatment.

For underwater welding, additional information is, if applicable, to be specified, including water depth, pressure and temperature, product composition inside the chamber and the welding umbilical and equipment.

3.11 Weld Inspection

As part of the quality control program, a detailed plan for the inspection and testing of welds is to be prepared.

The physical conditions under which welding is to proceed, such as weather conditions, protection, and the condition of welding surfaces, are to be noted. Modifications to the physical conditions may be required should it be determined that satisfactory welding cannot be obtained.

Where weld defects exceed the acceptance criteria, they are to be completely removed and repaired. Defect acceptance criteria may be project-specific, as dictated by welding process, nondestructive testing resolution and results of fatigue crack growth analysis. The repaired weld is to be reexamined using acceptable nondestructive methods.

3.13 Tolerances and Alignments

Dimensional tolerance criteria are to be specified in developing the riser pipe manufacturing specification. Inspections and examinations are to be carried out to check that the dimensional tolerance criteria are being met. Particular attention is to be paid to the out-of-roundness of pipes for which buckling is an anticipated failure mode. Structural alignment and fit-up prior to welding are to be monitored for the consistent production of quality welds.

3.15 Corrosion Control Systems

The details of any corrosion control system employed for risers are to be submitted for review. Installation and testing of the corrosion control systems are to be carried out in accordance with the approved plans and procedures.

Where employed, the application and resultant quality of corrosion control coatings (external and internal) are to be inspected to confirm that specified methods of application are followed and that the finished coating meets specified values for thickness, lack of holidays (small parts of the structural surfaces unintentionally left without coating), hardness, etc. Visual inspection, micrometer measurement, electric holiday detection or other suitable means are to be employed in the inspection.

3.17 Nondestructive Testing

A Nondestructive Testing Plan is to be included in the fabrication and construction specification of the riser. The minimum extent of nondestructive testing is to be in accordance with this Guide or a recognized design Code. Nondestructive testing records are to be reviewed and approved by ABS. Additional nondestructive testing may be requested if the quality of fabrication or construction is not in accordance with industry standards.

3.19 Fabrication Records

A data book of the record of fabrication activities is to be developed and maintained so as to compile as complete a record as is practicable. The pertinent records are to be adequately prepared and indexed, and they are to be stored in a manner that is easily recoverable.

As a minimum, the fabrication record is to include, as applicable, the following:

- Manufacturing specification and qualification procedures records
- Material traceability records (including mill certificates)
- Welding procedure specification and qualification records
- Welder qualification
- Nondestructive testing procedures and Operator's/Owner's certificates
- Weld and nondestructive testing maps
- Shop welding practices
- Welding inspection records
- Fabrication specifications
- Structural dimension check records
- Nondestructive testing records
- Repairs
- Records of completion of items identified in the quality control program
- Assembly records
- Pressure testing records
- Coating material records
- Batch Number, etc.

The compilation of these records is a condition of certifying risers.

5 Inspection and Testing during Installation

This Subsection gives the specifications and requirements for the installation phase, covering route survey of risers prior to installation, installation manual, installation procedures, contingency procedures, as-laid survey, system pressure test, final testing and preparation for operation.

5.1 Specifications and Drawings for Installation

The specifications and drawings for installation are to be detailed and prepared giving the descriptions of, and requirements for, the installation procedures to be employed. The requirements are to be available in the design premise, covering the final design, verification and acceptance criteria for installation and system pressure test, records and integrity of risers. The drawings are to be detailed enough to suitably depict the installation procedures. The final installation results are to be included in the drawings.

5.3 Installation Manual

The Installation Manual is specified in 1-4/13 of this Guide.

5.5 Inspection and Survey During Installation

Representatives from ABS are to witness the installation of the riser to verify that the installation adheres to approved procedures.

5.7 Final Inspection and Pressure Testing

A final inspection of the installed riser is to be completed to verify that it satisfies the approved specifications used in its fabrication and the requirements of this Guide. As appropriate, additional inspections, which may include those for the proper operation of corrosion control systems, buckle detection by caliper pig or other suitable means, the testing of alarms, instrumentation, safety systems and emergency shutdown systems, are to be performed.

5.9 Inspection for Special Cases

Areas of risers may require inspection after one of the following occurrences:

- Environmental events of major significance
- Significant contact from surface or underwater craft, dropped objects or floating debris
- Collision between risers in parallel or between risers and mooring lines
- Any evidence of unexpected movement
- Any other conditions which might adversely affect the stability, structural integrity or safety of risers

Damage that affects or may affect the integrity of risers is to be reported at the first opportunity by the Operator/Owner for examination by ABS. All repairs deemed necessary by ABS are to be carried out to their satisfaction.

5.11 Notification

The Operator/Owner is to notify ABS on all occasions when parts of risers not ordinarily accessible are to be examined. If at any visit a Surveyor should find occasion to recommend repairs or further examination, this is to be made known to the Operator/Owner immediately in order that appropriate action may be taken.

7 In-service Inspection and Survey

The phases of operation include operation preparation, inspection, survey, maintenance and repair. The underwater examinations of the riser and riser support components are to be done by an approved (external specialists) diving company/ROV company. During the operation condition, in-service inspections and surveys are to be conducted for the riser. The In-Service Inspection Plan (ISIP) for such inspection and survey scope is to be established and submitted to ABS for review. In-service inspections and surveys are to be planned to identify the actual conditions of risers for the purpose of integrity assessment. In-service inspection can be planned based on an approved In-Service Inspection Plan (ISIP) for the offshore installation, including the riser system.

For riser components which can be inspected visually, the inspection interval is annually for components above the water and 3-5 years for components below the water. The Nondestructive Testing Plan (NDT) is to be developed and performed as required to the satisfaction of the attending ABS Surveyor. Cathodic protection is to be inspected every 3-5 years. The riser may be inspected at the same time with the survey for FPI or at the time when components are retrieved to surface.

For top tensioned risers, all tensioner wires are to be routinely visually checked for broken strands. A regular slip and cut program should be planned, in which a length from the end of the wire is removed and the wire moves through the tensioner system from a storage drum to distribute wear and prevent reoccurring stress on critical points. The riser tension is to be monitored. The tensioner system is to provide the full range of required tension during inspection and maintenance. Critical valve functions are to be checked and locked off, to prevent inadvertent operation.

9 Inspection for Extension of Use

The inspection for extension of use is specified in 2-11/3.3.



CHAPTER 1 Scope and Conditions of Classification

SECTION 6 Definitions and Abbreviations

1 Definitions

1.1 Classification

The term *Classification*, as used herein, indicates that the riser has been designed, constructed, installed and surveyed in compliance with accepted Rules and Guides.

1.3 Contractor

A *Contractor* is any person or organization having the responsibility to perform any or all of the following: analysis, design, fabrication, inspection, testing, load-out, transportation and installation.

1.5 Extension of Use

An existing riser used at the same location beyond its original design life.

1.7 Maximum Allowable Operating Pressure

The *Maximum Allowable Operating Pressure* is defined as the Design Pressure less the positive tolerance of the pressure regulation system.

1.9 Offshore

Offshore is the area seaward of the established coastline that is in direct contact with the open sea.

1.11 Operator

An *Operator* is any person or organization empowered to conduct commissioning and operations on behalf of the Owners of the riser.

1.13 Owner

An *Owner* is any person or organization who owns risers/facilities.

1.15 Recurrence Period or Return Period

The *Recurrence Period* or *Return Period* is a specified period of time that is used to establish extreme values of random parameters, such as wave height, for design of the riser.

1.17 Riser

1.17.1 Production Riser

A *Production Riser* is a conducting pipe connecting subsea wellhead, riser end terminator (e.g., PLET, PLEM) or pipeline to equipment located on a Floating Production Installation (FPI).

1.17.2 Injection Riser

An *Injection Riser* transports fluids from the FPI to the subsea wellhead for reservoir pressure maintenance and other production management purposes.

1.17.3 Export Riser

An *Export Riser* transports the processed fluids (oil, gas, water, or combination of these) to facilities further downstream. A riser to or from a bottom-founded (fixed) Offshore Installation is out of the scope of this Guide.

3 Abbreviations

ABS	American Bureau of Shipping
ALS	Accidental Limit State
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BPVC	Boiler and Pressure Vessel Code
BT	Buoyancy Tank
CFD	Computational Fluid Dynamics
CRA	Corrosion Resistant Alloy
CP	Cathodic Protection
DBM	Distributed Buoyancy Modules
DSAW	Double submerged Arc Welded
DSC	Differential Scanning Calorimetry
ECA	Engineering Criticality Assessment
ERW	Electric Resistance Welded
FAT	Factory Acceptance Test
FEA	Finite Element Analysis
FLET	Flowline End Termination
FLS	Fatigue Limit State
FPI	Floating Production Installation
FSO	Floating Storage and Offloading
FPSO	Floating Production Storage and Offloading
FR	Flexible Riser
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HDT	Heat Distortion Temperature
HR	Hybrid Riser
HRT	Hybrid Riser Tower
ID	Internal Diameter
ISIP	In-Service Inspection Plan
ISO	International Organization of Standardization
JONSWAP	Joint North Sea Wave Project
LCL	Lower Confidence Limit
LR	Locking Radius
LTSJ	Lower Taper Stress Joint
MAOP	Maximum Allowable Operating Pressure
MBR	Minimum Bend Radius

MODU	Mobile Offshore Drilling Units
MRU	Motion Reference Units
MTM	Metal-To-Metal
NDT	Nondestructive Testing
OD	Outside Diameter
PA	Polyamide
PE	Polyethylene
PIP	Pipe-in-Pipe
PR	Performance Requirement
PP	Polypropylene
PSL	Product Specification Level
PU	Polyurethane
PVDF	Polyvinylidene Fluoride
RAO	Response Amplitude Operators
RBJ	Riser Base Jumpers
ROV	Remotely Operated Vehicle
PLEM	Pipeline End Manifold
PLET	Pipeline End Termination
SCF	Stress Concentration Factor
SCR	Steel Catenary Riser
SLHR	Single Line Hybrid Riser
SLS	Serviceability Limit State
SMBR	Storage Minimum bend radius
SMUS	Specified Minimum Ultimate Strength at Design Temperature
SMYS	Specified Minimum Yield Strength at Design Temperature
S-N	Stress range (S)-Number of Cycles (N)
TLP	Tension Leg Platforms
TRA	Top Riser Assembly
TRB	Three Roll Bending
TTR	Top Tensioned Riser
TSA	Thermal Sprayed Aluminum
TSJ	Tapered Stress Joint
ULS	Ultimate Limit State
UO	U shape by the U-press, O shape by the O-press
UOE	U-ing, O-ing, Expanding Process (pipe fabrication process for welded pipes, expanded)
UTSJ	Upper Taper Stress Joint
VIM	Vortex-Induced Motion
VIV	Vortex-Induced Vibration
WSD	Working Stress Design



CHAPTER 2 Common Criteria

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CHAPTER 2 Common Criteria

SECTION 1 Design Requirements and Loads

1 Scope

This Chapter contains eleven Sections that provide general criteria for the classification of metallic risers. Section 1, 2, 4, 5 and 9 are also applicable to flexible risers (FR, including flexible jumpers in hybrid riser systems). Additional requirements for steel catenary risers (SCRs), top tensioned risers (TTRs), flexible risers and hybrid riser (HR) systems are given in Chapter 3.

The explicit criteria given herein primarily relate to riser pipe bodies. The criteria for flanges and other connectors used in a riser are to be obtained from recognized standards such as the *ASME Boiler and Pressure Vessel Code* as stated in Chapter 2, Section 7.

The design process is to be fully documented and supported by comprehensive calculations in which assumptions are fully justified. A Design Report is to be prepared, in accordance with 1-4/11.

Requirements for a composite riser including design, testing and survey during manufacturing and installation are given in Appendix 1.

1.1 Riser Configuration

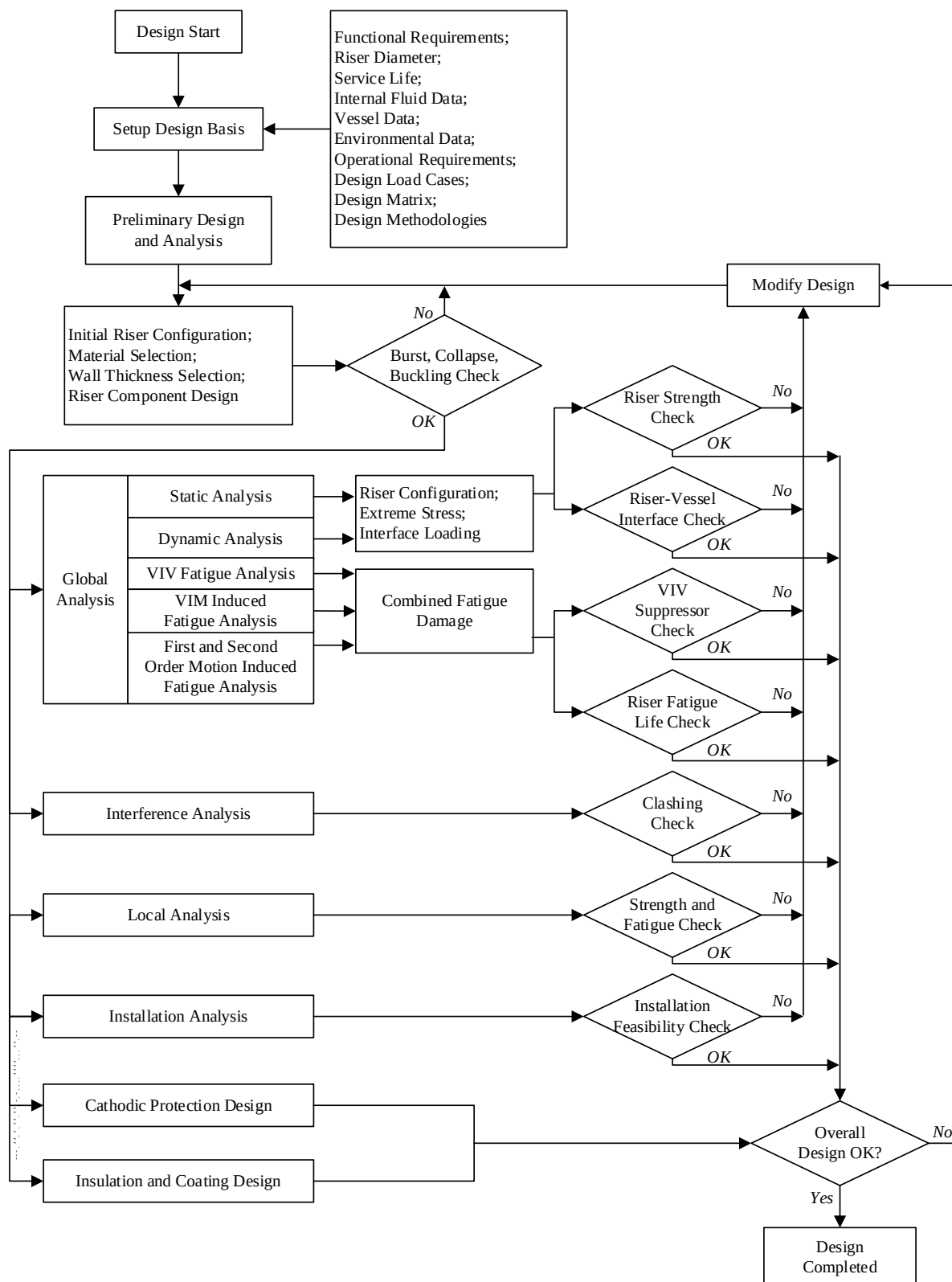
Risers, regardless of function, have a wide range of possible configurations. There are three riser types commonly used (i.e., top tensioned riser, compliant riser, and hybrid riser).

A top tensioned riser is a vertical or nearly vertical riser supported by top tension in combination with boundary conditions that allows for relative riser/FPI motions in the vertical direction and constrained to follow horizontal FPI motions.

The compliant riser is designed to change geometry in response to FPI motions without the use of a heave compensation system. The typical configurations of compliant risers are a free-hanging catenary, Steep-S, Lazy-S, Steep-wave, Lazy-wave, Pliant wave and Chinese Lantern. A compliant riser is primarily used for production, export and injection. The SCR is one of the most commonly found compliant risers. An SCR is a prolongation of a subsea steel pipeline attached to an FPI in a catenary shape.

A hybrid riser is a riser with a vertical or nearly vertical section connected at the seabed, supported by a subsurface buoyancy tank at the top and connected to the floating facility by flexible jumpers. A free-standing hybrid riser effectively combines the attributes of a top tensioned and a compliant riser.

FIGURE 1
Riser Design Flowchart



3 Common Design Requirements

This Section pertains to the identification, definition and determination of general design requirements and loads that are to be considered in the design of risers. Loads acting on a riser are categorized into various types that are described below in subsequent Sections. This Subsection provides the general requirements for the design of metallic risers. More detailed criteria are to be given in subsequent Subsections. The flowchart given in 2-1/Figure 1 summarizes the general design requirements for risers.

For a riser linked to a floating installation, the platform motions due to environmental loads (wave, wind and current) influence the riser system through the interface of the riser and FPI. The platform's static offset and motion response due to wind, wave and current are to be considered based on the ABS *FPI Rules* or other recognized standards such as API RP 2SK and API RP 2T.

As a basis, the riser analysis is to consider the following:

- Floating installation at the neutral, far, near and transverse positions
- Partial loss of riser tension or buoyancy

3.1 Design Basis

The Design Basis is the document that defines the data and conditions needed for the design of a riser system. See 1-4/9.

3.3 Load Combinations and Design Load Conditions

Risers are to be designed to satisfy the functional requirements under loading conditions corresponding to the internal conditions, external environment, system requirements and service life defined by the project.

Risers are to be designed for the load combinations that yield the most unfavorable conditions in terms of overall stress utilization. All potential external and internal loads are to be identified and load combinations developed to represent superposition that may occur within defined degrees of probability. In preparing load conditions, the probable duration of an event (e.g., installation) is to be taken into account in the selection of concurrent environmental conditions. Extreme environmental events are unlikely to coincide, and therefore, the design process should exclude unrealistic load combinations.

Load conditions for the riser systems are to be defined to reflect manufacturing, storage, transportation, testing, installation, operation, retrieval and accidental events. Imposed loads are to be classified as either functional, environmental or accidental and may be continuous or incidental, unidirectional or cyclic in nature. Accidental loads are to be considered separately, following review of risk factors for the particular development, and are to be applied under agreed combinations with functional and environmental loads. The design of the riser is to be based on design load conditions, which are to be given in a project-specific Design Basis document.

The required loading conditions are specified in 2-2/23. They are:

- Design Operating Condition (see 2-2/23.1)
- Design Extreme Condition (see 2-2/23.3)
- Temporary Conditions (see 2-2/23.5)
- Abnormal/Accidental Conditions (see 2-2/23.7)
- Fatigue Loading Condition (see 2-2/23.9).

3.5 Design Criteria

It is to be verified that the each riser is capable of withstanding all loads that are reasonably anticipated over its specified design life. The risers are to be designed to meet all applicable design criteria, as specified in Chapter 2, Section 3, with the following failure modes considered:

- Burst
- Leakage
- Yielding
- Local buckling
- Global buckling
- Fatigue
- Wear and tear
- Cross sectional out-of-roundness.

Other industry-recognized criteria such as those stated in API STD 2RD, API RP 1111, ASME B31.4 and ASME B31.8 may also be used for the design of risers.

3.7 Wall Thickness Sizing

The wall thickness of the riser is to be checked against the applicable design criteria for loads arising from the following conditions:

- Transportation
- Collapse during installation
- In-service collapse during normal operation
- Burst at maximum internal pressure during wellhead shut-in
- Burst under hydrotest

The wall thickness reduced for corrosion, wear and/or erosion is used in riser burst and collapse check in the design.

3.9 Riser and Soil Interaction Modeling

Soil interaction with SCR, TTR, and free-standing hybrid riser types are considered in this Guide. As specified in API RP 2GEO, soil properties such as undisturbed undrained shear strength profile, remolded shear strength, and soil density determined from geotechnical site investigation are to be included in the geotechnical report and used to derive riser-soil interaction behavior.

For SCR, riser-soil interaction for the design extreme and the fatigue loading conditions at the touchdown zone is to be included. In the design extreme condition, high local curvature of the riser induced by SCR break out from a trench (berm) due to high out-of-plane motion is to be considered. In the fatigue loading condition, nonlinear riser-soil interaction to simulate SCR penetration, uplift and re-penetration cycle, and soil softening effect due to the SCR cyclic motion along the touchdown zone are to be considered.

For TTR, the riser (conductor) soil interaction for the design extreme and fatigue loading conditions are to be included. In the design extreme condition, soil lateral reaction to the maximum vessel offset distance from its mean position is to be considered. In the fatigue loading condition, the soil lateral reaction due to repeated cyclic vessel motions is to be considered.

For free-standing hybrid risers, the riser base foundation and soil interaction are to be considered. Hybrid riser foundation types can be either suction caissons or driven piles. Foundation capacity in terms of axial and lateral resistance determined according to API RP 2GEO together with specified safety factors are to be used to check for permanent and cyclic loads in the design extreme and the fatigue loading conditions. Load combination in these two conditions should be determined based on anticipated and the most unfavorable results. Safety factors in API RP 2T for driven piles and API RP 2SK for suction caissons are to be considered.

3.11 Global Analysis

3.11.1 Static Analysis

Static strength analysis is to be conducted to define the risers' global configuration and to confirm the adequacy of initial wall thickness selection. The most reasonable configuration from the potential solutions is to be determined through consideration of design water depth, the maximum static offset, top tension requirement if any, articulation angle at riser top connection, floating installation motions, and the most onerous current direction and profile. Sufficient margins are to be added to account for amplification due to the most severe dynamic responses of risers.

3.11.2 Dynamic Analysis

Dynamic analysis is to be conducted for the riser subjected to each design load condition (see 2-2/23). The extreme response of a riser is to be determined and checked against the relevant acceptance criteria given in Chapter 2, Section 3.

A riser can be analyzed using a regular wave approach, a frequency domain random wave approach, or a time domain random wave approach.

For the regular wave analysis, load conditions critical to the design of the riser are to be identified and further analyzed using the random wave approach to validate the regular wave analysis results and to determine if prior results are unduly conservative.

For the random wave approach, time domain analysis is preferred so that more accurate evaluations of the extreme response of the riser can be obtained. Frequency domain analysis may be used for preliminary purposes, but the results should be verified by the time domain analyses.

When the random wave approach is used in the time domain analysis, sufficient simulation time duration is required to establish suitably representative statistics for the extreme storm and for the extreme riser responses.

3.11.3 Fatigue Analysis

3.11.3(a) General. The fatigue damage in the risers is induced from three main sources:

- Wave fatigue due to the motions of the floating installation (or buoy)
- Vortex-Induced Vibration (VIV) fatigue due to current and heave motion of the floating installation (or buoy)
- Fatigue due to VIM of the floating installation (or buoy), if any
- Riser installation, riser internal fluid slugging, and cyclic riser-soil interactions may also add fatigue damage to the risers. The overall fatigue life is to be determined by combining the fatigue damage from each contributing source. An appropriate weighting factor needs to be applied to individual fatigue damage prior to the combination. See 2-3/7.

3.11.3(b) First and Second Order Motion-induced Fatigue Analysis. Depending on the required level of detail and accuracy, the motion-induced fatigue analyses are to be carried out for a set of sea state windows selected from the sea state scatter diagram. For each sea state window, a representative sea state is to be selected and applied to the floating installation and risers. The random sea analysis in the time domain is to be conducted for a sufficiently long duration so that the statistical features of riser responses can be accurately captured.

The fatigue damage at a specific point of riser pipe body or riser end connection is to be obtained by counting the stress cycles and using the appropriate Stress Concentration Factors (SCFs) and S-N curve given in the Design Basis document. As the combined stress varies around the circumference of the riser pipe, the fatigue damage is to be calculated at 8 or more regularly spaced points around the circumference to identify the most critical location. The maximum damage accumulation around the circumference of the riser body is to be considered as the fatigue damage at a specific location along the riser length. The resultant fatigue damage from each sea-state is to be factored by the associated probability of occurrence and then summed according to the Palmgren-Miner rule to determine the annual fatigue damage.

Validation study needs to be conducted to verify the adequacy of finite element meshing, the convergence of statistics and the sufficiency of the number of selected critical sea state windows, loading directions and stress bins, so as to produce a reliable calculation of fatigue damage.

Other methods for the motion-induced fatigue analysis, such as the regular wave-based fatigue analysis or frequency domain analysis, may be used on the condition that sufficient validation studies are to be performed using the time domain random sea analysis.

3.11.3(c) VIV Fatigue Analysis. The VIV fatigue analysis is to be conducted to assess the magnitude of VIV-induced fatigue damage on risers, and to determine whether VIV suppression devices are required to mitigate the vibration. Dedicated analysis software is to be used to perform the analysis.

Each of the anticipated directional current profiles with a one-year return period is to be used in the long term (during the service life of the risers) VIV fatigue analysis. Responses to both uniform and non-uniform current profiles need to be accounted for. The VIV fatigue damage due to each current profile is to be factored by the associated occurrence probability and then summed up according to the Palmgren-Miner's rule to determine the annual VIV fatigue damage.

The short term VIV fatigue analysis associated with the duration of 100-year return period current during the service life of the risers is to be considered with 100-year return period current profiles coming from different directions. The damages from the critical current profiles are to be factored by the associated occurrence probability and then added up to the total short term VIV fatigue damage.

Whenever VIV suppressors are determined to be necessary, the VIV fatigue analysis is to be reevaluated to determine the lengths and locations of VIV suppressors and the improvement on fatigue behavior expected.

3.11.4 Parameter Sensitivity

Submitted design documentation is to indicate that the sensitivity of analysis results to variations in design parameters has been considered. Design parametric variation can include:

- Riser length and weight
- Drag coefficients
- Floating installation offsets and motions
- External environmental loads
- Internal fluid densities
- Riser-soil interactions

3.13 Interference and Clashing Analysis

As applicable, the potential interference between the following is to be evaluated:

- Riser and riser
- Riser and mooring lines
- Riser and umbilicals
- Riser and offshore installation
- Riser and any other obstructions

The load conditions, which include the combination of current, waves, offsets and motions of the floating installation, fluid densities in risers, and top tension at riser end connection for top tensioned risers, are to be selected in such a way that the distance between a pair of risers may be small enough to cause interference. Detailed calculations may be needed to evaluate the velocity reduction due to wake effects and the drag coefficient variations due to VIV.

The general design idea is that there should be no clashing involving risers. However, if clashing becomes unavoidable due to design restrictions on the offshore installation and riser, the cumulative occurrence probabilities of clashing, clashing forces and clashing locations are to be evaluated. Local analyses are to be conducted to check the integrity of structures and operations if clashing is predicted.

3.15 Riser Stroke Design

For top tensioned risers, tensioner strokes are to be sufficient to avoid potential damage to riser pipes, components and equipment. The most onerous combination of environmental conditions, top tensions, riser internal fluid densities, and the associated relative motions of the offshore installation and the riser are to be considered to determine the stroke of the tensioner.

3.17 Installation Analysis

An Installation Analysis is to be conducted to determine limiting conditions for installation procedures, resultant loadings and responses, and functional requirements for installation equipment. Metocean data with annual return periods are to be used in the installation analysis so that the seasonal requirements for installation and the acceptability of proposed installation procedures can be established.

Installation feasibility is to be examined, considering the following issues:

- Load capacity and positioning capacity of installation vessel
- Load capacity of pull-in/pull-out equipment
- Interference between pull-in cable and offshore installation structures and receptacles
- Interference between the riser being installed and other already-installed risers, mooring lines and umbilicals
- Combined static and dynamic stress level of the riser
- Fatigue damage accumulation of the riser

3.19 Local Analysis

3.19.1 Fracture Mechanics Analysis

If required, Fracture mechanics analyses are to be used to develop flaw acceptance criteria for risers. The fracture mechanics analysis can address:

- Engineering Critical Assessment (ECA)
- Fatigue crack growth assessment using Paris' Law
- Acceptance and inspection criteria for fatigue crack growth

Detailed information about the weld procedure and heat-affected zones is to be considered in the fracture mechanics analysis. The procedures and criteria are to be in accordance with recognized procedures (e.g., BS 7901 or API RP 579-1).

3.19.2 Local Component Analysis

Detailed analyses may be needed to evaluate the strength and fatigue resistance, and Stress Concentration Factors (SCFs) of the components used in riser systems, such as connectors, collars, flanges and riser hang-off assemblies. The maximum SCFs are to be determined for both welded and unwelded sections.

3.21 Component Design for Subsea Riser Systems

The design of riser components, including connectors, buoyancy modules, VIV suppressors and support systems, is to make that the riser components have adequate structural strength, fatigue resistance and leak tightness under the most onerous load combination. Local detailed finite element analysis may be required.

5 Definitions of Design Loads

Loads acting on risers can be categorized into environmental, functional and accidental loads.

5.1 Environmental Loads

Environmental loads are defined as loads imposed directly or indirectly by environmental phenomena such as waves, current, wind, ice and snow. In general, the environmental loads vary with time and include both static and dynamic components. The characteristic parameters defining environmental loads are to be appropriate to the different phases, such as transportation, storage, installation, testing and operation. Environmental loads and load effects are further described in Chapter 2, Section 2.

5.3 Functional Loads

Functional loads are dead, live and deformation loads occurring during transportation, installation, testing and operation.

- *Dead loads* are loads due to the weight in air of principal structure (e.g., pipes, coating, anodes, etc.), fixed/attached parts and loads due to external hydrostatic pressure and buoyancy calculated on the basis of the still water level.
- *Live loads* are loads that may change during operation, excluding environmental loads which are categorized separately. Live loads are typically loads due to the flow, weight, pressure and temperature of containment and fluid absorption.
- *Deformation loads* are loads due to deformations imposed on risers through boundary conditions such as reel, stinger, rock berms, tie-ins, seabed contours, constraints from the floating installation, etc.

The functional loads are to be determined for each specific operation expected to occur during the riser's life cycle and are to include the dynamic effects of such loads, as necessary. In addition, extreme values of temperatures of the internal fluid expressed in terms of recurrence periods and associated highest and lowest values are to be used in the evaluation of pipe materials.

5.5 Accidental Loads

Accidental loads are defined as loads that occur accidentally due to abnormal operating conditions, technical failure and human error. Examples are soil-sliding, 'ductility-level' earthquakes, mooring failure and impacts from dropped objects, trawl board or collision. It is normally not necessary to combine these loads with other environmental loads unless site-specific conditions indicate such requirement. Dynamic effects are to be properly considered when applying accidental loads to the design. Risk-based analysis and past experience may be used to identify the frequency and magnitude of accidental loads.

Risers are to be adequately designed to avoid collisions with floating installations or from other risers. The riser is to have adequate strength to withstand impact loads caused by small dropped objects, floating debris or ice, where applicable. See the *ABS Guidance Notes on Accidental Load Analysis and Design for Offshore Structures*.

Typical design loads may be categorized in accordance with 2-1/Table 1.

TABLE 1
Categorization of Design Loads for Risers

<i>Environmental Loads</i>	<i>Functional Loads</i>	<i>Accidental Loads</i>
Wind Waves Current Tides Surge Marine growth Sea ice Seabed subsidence	Weight in air of: - Pipe - Coating - Anodes - Attachments - etc. Buoyancy Towing External hydrostatic pressure Internal pressures: - Mill pressure test - Installation - Storage, empty/water filled - In place pressure test - Operation Installation tension (pipes) Installation bending Top tension (top tensioned risers) Makeup (connectors) Boundary conditions: - Reel - Stinger - Tie ins - Rock berms - Seabed contours - Top constraints (risers) - etc. Soil interaction Loads due to containment: - Weight - Pressure - Temperature - Fluid flow, surge and slug - Fluid absorption Inertia Pigging and running tools	Impacts from dropped objects Impacts from collision between risers Mooring or tendon failure Loss of floating installation stationkeeping capability Tensioner failure



CHAPTER 2 Common Criteria

SECTION 2 Environmental Effects

1 General

Design environmental conditions are to be defined by the Operator/Owner, together with qualified oceanographic specialists. The foreseeable environmental phenomena that may influence the riser's integrity are to be described in terms of their characteristic parameters relevant to the strength evaluations.

Field and model-generated data are to be analyzed by statistical and mathematical models to establish the range of pertinent variations of environmental conditions to be employed in the design. Methods employed in developing available data into design criteria are to be described and submitted in accordance with Chapter 1, Section 4. Probabilistic methods for short-term, long-term and extreme-value predictions employing statistical distributions are to be verified by relevant statistical tests, confidence limits and other measures of statistical significance. Hindcasting methods and models are to be fully documented. Due to the uncertainty associated with the definition of some environmental processes, studies based on a parametric approach may be helpful in the development of design criteria.

Generally, suitable environmental data and analyses are accepted as the basis for design when fully documented with sources, dates and estimated reliability noted. For risers in areas where published design standards and data exist, such standards and data can be cited as reference.

3 Wind

Wind loads are exerted upon parts of risers that are above the water surface and marine structures to which risers might be attached. Statistical wind data are normally to include information on the frequency of occurrence, duration and direction of various wind speeds. For design cases where the riser is attached to a floating installation, it might also be necessary to establish the spectrum of wind speed fluctuation for comparison with the structure's natural sway periods.

Long-term and extreme-value predictions for winds are to be based on recognized techniques and clearly described. Vertical profiles of horizontal wind are to be determined based on recognized statistical or mathematical models. Published data and data from nearby land and sea stations can be used, if available. Wind data are, in general, to refer to a specified reference level and averaging time. During design, the wind data may be adjusted to any specified averaging time and elevation based on standard profiles and gust factors, such as given in API RP 2A-WSD.

Wind loads and local wind pressures are to be determined based on analytical methods or wind tunnel tests on a representative model of the riser system. In general, gust wind loads, which are loads based on wind speeds averaged over one-minute or less are to be used in the riser design combined with other simultaneous environmental loads acting on the riser and floating installation to which the riser may be attached. When appropriate, dynamic effects due to the cyclic nature of gust wind and cyclic loads due to vortex-induced vibrations, including both drag and lift components, are to be investigated. For risers with negligible dynamic response to wind, a one-hour sustained wind speed may be used to calculate the wind loads.

For wind normal to the riser axis, the following relationship may be used to calculate the wind load:

$$F_w = \frac{1}{2} \rho_a \cdot C_s \cdot V_z^2 \cdot A$$

where

- F_w = wind load
- ρ_a = density of air
- C_s = shape coefficient (dimensionless, = 0.50 for cylindrical sections)
- V_z = wind speed at altitude z
- A = projected area of pipe on a plane normal to the wind direction.

As an alternative to applying wind loads, the effect of wind can be indirectly accounted for through the modeling of floating installation offset and slow drift movement.

5 Current

Current may be a major contributor to both static and dynamic loading on risers installed at any depth. The current velocity and direction profile at a given location may have several contributions of which the most common are:

- Oceanic scale circulation patterns (e.g., Loop Current)
- Lunar/astronomical tides
- Wind and pressure differential generated storm surge
- River outflow

The vector sum of all current components at specified elevations above the seafloor to the water surface describes the current velocity and direction profile for the given location. The current profile might be seasonally dependent, in which case, this is to be accounted for in the design.

The total current profile associated with the sea state producing extreme waves or winds and the extreme loop current profile with associated waves and winds are to be used in design analyses. The current velocity and direction normally do not change rapidly with time and may be treated as time invariant for each sea state.

On-site data collection may be required for previously unstudied areas and/or areas expected to have unusual or severe current conditions. If the current profile is not known from on-location measurements, but is judged not to be severe for the design, the current velocity at a given depth may be established using a velocity profile formulation. Current velocity profiles are to be based on site-specific data or recognized empirical relationships, and the worst design direction is to be assumed.

7 Waves

Waves are a major source of dynamic loads acting on risers located in shallower waters (normally less than 150 m), and their description is therefore of increased importance. Statistical site-specific wave data, from which design parameters are to be determined, are normally to include the frequency of occurrence for various wave height groups and associated wave periods and directions. For areas where prior knowledge of oceanographic conditions is insufficient, the development of wave-dependent design parameters is to be performed in cooperation with qualified specialists.

For a fully-developed sea, a sea state may be represented using the Bretschneider spectrum, while the JONSWAP spectrum is normally applicable for less developed seas. In the calculation of spectral moments, a proper cut-off frequency, based on an appropriate confidence level, is to be applied. Wave scatter diagrams can be applied to describe the joint probability of occurrence of the significant wave height and the mean zero crossing period. Where appropriate, alternative traditional regular wave approaches may be used.

When dealing with extreme response estimations, the regular design wave heights are to be based on the maximum wave height of a given return period (e.g., 1, 10 or 100 years) found from long term wave statistics. The estimation of the corresponding extreme wave period is, in general, more uncertain due to a lack of reliable data, and it is consequently important that the wave period be varied over a realistic interval to consider all extreme wave cases. For systems with obviously unfavorable wavelengths and periods due to geometry or eigen-frequencies, the design wave period can be identified based on such criteria while the wave height follows from breaking wave criteria or statistical considerations.

Frequency domain analysis can be applied in fatigue damage assessment and long-term response statistics, whereby a scatter diagram of the joint probability of the sea state vector and the wave spectrum represents the wave climate defined by significant wave height, peak period and main wave direction. Long-term response statistics are important to identify design conditions for time domain analysis. A simplified representation of the long-term distribution for the response may be based on the frequency domain method consisting of:

- Establishing an approximate long-term response distribution based on stochastic dynamic analyses
- Calculation of an approximate lifetime extreme response
- Identification of the design storm
- Estimation of lifetime maximum response based on time domain simulations

In analysis, a sufficient range of realistic wave periods and wave crest positions relative to the riser are to be investigated to accurately determine the maximum wave loads. Consideration is also to be given to other wave-induced effects such as wave impact loads, dynamic amplification and fatigue. The need for analysis of these effects is to be assessed on the basis of the configuration and behavioral characteristics of risers, the wave climate and past experience.

9 Combinations of Wind, Current and Waves

The worst combinations of wind, current and waves are to be addressed in the design. When current and waves are superimposed, the current velocity and direction are to be added as vectors to the wave-induced particle velocity and direction prior to computation of the total force, and where appropriate, flutter and dynamic amplification due to vortex shedding are to be taken into account.

Because risers have small diameters compared to the wavelengths being considered, semi-empirical formulations such as Morison's equation are considered to be an acceptable basis for determining the hydrodynamic load acting on a riser.

11 Tides

Tides, when relevant, are to be considered in the design of risers. Tides may be classified as lunar or astronomical tides, wind tides and pressure differential tides. The combination of the latter two is defined as "storm surge" and the combination of all three as "storm tide". The water depth at any location consists of the mean depth, defined as the vertical distance between the seabed and an appropriate near-surface datum, and a fluctuating component due to astronomical tides and storm surges. The highest and the lowest astronomical tide bound the astronomical tide variation. Storm surge is to be estimated from available statistics or by mathematical storm surge modeling.

13 Marine Growth

Marine growth may accumulate and is to be considered in the design of risers. The highest concentrations of marine growth are generally seen near the mean water level but may be found over 200 feet below the mean water level in some areas. Estimates of the rate and extent of marine growth may be based on past experience and available field data. Particular attention is to be paid to increases in hydrodynamic loading due to the change of:

- External pipe diameter
- Surface roughness

- Inertial mass
- Added weight

Marine growth increases structural mass, buoyancy diameter and drag diameter and changes the hydrodynamic coefficients of the riser pipe, therefore it is to be considered in the riser design.

15 Subsidence

The effects of seafloor subsidence are to be considered in the overall design of the stroke of the riser system.

17 Seafloor Instability

Wave pressure, earthquakes, soil weight or their combinations may induce seafloor movement. Seafloor instability may be experienced under negligible slope angles as weak, under-consolidated sediments in areas where wave pressures are significant. Movements of the seafloor may be activated as a result of: loads imposed on the soil due to riser installation, change in riser operating conditions, wave pressure, soil self weight, earthquakes or combinations of these phenomena. When applicable, such areas are to be identified by detailed surveys, and precautions such as rerouting of flowlines and risers are to be taken.

19 Seismic

The seismic activity level for the riser installation area is to be evaluated based on previous records or detailed geological investigations. For risers located in areas that are considered seismically active, the effects of earthquakes are to be considered in the design. An earthquake of magnitude that has a reasonable likelihood of not being exceeded during the design life is to be used to determine the risk of damage, and a rare intense earthquake are to be used to evaluate the risk of structural failure. These earthquake events are referred to as the *Strength Level* and *Ductility Level* earthquakes, respectively. The magnitudes of the parameters characterizing these earthquakes, having recurrence periods appropriate to the design life of the risers, are to be determined. The effects of earthquakes are to be accounted for in design, if applicable, but generally need not be taken in combination with other environmental factors such as the 100-year design wave and/or the 100-year design current.

The Strength Level and Ductility Level earthquake-induced ground motions are to be determined on the basis of seismic data applicable to the installation location. Earthquake ground motions are to be described by either applicable ground motion records or response spectra consistent with the recurrence period appropriate to the design life of pipelines and risers. Available standardized spectra applicable to the region of the installation site are acceptable, provided such spectra reflect site-specific conditions affecting frequency content, energy distribution and duration. These conditions include the type of active faults in the region, the proximity to the potential source faults, the attenuation or amplification of ground motion and the soil conditions.

The ground motion description used in design is to consist of three components corresponding to two orthogonal horizontal directions and the vertical direction. All three components are to be applied to a riser simultaneously.

As appropriate, the effects of soil liquefaction, shear failure of soft mud and loads due to acceleration of the hydrodynamic added mass by the earthquake, mud slide, tsunami waves and earthquake-generated acoustic shock waves are to be accounted for in the design, if applicable.

21 Sea Ice

For arctic and sub-arctic areas, sea ice may be experienced in the form of first-year sheet ice, multi-year floes, first-year and multi-year pressure ridges and/or ice islands. The strength of sea ice depends on features such as composition, temperature, salinity and speed of load application. The effect of sea ice on the risers is to be considered, as applicable, for the frozen-in condition (winter), breakout in the spring, and summer pack ice invasion.