



GUIDANCE NOTES ON

DRILLING RISER ANALYSIS

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Foreword

These Guidance Notes are intended to assist users of the *ABS Guide for the Classification of Drilling Systems (CDS Guide)* to deal with the drilling riser analysis to meet ABS *CDS Guide* requirement.

These Guidance Notes provide the latest recommended practices for typical types of analyses that may be required for a drilling riser. The actual types and scopes of analyses that will be required for a particular drilling riser will be decided on a project specific basis. In addition, considerations and suggestions are also provided in these Guidance Notes on important features of these analyses with sufficient details including evaluation parameters, approaches, procedure, modeling, and sample figures of results, etc.

The design acceptance guideline of a drilling riser is based on API RP 16Q, while the detail analysis process is provided in these Guidance Notes.

In these Guidance Notes, the word “Unit” is used in general to refer to the structure from which the drilling riser is deployed. In an actual case, that structure can be a Mobile Offshore Drilling Unit, Floating Production Installation, or other type of structure as considered in the *CDS Guide*.

These Guidance Notes become effective on the first day of the month of publication.

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SECTION 1 Summary of Drilling Riser Analyses

The types of analyses typically required for a drilling riser may include those listed below. Section 1, Figure 1 depicts the general sequence of the analyses and gives the primary purpose of each analysis type.

The actual analyses types and scopes, which will be required in ABS's review of the riser for Classification in accordance with the *ABS Guide for the Classification of Drilling Systems (CDS Guide)*, will depend on the specifics of an individual project. The information given in these Guidance Notes is meant to give an indication of the possible scope for the listed types of analyses which may apply.

1 Riser Space-out and Stability Calculations

This is often the first step in the drilling riser analyses. The purpose of this analysis is to establish feasible riser space-out (i.e., layout or arrangement) configurations based on the water depth and available types of riser joints and to determine whether the top tensioning system has sufficient capacity to support the riser space-out and anticipated mud weight.

3 Storm Hang-off Analysis

The purpose of this analysis is to determine the limiting sea states (environmental window), in which the riser can be hung-off without damaging the riser. This analysis is especially important for a deep water riser, since the natural period of the riser's axial dynamic response may fall in the frequency range of highly energetic waves.

5 Operability Analysis

The purpose of this analysis is to determine, for each mud density, the operating envelopes that define the required top tension range and the allowable Unit offsets for normal drilling operation and/or for keeping the riser connected to well but no drilling.

7 Deployment/Retrieval Analysis

This analysis is performed when the Unit moves to a site that is in deepwater or is sensitive to the environment (e.g., high current). The purpose of this analysis is to determine the environmental window for running/pulling the riser.

9 Vortex Induced Vibration (VIV) fatigue Analysis

This analysis is often required when the Unit is operating in an area of strong current with riser either connected or hung off for long duration. The purpose of the analysis is to predict the fatigue damage induced by vortex induced vibration due to currents and to identify critical locations for regular inspection.

11 Wave Fatigue Analysis

The purpose of the analysis is to predict the fatigue damage induced by sea waves. Because drilling riser joints are in general considered robust and can be often inspected between deployments, this analysis may not be required. However, if the Unit is in high waves with the riser connected to a well or hung off in storm waves for long duration and/or multiple times, such analysis is often warranted to verify that no excessive fatigue damage is sustained by the riser joints.

13 Drift-off/Drive-off Analyses

These two analyses are specifically for dynamically positioned (DP) Units. The purpose of the analyses is to define the radius of the “yellow” and “red” watch circles for emergency disconnection when the Unit suffers a black-out or DP system malfunction.

15 Recoil Analysis

This analysis is typically performed for DP Units. The purpose of this analysis is to determine the requirements of the recoil system on a DP Unit for safe emergency disconnection.

17 Weak Point Analysis

This analysis is to identify the weak points in a drilling riser/well system under extreme Unit offsets due to drive-off/drift-off or mooring line failure. The focus of this analysis is on well integrity. Extreme offsets can lead to overloading of various components in the drilling riser/well system such as connectors, BOP stack, wellhead, and casing, etc. The maximum load predicated from the weak point analysis can be used for design/selection of the drilling riser and well system components or compatibility check between riser and existing well system. This analysis is often required before the Unit’s first deployment or before an important drilling campaign by the Operator.

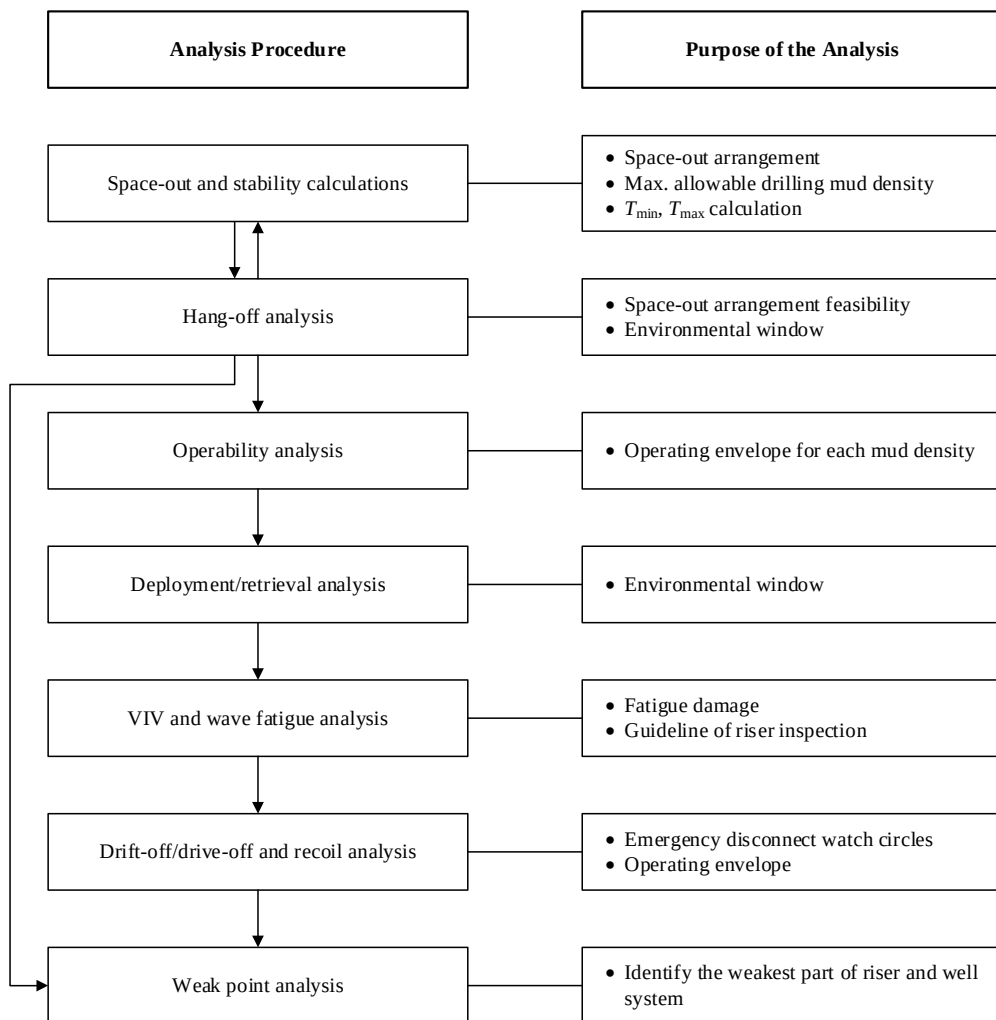
19 Abbreviations

BOP	Blow Out Preventer
C&K	Choke and Kill
DP	Dynamic Position
DTL	Dynamic Tension Limit of a tensioner
FEA	Finite Element Analysis
LMRP	Lower Marine Riser Package
MWL	Mean Water Level
PEL	Pressure End Load
RAO	Response Amplitude Operator
RKB	Rotary Kelly Bushing
SAF	Stress Amplification Factor
SMYS	Specified Minimum Yield Strength
TTF	Tension Transfer Function
VIV	Vortex Induced Vibration

21 Symbols

T_{MAX}	Maximum permissible tension setting at tensioner mid-stroke
T_{MIN}	Minimum required top tension of the riser system
T_{SRmin}	Minimum slip ring tension

FIGURE 1
Typical Drilling Riser Analysis Procedure



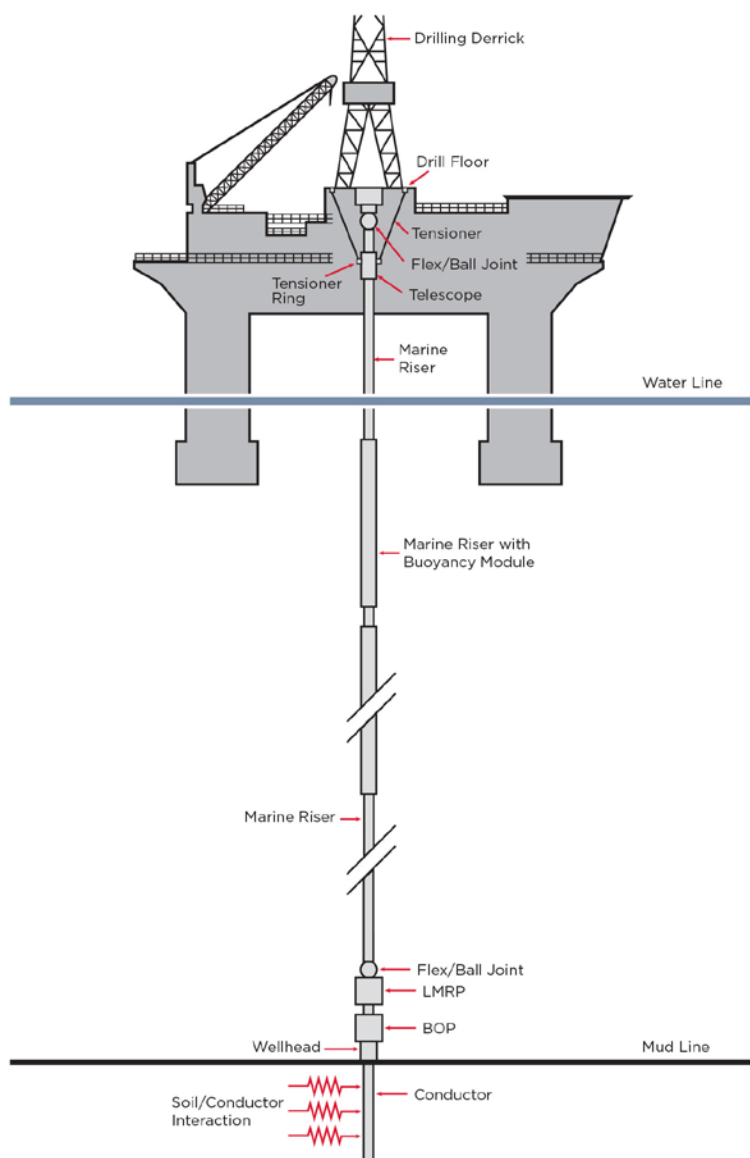
SECTION 2 Drilling Riser System Components

1 Overview of Riser System

There are many different components and subsystems that make up a drilling riser system. See Section 2, Figure 1 for a typical drilling riser system and components.

The following Subsections present descriptions of the main components of a drilling riser system.

FIGURE 1
Typical Drilling Riser System and Components



3 Top Tensioning System

The top tensioning system is used to pull at the top of the drilling riser to support the weight of the riser, its components, and the fluid inside the riser; and it is also used to control the shape of the riser when subjected to environmentally-induced load effects. The tensioning system is normally composed of a number of “tensioners”. The number and rating of the tensioner units will determine the total capacity of the tensioning system.

There are two types of tensioner designs (i.e., wireline tensioners and direct-acting tensioners).

A wireline tensioner unit uses a hydraulic ram with a large volume air-filled accumulator to maintain near constant tension on the tensioner wires. One end of the wire is attached at the tensioner and the other is attached to the outer barrel of the telescopic joint through sheaves underneath the drill floor.

A direct-acting tensioner has a hydraulic rod and piston assembly, which are attached directly to the drill floor structure and the outer barrel of the telescopic joint.

5 Diverter System

The purpose of a diverter system is to direct mud returns to processing and to divert any low pressure gas in the riser away from the drill floor, and to discharge it to a safe area. The diverter is mounted in the housing directly below the drill floor. The upper flex/ball joint is typically attached below the diverter.

7 Flex and Ball Joints

Flex or ball joints are used at the top and bottom of the riser to allow for angular displacement thus reducing the bending stresses at both ends of the riser string. Intermediate flex or ball joint may also be fitted below the telescope joint. Typically flex joints have a rotational stiffness which makes them more effective in controlling riser angles.

9 Telescopic Joint

The basic function of the telescopic joint is to accommodate the relative translational movement between the Unit and the riser due to heave, tidal changes, Unit offset, and riser shape. A telescopic joint has an outer barrel which is connected to the riser string and an inner barrel which is connected to the drilling Unit. The telescopic joint also has brackets for the goosenecks which connects to the drape hoses for auxiliary lines. The tensioning system is connected to the outer barrel of the telescopic joint, normally through a tensioner ring, to provide tension to the riser string.

11 Riser Joints

11.1 Typical Riser Joint

A riser joint is typically an assembly of riser pipe, coupling box and pin, choke and kill lines, auxiliary lines, choke/kill/auxiliary line support brackets, and other devices for guidance and/or supporting buoyancy modules. A typical full length riser joint has length ranging from 50 to 90 feet.

11.3 Riser Couplings

Riser couplings are the connectors at each end of the riser joint that link one joint to another. The riser joint coupling rating often controls the maximum allowable tension that can be applied to the riser string.

11.5 Auxiliary Lines

Auxiliary lines typically include Choke/Kill lines to carry fluid along the length of the riser. C&K lines are used during well control and should be rated for the maximum expected well pressure. Besides the C&K lines, the auxiliary lines of modern drilling risers may also consist of a mud booster line, and one or two hydraulic lines. They are mounted to the main tube through supporting brackets. Depending on the design of the riser joint couplings, these lines may be able to share the tension load of the main tube.

11.7 Buoyancy Module

The main function of buoyancy modules is to reduce the top tension requirement for deeper water applications. The buoyancy modules are fixed to the riser joints with clamps. Syntactic foam is the most commonly used material for the module. Foam buoyancy modules are typically installed in pairs around the riser joint, several pairs per joint, and have cutouts to accommodate auxiliary lines. The buoyancy modules are normally rated for a specific water depth based on the foam collapse pressure.

11.9 Pup Joints

Pup joints are riser joints that are shorter than full length riser joints. The pup joints are normally available in variable lengths to accommodate different operating water depths.

13 Other Special Riser Joints

13.1 Spider and Gimbal

The spider is a device equipped with dogs to suspend the riser string at the rotary table during riser deployment and retrieval.

The gimbal is a device for hanging-off the riser in severe weather, which allows the top of the riser to rotate freely to avoid excessive bending moment.

Both the spider and gimbal have a maximum tension rating, which is often less than the tension rating of the tensioning system and/or the riser joints.

Gimbal also has rated rotation angle limit, which is not to be exceeded during operation.

13.3 Landing Joint

The landing joint is a riser joint temporarily attached above the telescopic joint used to land the BOP stack on the wellhead, when the telescopic joint is collapsed and pinned. It may also be used as the top-most joint for hanging-off the riser in a storm.

13.5 Subsea Fill-up Joint

The subsea fill-up joint is a special riser joint, which has a valve to allow the riser annulus to be opened to the sea in order to prevent the collapse of the riser pipe in case of mud loss. In order to have it function automatically, there is often a minimum water depth requirement.

13.7 Various Adapters

There are often various riser adapters in the riser string, which are special joints for the transition of different riser diameters, especially around the diverter and upper ball/flex joint at the top, and the LMRP and bottom ball/flex joint at the bottom.

15 Lower Marine Riser Package (LMRP)

The Lower Marine Riser Package (LMRP) usually includes a riser adapter, flex/ball joint, annular BOPs, subsea control pods, and a hydraulic connector, which mates the riser system to the BOP stack. The LMRP provides a disconnection point between the riser and the BOP stack. It also provides hydraulic control of the BOP stack's functions through the control pods.

17 Blowout Preventer (BOP) Stack

The Blowout Preventer (BOP) stack, normally at the bottom of the riser string and on top of the wellhead, is able to shear the drill pipe and/or inner casing inside the riser main tube and close-off the well opening to prevent a blowout event or to prepare for an emergency disconnect. The time required to shear a drill pipe and/or inner casing is often the required lead time for the drift-off/drive off red circles.



SECTION 3 Riser Analysis Evaluation Considerations

1 General

The purpose of riser analysis is to evaluate if the riser system is adequate and fit for purpose, which should include evaluation on functional requirement and structural integrity. In general, the riser analysis is to evaluate the following:

- i) The riser has sufficient top tension to maintain the structural stability of the riser string.
- ii) The riser has sufficient top tension to resist environmentally induced load effects while performing its intended functions.
- iii) The riser has sufficient top tension at emergency disconnection to prevent damaging subsea equipment and be able to keep the riser recoil to acceptable level.
- iv) All riser components are operating within their intended limits.
- v) The forces and moments transferred to the BOP stack, wellhead and casings are at or below specified limits to avoid damage to the well facility.

3 Riser Design Guidelines

API RP 16Q “Design, Selection, Operation and Maintenance of Marine Drilling Riser Systems” [3] provides drilling riser structural integrity acceptance guideline applicable to riser global responses, which include allowable flexible joint angle, allowable stresses, and top tension requirement as listed below. The results from the riser system analysis will be used to evaluate if the riser system is adequate and fit for purpose.

- i) *Allowable Flexible Joint Angle.* Applicable to flexible joints at all locations of the riser system
 - For normal drilling condition, the allowable mean value of 2° and allowable maximum value of 4° is applied. Less mean and/or maximum angle may be applied in order to reduce wearing to the flexible joint and avoid key seating.
 - For condition riser is connected to well but no drilling or riser is disconnected from well, 90% flexible joint capacity is applied.
- ii) *Allowable Stresses.* The maximum allowable nominal stress for strength check and significant dynamic stress range for fatigue check are considered.
 - The maximum allowable nominal stress of $0.67 \times SMYS$ is applied for all conditions. The stress refer to the static stress plus the maximum dynamic stress amplitude at the mid-wall of the main riser pipe away from any stress concentration, and it is to be calculated according to Von-Mises stress failure criteria,
 - Significant dynamic stress range amplitude of 10 ksi for nominal stresses and 15 ksi for local peak stresses is applied for normal drilling operation condition. These values refer to the average of the one third highest variation ranges in principal stress time history, and they are not fatigue limits but are indicator that further fatigue analysis may be necessary.

iii) *Top Tension Requirement.* Three top tension requirements including the minimum top tension, dynamic tension limit, and maximum tension setting are considered.

- The minimum top tension (T_{MIN}) is the minimum top tension required to prevent global buckling of riser in the event of the sudden loss of pressure in a tensioner or tensioner pair.
- The dynamic tension limit (DTL) is the highest dynamic tension that tensioner can safely generate. Determination of the DTL should consider pressure and structure limits of each tensioner and its supporting structure as well as tension oscillation in any tensioner caused by Unit offset and wave induced motion.
- Maximum top tension setting (T_{MAX}): the highest permissible tension setting at tensioner mid-stroke. Sufficient margin should be considered so that any anticipated condition (such as wave-induced vessel motions, offset, and/or tide change) will not cause tension in any tensioner to exceed DTL.

Other considerations, such as riser or wellhead loads, riser recoil response, and minimum tension required to separate the LMRP connector for emergency disconnection may also affect the above top tension requirement and setting.

The determination of the minimum top tension, T_{MIN} , for a typical wire-rope tensioner system in-which sudden loss of tension due to failure of one or two tensioners, can be calculated by the following equations from [3]:

$$T_{MIN} = \frac{T_{SRmin} N}{R_f (N - n)} \dots\dots\dots (3.1)$$

$$T_{SRmin} = W_s f_{wt} - B_n f_{bt} + A_i (d_m H_m - d_w H_w) \dots\dots\dots (3.2)$$

where

- T_{MIN} = minimum top tension
- T_{SRmin} = minimum slip ring tension
- N = total number of tensioners supporting the riser
- n = number of tensioners subject to sudden failure
- R_f = reduction factor relating vertical tension at the slip ring to tensioner setting to account for fleet angle and tension variation due to mechanical and hydraulic effects in the tensioner system. The amount of tension variation can increase as Unit motion increases (value of 0.9 - 0.95 is typically used for non-drilling and drilling modes)
- W_s = submerged riser weight above the point of consideration
- f_{wt} = submerged weight tolerance factor, minimum value = 1.05 unless accurately weighted
- B_n = net lift of buoyancy material above the point of consideration
- f_{bt} = buoyancy loss tolerance factor resulting from elastic compression, long term water absorption, and manufacturing tolerance, maximum value = 0.96 unless accurately measured by submerged weighing with compression of rated water depth
- A_i = internal cross sectional area of riser including choke, kill, and other auxiliary lines
- d_m = drilling fluid density
- H_m = drilling fluid column to point of consideration
- d_w = sea water density
- H_w = sea water column to point of consideration including storm surge and tide.

For a typical direct-acting tensioner system, a sudden loss of all pressure on the rod side of a tensioner can produce a downward-acting force on the tension ring. In order to resist the pressure acting to the blind side of the piston as well as weight of the piston, rod, and portion of the ring supported by the failed tensioner, the determination of the minimum riser tension, $T_{\min}$, may be calculated by the following equation from [3]:

$$T_{\min} = \frac{N}{R_f(N-n)} \cdot \left(T_{SR\min} + nW_{piston/Rod} + \frac{nW_{Ring}}{N} + nF_{BSP} \right) \dots\dots\dots (3.3)$$

where

- $T_{SR\min}$ = defined by Equation (3.2)
- N = total number of tensioners supporting the riser
- n = number of tensioners subject to sudden failure
- $W_{Piston/Rod}$ = weight of the failed tensioner piston and rod
- $\frac{W_{Ring}}{N}$ = portion of the ring supported by the failed tensioner
- F_{BSP} = force generated by pressure acting on the blind side of the piston.

Other failure scenarios, such as the failure of the upper connection of a direct-acting tensioner to the rig, or other tensioner system configurations may create a different set of loads that the remaining intact tensioners should support. If so, Equation (3.3) may require additional modifications to meet the intent of this sudden tensioner-loss criterion.

The minimum top tension settings should be set high enough that the failure scenarios will not produce momentary effective compression in the riser.

5 Other Analysis Evaluation Considerations

Other riser analysis considerations may include the following:

- Overpull requirement above specified riser location to maintain positive tension for safe riser operation.
- The stroke limit of the tensioners and the telescopic joint
- The clearance in the moonpool, which can result in an additional limitation on the upper ball/flex joint.
- Possible impact between the riser and diverter housing or moonpool during deployment and retrieval.
- The offset limit for a connected riser based on the capability of the station-keeping system
- The tension rating of the riser joints and couplings
- The fatigue life requirement when operating in areas with high/storm waves and/or strong current. A factor of safety of 3 is often applied for typical drilling riser with frequent inspection. For drilling riser cannot be inspected frequently, higher factor of safety may be required.