

GUIDANCE NOTES ON

DYNAMIC ANALYSIS PROCEDURE FOR SELF-ELEVATING UNITS FEBRUARY 2014

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The following summarizes the colors corresponding to Rule Changes, Corrigenda items and editorial changes in the Guidance Notes files which are available for download.

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Updates

February 2017 consolidation includes:

- September 2014 version plus Corrigenda/Editorials

September 2014 consolidation includes:

- February 2014 version plus Corrigenda/Editorials

Foreword

The guidance contained herein should be used in conjunction with the *ABS Rules for Building and Classing Mobile Offshore Drilling Units* for the purpose of ABS Classification of a **Self-Elevating Unit**. The guidance indicates acceptable practice in a typical case for types of designs that have been used successfully over many years of service. The guidance may need to be modified to meet the needs of a particular case, especially when a novel design or application is being assessed. The guidance should not be considered mandatory, and in no case is this guidance to be considered a substitute for the professional judgment of the designer or analyst. In case of any doubt about the application of this guidance ABS should be consulted.

A self-elevating unit is referred to herein as an “SEU”, and the *ABS Rules for Building and Classing Mobile Offshore Drilling Units*, are referred to as the “MODU Rules”.

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

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of these Guidance Notes is the most current.

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



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SECTION 1 Introduction (1 February 2014)

1 Background

These Guidance Notes present acceptable practice for an important aspect in the Classification of **self-elevating units (SEUs)**. The technical criteria contained in **the original version of** these Guidance Notes **published in 2004** **were** based on the results of a Joint Industry Project sponsored by Owners, Designers, Builders, Operators and Classification Societies. The criteria were subsequently published as Reference 1. That reference is specifically aimed at providing assessment criteria for the site-specific use of the **SEU**. **Reference 1 was also used in the development of the International Standards Organization (ISO) Standard 19905-1 [Reference 6] for site-specific assessment of mobile offshore units – Jack-Ups. There were changes in both required and acceptable methods of assessment when the ISO 19905-1 standard was developed from Reference 1. The changes that are relevant to Classification were incorporated into this revision of these GNs.**

The fundamental difference between site-specific evaluation and Classification is that the latter is not site-specific in nature. Instead, the Owner specifies conditions for which the unit is to be reviewed for Classification. The basic dimensions of the envelope of conditions that the Owner may specify for Classification are:

- i) Water depth (plus air gap and penetration depth into the seabed)
- ii) Environmental conditions of wind, wave and current
- iii) Total elevated load
- iv) Spudcan-soil rotational stiffness

(The last item **is** a consideration introduced by ABS in 2003 when dynamic response is assessed for Classification.)

Therefore, a major theme of these Guidance Notes is to **designate** the portions of the criteria in **References 1 and 6** that **can** be applied without modification and the portions of the criteria that may need to be adapted for Classification purposes.

3 Basic Concepts of the Inclusion of Dynamic Effects into Structural Analysis

Because the natural period of an **SEU** is typically in the range of 5 to 15 seconds, there may be a concern that there will be dynamic amplification (resonance) with waves in this period range. It is therefore often desirable to account for the dynamic effects of the **SEU** in the elevated condition due to waves (and waves with current).

The basic approach most commonly used to include dynamic effects into structural analysis is characterized as a “quasi-static” method, which entails a two-step procedure. In the first step, a *Dynamic Analysis* model of the structural system is analyzed. Then, the static response to the same loads is obtained using the same model. A Dynamic Amplification Factor (DAF) is obtained as the ratio of the **most probable maximum** extreme (**MPME**) of a response when dynamics is considered to the **most probable maximum** extreme (**MPME**) of the same response statically considered. DAFs can be **obtained** for various structural responses, such as the global overturning moment of the unit, base shear force or the lateral displacement of the elevated hull (i.e., surge and sway). From the DAFs, an “inertial load set” is established that simulates the dynamic effects. The loads considered to produce the dynamic response are those induced by waves or waves acting with current. Usually, it is sufficient that the level of structural system idealization used to determine DAFs is, as often described, an “equivalent model”, which is an “equivalent 3-leg idealization” coupled with an “equivalent hull structural model”. The need to appropriately account for the stiffness of the leg-to-hull interaction and **spudcan-soil** interaction adds some minor complexity to this simplified modeling approach.

In the second step, the “inertial load set” is imposed, along with all of the other coexisting loads, onto the usual, detailed static structural model that is used to perform the “unity checking” for structural acceptance based on the Rules. Because this model now includes the “inertial load set” to simulate the dynamic response, it is often also referred to as the *Quasi-Static* model.

The two-step procedure is summarized as:

- i) Use an “equivalent” model to perform a random wave dynamic analysis deriving the DAFs and subsequently the inertial load set caused by wave-induced structural dynamics.

Alternatively, the DAFs may also be estimated using the single degree-of-freedom (SDOF) approach given in 4/5.1.2 as an alternative to the random wave dynamic analysis, above. However, care should be exercised since the SDOF approach may significantly over or underestimate the DAF. See the limitations of the SDOF approach for deriving the DAFs given in 4/5.1.4.
- ii) Use a “detailed” model to perform, with static gravity and wind loads and quasi-static wave loads plus the derived inertial load set, a static structural analysis deriving the stresses for unity checks in accordance with the ABS strength requirements in the *MODU Rules* for the leg chords, braces and the jacking pinions.

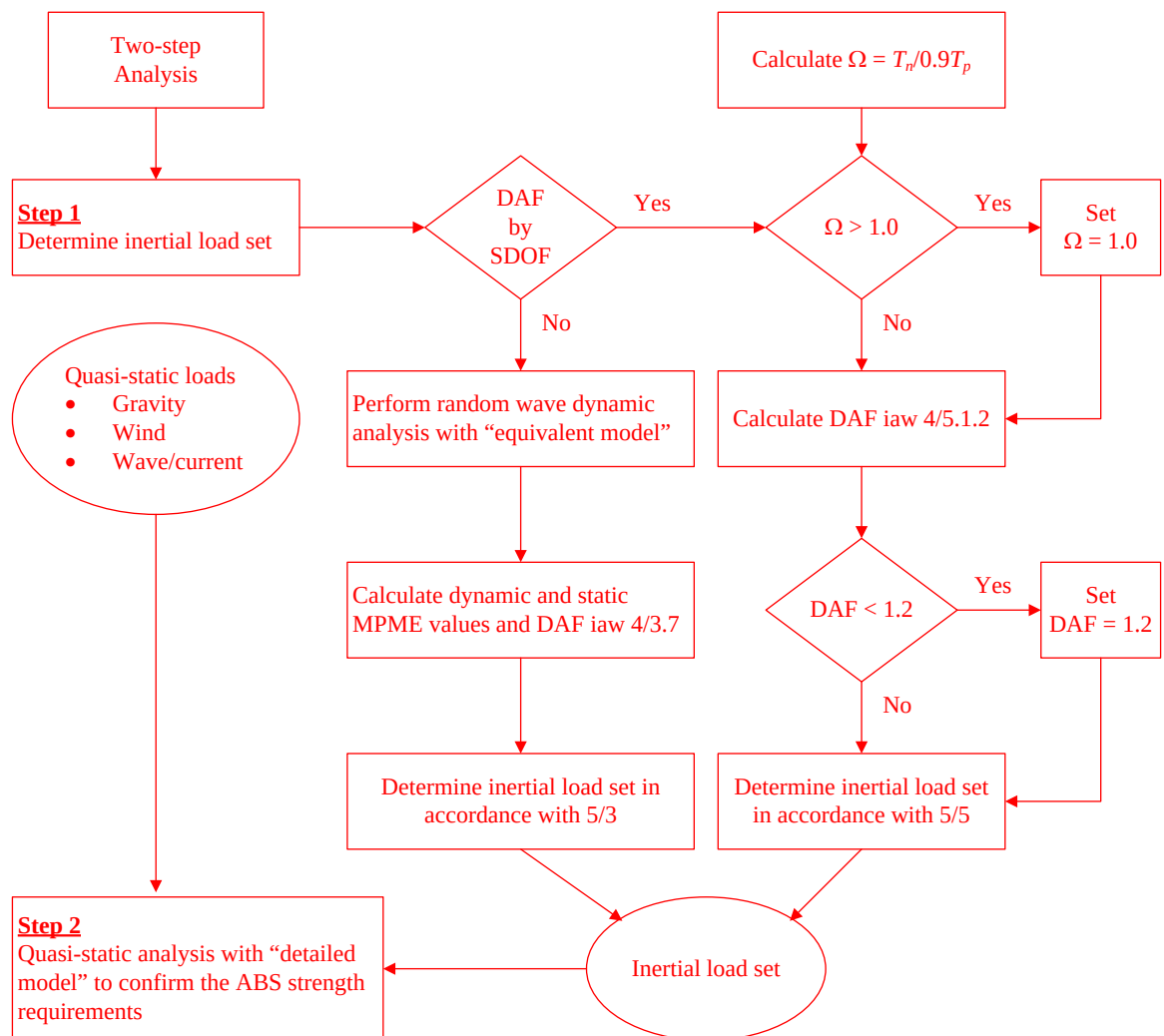
The flowchart of the two-step procedure is shown in Section 1, Figure 1. More details on the modeling procedure and the determination and application of the inertial load set are given in these Guidance Notes as follows:

- Specification of Wave Parameters and Spudcan-Soil Stiffness Section 2
- Dynamic Analysis Modeling Section 3
- Dynamic Response Analysis Methods Section 4
- Dynamic Amplification Factor and Inertial Load Set Section 5

5 Exception

Since 2008 the ABS MODU Rules require that wave induced dynamic response is to be included in the SEU design, except when the dynamic amplification factor (DAF) obtained from SDOF given in 4/5.1 is less than 1.1 considering the SEU as pin-ended at least 3 m (10 ft) below sea bed. However, caution should still be exercised since the SDOF approach may underestimate the dynamic response when the ratio of the natural period of the SEU to the wave period exceeds unity (1.0) or is less than 0.6. See also the limitations for use SDOF given in 4/5.1.4.

FIGURE 1
Flowchart of the Two-Step Procedure (1 February 2014)





SECTION 2 Specification of Wave Parameters and Spudcan-Soil Stiffness (1 February 2014)

1 Introduction

Environmental and geotechnical data are inherent to site-specific design and analysis. In the Classification of a **MOU**, the environmental **conditions** (such as wave, current and wind) that are used in design are selected by the Owner and become a basis of the unit's Classification. It is an assumption of Classification that the Owner will not operate the unit in environmental and other conditions that produce **loads** that are worse than those reviewed for Classification. This principle carries over to the dynamic response assessment.

In Classification, it is usual that the design storm is expressed deterministically, via the parameters $(H_{\max}, T_{\text{ass}})$. However, procedures used to explicitly compute dynamic response mostly rely on a spectral representation of the design-level sea states, so guidance is provided below in Subsection 2/3 on characterizing the design storm sea state in terms of (H_s, T_p) and the defining spectral formulation.

Also in Classification, the *MODU Rules* have specified that the bottoms of the legs should be assumed to penetrate to a depth of at least 3 meters below the seabed, and that each leg end (i.e., spudcan) is pinned (i.e., free to rotate about the axes normal to the leg's longitudinal axes, but fixed against displacements). **Since** (2003), a change **was made to** the *MODU Rules* that affects this practice. When the Owner wishes to credit spudcan-soil rotational stiffness at the bottom of each leg, this can be done in a manner as outlined in Subsection 2/5 below.

3 Spectral Characterization of Wave Data for Dynamic Analysis

The wave conditions **typically specified** for Classification are regular waves. The **deterministic** parameters $(H_{\max}, T_{\text{ass}})$ of the regular **wave** need to be **restated as wave** spectral parameters (H_s, T_p) **for** the dynamic analysis.

Where suitable data is not available, the following procedures **may** be used to convert the **deterministic wave parameters to spectral parameters**:

$$\begin{aligned} H_{\text{srp}} &= H_{\max}/1.75 \quad (\text{for cyclonic areas}) \\ &= H_{\max}/1.86 \quad (\text{for non-cyclonic areas}) \end{aligned} \quad (2.1)$$

$$H_s = [1.0 + (10H_{\text{srp}}/T_p^2) e^{(-d/25)}] \times H_{\text{srp}} \quad (2.2)$$

$$\begin{aligned} T_p &= 1.05T_{\text{ass}} \quad \text{when } 4.00\sqrt{H_{\text{srp}}} < T_p < 4.72\sqrt{H_{\text{srp}}} \\ &\quad \text{but if } T_p > 4.72\sqrt{H_{\text{srp}}}, \text{ then use } T_p = 4.72\sqrt{H_{\text{srp}}} \\ &\quad \text{if } T_p < 4.00\sqrt{H_{\text{srp}}}, \text{ then use } T_p = 4.00\sqrt{H_{\text{srp}}} \end{aligned}$$

where

$$\begin{aligned} H_{\text{srp}} &= \text{significant wave height, in meters, of the three-hour storm for the assessment return period} \\ H_s &= \text{effective significant wave height, in meters} \\ d &= \text{water depth, in meters } (d > 25 \text{ m}) \\ T_p &= \text{peak period associated with } H_{\text{srp}} \text{ (also used with } H_s), \text{ in seconds} \end{aligned}$$

Equation (2.2) is the Wheeler stretching adjustment that accounts some nonlinear effects around the free surface in shallower water depth. The JONSWAP spectrum with a peak enhancement factor of 3.3 and the above calculated H_s and T_p should be used to represent the considered sea state. The short-crestedness of waves should not be considered.

5 Spudcan-Soil Rotational Stiffness (SC-S RS)

Since 2003, the ABS *MODU Rules* permits consideration of “spudcan-soil rotational stiffness” for cases involving dynamic response. The maximum extent to which this rotational stiffness can be applied to the system, $K_{rs, fixed}$, is defined by the following equation.

$$K_{rs, fixed} = E I / (L C_{min})$$

where

E	=	Young’s modulus, 209GPa for steel
I	=	moment of inertia, in m^4
L	=	the sum of the distance, in m, from the underside of the hull to seabed plus the seabed penetration (minimum 3 meters) $\geq 4.35(I/A_s)^{0.5}$
C_{min}	=	$(1.5 - J)/(J + F)$
J	=	$1 + [7.8 I / (A_s L^2)]$
F	=	$12 I F_g / (A Y^2)$
A	=	axial area of the equivalent leg, in m^2
A_s	=	shear area of the leg, in m^2
Y	=	the distance, in m, between the centerline of one leg and a line joining the centers of the other two legs for a 3-leg unit; the distance, in m, between the centers of leeward and windward rows of legs; in the direction of being considered
F_g	=	1.125 for a three leg unit and 1.0 for a four leg unit

The Owner may select values of SC-S RS ranging from zero (the pinned ended condition) up to the maximum value indicated.



SECTION 3 Dynamic Analysis Modeling (1 February 2014)

1 Introduction

To determine a DAF, a simplified Dynamic Analysis model, as indicated below, may be used. The usual level of modeling employed in this case is designated as an “equivalent model”. Inaccurate or inappropriate modeling can have a major **effect** on the calculated structural responses, therefore, special care should be exercised to assure that the modeling and application of the dynamic loading is done **appropriately**. The stiffness of the Dynamic Analysis model should also be consistent with that of the “**detailed**” model used for the Quasi-Static structural **analysis** to check the adequacy of the structure by the permissible stress unity check criteria of the *MODU Rules*.

3 Stiffness Modeling

The level of stiffness modeling of the “equivalent model” for dynamic analysis discussed in this section includes

- Leg stiffness
- **Hull stiffness**
- Leg-to-hull connection **stiffness** (stiffness of jacking system, proper load transfer direction of guides, pinions and clamps, etc.)
- **P-Delta effect**
- **Foundation stiffness (leg-to-seabed interactions)**

3.1 Leg Stiffness

The stiffness of a leg is characterized by the following equivalent cross sectional properties:

- Cross sectional area
- Moment of inertia
- Shear area
- Torsional moment of inertia

The dominant factor affecting the **leg** stiffness is leg bending, but other compliance should be incorporated, such as the shear deflection of legs. The shear deflection of most members is small, but it can be significant in a ‘**lattice**’ structure. Therefore, shear deflection of legs should be properly incorporated in the analysis model.

In an equivalent model, a leg can be modeled by a series of collinear beams. The cross sectional properties of the beams may be derived by employing the formulas given in **Subsection A1/3** or by applying various unit **load cases** to the detailed leg model, **following the procedure given in Subsection A1/5**. If the properties are calculated with the formulas, they may change along the axis of the leg because the properties of the members constituting the leg may vary along the axis of the leg. Although it is not required to model each bay of the leg with a beam element, doing this will facilitate a more accurate mass distribution along the leg.

A spudcan may usually be modeled as a rigid member.