MANUAL

MOORING OF MOBILE UNITS

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DESIGN AND ENGINEERING PRACTICE

PREFACE

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Shell International Oil Products B.V. (SIOP)
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Shell International Exploration and Production B.V. (SIEP)
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The Hague, The Netherlands,

and other Service Companies.

They are based on the experience acquired during their involvement with the design, construction, operation and maintenance of processing units and facilities, and they are supplemented with the experience of Group Operating companies. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

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1) Operating companies having a Service Agreement with SIOP, SIEP, SIC or other Service Company. The use of DEPs by these Operating companies is subject in all respects to the terms and conditions of the relevant Service Agreement.

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All administrative queries should be directed to the DEP Administrator in SIOP.

NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the assessment of catenary mooring systems for mobile units.

Assessment criteria for mooring analyses and mooring equipment contained in this DEP are based on the requirements of the DnV Rules for Classification of Mobile Offshore Units, Part 6 Chapter 2: Position Mooring (POSMOOR), January 1996.

This DEP provides additional standards and guidance in cases where the POSMOOR rules do not correspond to Shell Group requirements and prescribes the methodology that should be adopted where POSMOOR is non-specific.

In order to assist users of this DEP, (Appendix 1) identifies the sections of POSMOOR for which the DEP provides either:

- substitute requirements;
- clarification;
- additional requirements;
- no change.

This DEP applies to units whose primary method of station keeping is provided by a spread, catenary mooring system. Vessel types covered by this DEP include:

Mobile Units A floating offshore installation which can be moved from place to place without major dismantling or modification.

Emergency Support Vessels (semi-submersible or ship).

Mobile Accommodation Units (semi-submersible or ship).

Mobile Offshore Drilling Units (semi-submersible or ship).

Specialist vessel types, which are **not** covered by this DEP, include:

Dynamically Positioned Vessels.

Floating Production Units.

Single Point Moored Units.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors nominated by them (i.e. the distribution code is "C" as described in DEP 00.00.05.05-Gen.).

This DEP is intended for use by in oil and gas production facilities and other facilities which employ floating offshore installations.

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

1.3 DEFINITIONS

1.3.1 General definitions

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

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

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act on behalf of the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

The word **may** indicates one acceptable course of action.

1.3.2 Specific definitions

Response amplitude operator	Basic data which can be used to calculate the motions, e.g. heave, surge, sway, roll, pitch of a floating vessel in waves.
Remote location	A mobile unit location which is more than 300 m from the nearest surface obstruction.

1.4 ABBREVIATIONS

BROA	The British Rig Owners' Association
CBS	Catalogue Break Strength
DnV	Det Norske Veritas (Ship Classification Society)
FOS	Factor of Safety
FPSO	Floating Production Storage and Offloading (unit/system)
HSE	The UK Health and Safety Executive
IADC	The International Association of Drilling Contractors
LAT	Lowest Astronomical Tide
MAU	Mobile Accommodation Unit
MCR	Maximum Continuous Rating
MODU	Mobile Offshore Drilling Unit
NDT	Non Destructive Testing
RAO	Response Amplitude Operator
UTM	Universal Transverse Mercator

1.5 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced in this DEP are listed in (6).

2. CENTRAL CONCEPTS AND OBJECTIVES

2.1 GENERAL

When an assessment of a mobile unit's mooring performance is required, the standards detailed in this DEP shall be applied.

The objective of an assessment is to demonstrate that the unit can safely maintain station at the proposed location by ensuring that the mooring equipment is:

- fit for purpose;
- adequately maintained;
- regularly inspected;
- operated in accordance with acceptable procedures.

This DEP considers the full assessment under the following main sections:

- Mooring analysis;
- Mooring equipment;
- Operational considerations.

The mooring analysis is based upon an allowable stress approach using calculated line tension factors of safety. Maximum system excursions, mooring line catenaries etc. are also calculated and compared with allowables. The suitability of mooring equipment is determined following a review of potential failure modes and inspection and maintenance procedures. Finally the practical aspects of mooring system deployment, operation and recovery are reviewed.

2.2 INTERNATIONAL APPLICATION

The POSMOOR rules were developed in North West Europe and are therefore considered the most suitable for application in the North Sea, to the West of Shetland and in other similar harsh environment locations. They can also be applied world-wide but in some areas (for example the Gulf of Mexico, the South China Sea etc.) they may result in unnecessary conservatism. An API-based methodology will result in adequate station keeping standards in these areas.

Mooring calculations performed in accordance with API RP 2SK may therefore be accepted for mobile unit operations in those geographical areas which are subject to the effects of tropical cyclones as defined in Appendix 7.

Fatigue analysis for long-term moorings, shall, however be conducted in accordance with the guidance given in EP 97-5598.

Whilst there are similarities between the DnV and API codes the fundamental methodologies and design and acceptance criteria are different and cannot easily be integrated. Therefore whilst some of the supplementary guidance given in each code can be transferred, great care shall be exercised to ensure that the methodology to be used is determined at the outset and that all the fundamental elements of the selected code or rule are applied as a whole without mixing and matching.

2.3 LOCATION-SPECIFIC FEATURES

The assessment of the mooring system shall take account of all relevant local features including: environmental conditions, bathymetry, seabed soil conditions, other installations, pipelines, wellheads etc.

3. MOORING ANALYSIS

3.1 GENERAL

This section details the methodology and assessment criteria that shall be used when analysing the operating and survival mooring performance of a mobile unit. Figure 1 provides a diagrammatic illustration of the analysis procedure.

A survival mooring performance assessment will normally take the form of a site-specific analysis but in cases where a standard symmetrical mooring spread is to be utilised at a remote location, a "generic" analysis or vessel capability curves may be considered.

A mooring performance assessment shall also be undertaken to identify the operating limitations of the mooring arrangement. This will normally involve the production of a site-specific mooring analysis but in cases where a standard symmetrical mooring spread is to be used on a remote location the results of a "generic" analysis may be considered.

Operating limitations are generally defined by vessel excursion and mooring line tensions. In most operating conditions the mobile unit will either be connected to a wellhead or adjacent to another installation. Vessel excursions are therefore of great importance. Examples of specific instances where operating limitations on vessel excursion shall be considered are listed below:

a) MAU adjacent to platform: minimum allowable platform/vessel clearancespersonnel bridge operational capabilities minimum allowable platform/anchor line clearances

b) MODU Tender Drilling: minimum allowable platform/vessel clearances personnel bridge operational capabilities minimum allowable platform/anchor line clearances umbilical operational capabilities

c) MODU Drilling: marine riser operational capabilities

d) MODU / MAU: system limitations caused by requirement to maintain anchor line / pipeline clearances

Details of the acceptance criteria such as maximum allowable excursions, minimum allowable factors of safety etc., are given in (3.8).

3.2 DOCUMENTATION

3.2.1 Vessel information

For a mooring analysis to be undertaken or reviewed, various details concerning the mobile unit and its mooring equipment are required. These data requirements are described in (Appendix 2).

3.2.2 Location information

Site-specific data shall be submitted for review in accordance with the listing given elsewhere in this DEP (Appendix 3).

3.2.3 Mooring analysis report

For applications where a site-specific mooring analysis is undertaken, a full report detailing all aspects of the necessary analyses shall be produced. A suitable format for the information that should be contained in the report is given in (Appendix 4).

3.3 ANALYSIS METHODOLOGY

3.3.1 Aim

The aim of any mooring analysis is to predict the behaviour of a proposed anchoring arrangement in critical conditions and to determine whether it meets the applicable acceptance criteria. These criteria cover both the intact and damaged cases in operating and survival conditions. The primary areas of interest are listed below:

Line Tensions:	line factors of safety, anchor capacity
Vessel Excursions:	operating limits and clearances with other installations.

3.3.2 Selection of analysis technique

Quasi-static analysis and dynamic analysis are the two principal techniques available for the assessment of spread mooring systems. A quasi-static mooring simulation is likely to be appropriate for the majority of applications but some form of dynamic analysis may be required in specific situations.

Figure 2 provides initial guidance on the selection of an appropriate calculation method and further detail is given in (3.3.4) and (Appendix 8).

All mooring analyses shall be undertaken using a recognised computer program capable of simulating the performance of multi-element spread mooring systems. Suitable programs will be dictated by the type of analysis technique appropriate for the specific mooring application under review.

3.3.3 Quasi-static analysis

In a quasi-static analysis the loads due to mean wind, current, and wave drift, are applied to a mooring system stiffness model in order to determine vessel offsets. Horizontal vessel motions caused by wave effects are then applied and the resultant line tensions are calculated. A similar procedure is repeated with each of the critical mooring lines removed to give the maximum line tensions in the damaged (one line broken) condition.

Second-order system dynamics may be ignored for the quasi-static analysis of typical column stabilised units. However, second-order system effects shall be considered in accordance with the POSMOOR requirements for vessels which are sensitive to low-frequency wave effects, for example ship-shaped units. Low-frequency wind effects may be ignored in the quasi-static analysis of most vessels. Special consideration may, however, be required in cases where the vessel may be excited by wind gust.

Criteria to be used in assessing the suitability of quasi-static programs and examples of acceptable programs are given in (Appendix 6).

3.3.4 Dynamic analysis

A dynamic analysis shall be used to assess mooring systems where the system is considered to be particularly susceptible to dynamic effects (dynamics can be due to either system or line dynamic effects).

System dynamics occur when the mooring natural period is close to the forcing period of either the first- or the second-order loadings. The first-order wave periods associated with harsh environment survival conditions generally lie in the 10-16 second range. It therefore follows that the mooring system must be very stiff for first-order dynamics to be significant. Generally such stiffnesses only occur in very shallow water and the existence of significant first order system dynamics often implies that a catenary mooring system is no longer suitable.

Second-order system dynamic effects occur when system natural periods (60 - 200 seconds) are excited by the slowly varying wind and wave drift forces whose magnitude is a function of the second-order loading, mooring system stiffness and damping.

Line dynamics are caused by the inertia and fluid drag loads acting on the mooring line which prevent it from adopting an instantaneous catenary shape. These loads, together with vessel movement under the influence of wave action, cause tension fluctuations along the mooring line about the mean static value. Vortex-induced vibrations are rarely responsible for any increase in mooring line tensions but it is important to note that line dynamic tensions can be influenced by a number of other non-linear effects:

a) catenary shape which changes with line tension and fairlead position;
b) fluid loading on mooring line which is proportional to the square of the relative velocity between the line and its surrounding fluid;
c) length of contact between mooring line and seabed varying with line tension;
d) non-linear elastic characteristics of mooring line under tension.

All dynamic effects are affected to some extent by water depth (system dynamic effects because they are a function of system stiffness and line dynamic effects because they are a function of the mooring line drag and inertia). The POSMOOR code therefore states that dynamic analysis shall be carried out for all cases where:

(Semi-submersible) water depth > 450 m;

(Ship-shape) water depth > 200 m.

These limits can be used for initial guidance but cannot be relied upon in all instances because they ignore other important parameters such as vessel displacement and the size, weight and profile of moorings. The selection of the analysis method and the line tension based acceptance criteria is an important process which should be addressed on a case-by-case basis. Further guidance on the selection of analysis method is given in (Appendix 8).

3.3.5 Dynamic Analysis Methods

In order to simplify a dynamic analysis, it is sometimes possible to linearise some of the inherent non-linear effects at the mean offset position and so undertake the analysis in the frequency domain rather than the time domain. Further guidance on dynamic analysis methods is given in POSMOOR (section 3 note A200) from which it is clear that a mixture of time and frequency domain analysis methods may be required.

All dynamic analyses shall incorporate the effects of both high-and low-frequency wave effects and low-frequency wind effects. Detailed guidance on the calculation of motions due to these effects is beyond the scope of this DEP and it is therefore left to the analyst to substantiate any methods used. Some limited guidance on this is given in POSMOOR (section 2: B 300).

3.3.6 Transient analysis

Analysis shall also be undertaken to calculate line tensions and vessel excursions during transient motion following single line failure. Calculations should be based on a time step procedure which models the motion of the vessel under the influence of environmental forces and the loadings developed by the damaged (and thus asymmetric) mooring spread. The drag, added mass and inertia properties of the vessel should be considered in the calculations.

Mobile unit excursion and heading shall be calculated at regular intervals until the maximum oscillation in the direction of interest has been passed or the equilibrium position has been reached. The interval of calculation can be taken as one-hundredth of the system natural period but should not exceed 1 second. A record of line tensions should also be produced in order to determine the maximum/minimum tensions in individual lines.

Although the transient analysis represents a time domain dynamic method for the calculation of mobile unit motions, the resultant line tensions can be calculated quasi-statically. The environmental loadings should be calculated on the same basis as the associated intact and damaged equilibrium analyses and line dynamic effects should be added when required.

3.3.7 Fatigue

A fatigue analysis shall be performed for any long-term mooring where the vessel is to remain on the same location for more than 5 years. The analysis shall be conducted as described in (Appendix 8).

3.4 ENVIRONMENTAL CONDITIONS

3.4.1 General

Environmental data for the location shall normally be provided by the Principal. Where this is not possible, the information shall be obtained from a published source. Data generated by a competent person may also be utilised, provided documentation is produced to substantiate the proposed data. Directional and seasonal variations may also be considered if these have been derived in a similar way.

3.4.2 Survival conditions

A 50-year return extreme environment shall be used in conjunction with the survival mooring performance assessment methodology and criteria detailed in (3.7) and (3.8).

It should be noted that some operating areas are subject to governmental regulations which consider an alternative environment for survival assessment. Although this DEP (1.2) demands compliance with all such regulations, it is not the intention that locally enforced environmental extremes should be used in conjunction with DEP assessment criteria.

The DEP assessment methods shall be taken as a whole to determine acceptable integrity standards for use by the Principal, similarly alternative assessment criteria should be taken as a whole. In such situations, the overall conclusions of the DEP assessment and those of any mandatory governmental regulation should be compared and the most onerous consequences used in the mobile unit assessment procedure.

3.4.3 Operating conditions

If required (3.1), operating analyses shall be undertaken to either confirm acceptable performance in an environmental condition pre-defined by the Principal, or to obtain an indication of operating environmental limits.

3.4.4 Physical parameters

Wind velocities averaged over a 10-minute period at 10 m above sea level ($V_{10min10}$) shall be used to calculate wind loadings. A current velocity, including the effects of tide and wind, depth averaged at the centre of pressure of the underwater profile, shall be used to generate current loadings.

Wave parameters shall be given in the form of Significant Wave Height (H_S), Peak Spectral Period (T_p) and where appropriate, Mean Zero Upcrossing Period (T_z). Although a range of wave periods will normally be associated with a particular wave height, an average or most probable wave period should be used in conjunction with the assessment criteria given in this DEP. A suitable irregular wave spectrum for the location shall be adopted where spectral analysis is undertaken to determine vessel motions.

Mooring analysis should normally be undertaken for the LAT water depth. Consideration should, however, be given to the effects of increase in water depth in areas where tidal rise is significant.

Wind, wave and current loadings shall be assumed to act in a concurrent and collinear manner.

The mooring analysis will normally assume that the mobile unit is either at standard survival or standard operating draught. Actual draught should be within +/- 1.5 m of that assumed.

3.5 ANCHORING ARRANGEMENT

3.5.1 Anchor pattern

The anchoring pattern shall be arranged to maximise the mobile unit's performance in both the operating and survival conditions. In most instances this will be obtained from a symmetrical anchor spread (as detailed in the unit's operations manual) but when environmental conditions are highly directional, a non-symmetrical arrangement may be considered. Vessel heading will often be specified by non-mooring requirements but where it is not, consideration should be given to both the prevailing and extreme weather directions when orientating the unit.

If other installations or subsea items obstruct a symmetric spread, anchors shall be positioned so that mooring line clearance requirements are observed. Consideration should also be given to the local seabed slope when determining water depth at the anchors. Steeply shelving or complex seabed profiles could have a significant effect on line load extension characteristics. The line static position should thus be modelled as accurately as possible.

If vessel heading is critical (e.g. MAU alongside an installation, MODU over a template), extreme mooring system asymmetry should be avoided as significant line working tensions may be required to keep the vessel on the selected heading. This will lead to inefficient use of the anchor lines and a reduction in the overall performance of the system.

Mooring line bearing angles shall be selected so that any limitations in fairlead horizontal rotation are not exceeded.

3.5.2 Deployed line length

Horizontal distances from fairlead to anchor shall be set so that deployed line length is not in excess of the useable line length. Useable line length should be obtained by subtracting the amount of line which must remain in the locker or on the winch drum plus an allowance for winching (e.g. for moving from survival to operating position; for pull-off in the event of blow-out; or for line tension optimisation) from actual line length. The scope required to avoid uplift forces on the anchor shall be achieved within the useable line length and great care shall be taken to ensure that this condition is met even when anchor uplift forces are the limiting consideration for location approval.

Sufficient line length shall always be left to permit the unit to move at least 100 m off station in any direction in the event of an emergency.

3.5.3 Anchor position

Anchors shall not be placed within 200 m of a subsea item, e.g. a pipeline. If the anchor is pulling away from a subsea item, the analysed position must allow for distance to embed the anchor fully following its initial placement on the seabed 200 m from the obstruction. If the anchor is pulling towards a pipeline, its final embedded position must not be less than 400 m from the point at which the anchor line crosses the obstruction (see Figure 3). This is a minimum value and may be overruled by line clearance criteria given in (3.8.7).

3.5.4 Line tensions

Initial line tensions for operating analyses shall be set at the values recommended in the unit's operating manual for the location water depth.

When a mobile unit is in the survival condition, it is by implication unrestricted by excursion limitations. Thus it is acceptable to reduce the overall stiffness of the mooring system to limit line tensions. This approach may be simulated in the analysis by selecting a low initial system stiffness. It should be noted, however, that the minimum tensions defined by the requirements of pipeline clearance criteria given in (3.8.6) and (3.8.7) must be observed.

3.6 LOAD AND MOTION CALCULATIONS

3.6.1 Loading and motion coefficients

Environmental loads and vessel motions used to derive mooring line tensions and vessel excursions shall be generated from recognised coefficients for the specific mobile unit under review. Care should be taken to ensure that the utilised coefficients are applicable to the vessel draught being considered. It must be emphasised that the adoption of acceptable coefficients is of paramount importance when assessing mooring system performance.

In the first instance, values provided in the unit's approved operations manual shall be utilised. If these are not available, generally recognised values shall be used. Suitable coefficients for a number of typical MODU types are given elsewhere in (Appendix 6). These may be used to assess the validity of coefficients obtained from other sources.

Coefficients derived from model tests may be used provided they are converted to full scale including all relevant correction factors (e.g. for wind and current profile etc.). They should be substantiated by presentation of relevant extracts of the model test report. Vessel motion response coefficients based on computer analyses shall be treated in the same manner.

If no verifiable source of coefficients is available, calculations may be undertaken to determine wind, current and wave drift coefficients. A documented and proven methodology shall be applied.

3.6.2 Transient motion coefficients

In most instances, computer analysis programs require hydrodynamic mass and damping parameters to allow time-dependent motion of the mobile unit to be calculated following single line failure. These coefficients should generally be calculated according to model tests or computer analysis results.

3.6.3 Calculation methods for quasi-static analysis

The general procedure for calculating loads and motions for use in a quasi-static analysis shall be as follows:

a) Calculate steady state-loads on the unit.

These loads are due to wind, mean wave drift and current and are calculated for each of the selected load case directions using the previously described vessel loading coefficients (3.6.1). Note that the following example procedure is dependent on the type of loading coefficients adopted but is applicable to those given in (Appendix 6).

The mean wind loading, (Fw), can be expressed as:

$Fw = C_{wf} (V_{10min\ 10})^2$

C_{wf} = the mean wind force coefficient

$V_{10min\ 10}$ = the ten-minute mean wind speed measured at a 10 metre elevation

The mean current loading, (Fc), can be expressed as:

$Fc = C_{cf} (V_c)^2$

C_{cf} = the mean current force coefficient

V_c = the extreme current, depth averaged at the centre of pressure of the underwater hull form

Moored mobile units are also loaded by wave drift forces. This second-order loading mechanism can be treated in a relatively simplistic way when quasi-static analysis is applicable. For calculation purposes it is assumed that the loadings can be split into a steady-state component and a low-frequency oscillatory component.
The steady-state element is normally referred to as mean wave drift and this may be calculated either with the aid of simplified load coefficients or by using response curves

generated from model tests / computer analyses.

As an example, coefficients based on Hs and Tz can be used to generate the mean Wave Drift Force (FWD) in the following manner:

F_{WD} = $C_{wd} (H_s)^2 / (Tz)^2$

C_{wd} = the mean wave drift force coefficient

H_s = the significant wave height

T_z = associated mean zero upcrossing period

As noted in (3.3.3), this DEP allows low-frequency effects to be ignored when calculating the wave-induced motion of column-stabilised units. Ship-shaped vessels are, however, considered to be a special case and motions due to low-frequency wave effects may be calculated as shown in (3.6.3c).

Note that, strictly speaking, all of the mean load coefficients are dimensional in the sense that they remain functions of air or water density, gravity and projected reference dimensions, but as all these parameters are effectively constant for a given vessel or mobile unit it has become widespread practice to quote the shortened form. Occasionally some codes may refer to the full non-dimensional equivalents but these values can be quickly converted using the relevant reference dimensions and standard physical parameters (i.e. $\rho_{air,}$ ρ_{sw}, g etc.).

b) Calculate the vessel horizontal wave frequency motions. Base data for this calculation are normally provided in the form of RAO curves which have been generated by model tests or computer analyses. In order to generate these horizontal motions, a spectral analysis should be undertaken using the RAOs and the wave spectral properties defined in (3.4.4).

   If the most probable maximum motion values are required, they shall be calculated assuming a three hour storm.

   The effect of wave spread can be incorporated when predicting the most probable maximum motion using the RAOs generated from regular waves. If site-specific information concerning wave spread is not available, a factor of 0.9 may be applied to the motion derived in long-crested seas to obtain the equivalent response in short-crested seas.

c) If the mobile unit is particularly susceptible to low-frequency wave effects, the resultant motions shall be calculated and combined with the wave frequency motions using the method given in the POSMOOR code (section 3, A203).

   These motions may be obtained from model tests or from a detailed computer analysis. If this information is not available, the motions may be calculated using a simplified methodology such as that given in API RP 2SK.

d) The most onerous load cases shall be considered. For analyses where a directional environment is to be used, the most onerous load cases will be selected from the eight "standard" directions (i.e. head, beam, quarter) plus the "down the line" directions (i.e. reciprocal to the line headings) as shown in Figure 4. Where non-directional environmental data and a symmetric anchor pattern are used, it may be feasible to reduce the total number of loading directions.

e) The analyst should be aware that the accuracy of the analysis may be affected by rotations of the mobile unit during analysis and possible errors in environmental data, initial vessel heading and line headings. Figure 5 gives a representation of how calculated loadings and motions can vary depending on selected loading direction. In some situations the analyst should therefore consider additional load cases to ensure that the maximum line tensions and excursions have been correctly identified.

3.6.4 Calculation methods for dynamic analysis

A full dynamic analysis represents an extensive procedure and its detailed description is not included in this DEP. Normally a time domain analysis will be required to treat the non-linear problem. Non-linearities in mooring systems can, however, generally be linearised successfully and less time-consuming frequency domain methods can therefore be used. Normally the most complex analysis to be employed would require system dynamic analysis in the frequency domain combined with line dynamic analysis in the time domain. Further information on dynamic analysis methods is given in (Appendix 8).

Any dynamic analysis procedure shall be fully detailed in terms of its methodology and adopted algorithms. All methods shall be assessed individually but in all cases it should be demonstrated that all dynamic effects, e.g. line dynamics, slowly varying forcing, are correctly modelled.

3.6.5 Thrusters

For manned mobile units, POSMOOR allows the effect of thrusters to be incorporated in the simulation of some mooring situations. Where thrusters are considered, calculations or documentation shall be provided to indicate how the utilised thrust values were obtained. The POSMOOR code (section 4) describes how thrust values are to be determined and then applied in the mooring analysis.

It is important to note that POSMOOR requires the net thrust to be used. The net thrust value is obtained by reducing "open water" thrust values to account for reductions in propulsion efficiency due to hull interactions, vessel motions, local currents etc. Thus:

Net thrust = Open water thrust x efficiency factor

Thrust used in mooring analysis (manual systems) = Net thrust x 0.7

Thrust used in mooring analysis (automatic systems) = Net thrust x 1.0

If actual thrust values are not known for the mobile unit, Figure 6 may be used to estimate available net thrust per thruster.

If the mobile unit is equipped with 360-degree azimuthing thrusters it can be assumed that constant net thrust is available in all directions.

If the mobile unit is equipped with normal "ship type" propulsion (i.e. at stern), the thrust used in the mooring analysis should reflect the system’s inability to provide lateral thrust. In the absence of documented evidence showing the variation of thrust by direction, the following factors may be applied to the net thrust to obtain directional thrust:

	Factor
Ahead Direction	1.0
Bow Quarter	0.7
Beam	0.0
Stern Quarter	0.35
Stern	0.5

The normal POSMOOR factors should then be applied to the directional thrusts above to obtain the value to be used in the mooring analysis.

3.6.6 Shallow water effects

The effects of shallow water are described in (Appendix 8).

3.7 ANALYSIS PROCEDURE

3.7.1 Survival analysis

The performance of the mooring system shall be assessed for the following survival conditions:

a) INTACT SURVIVAL: Maximum design storm conditions with all mooring lines intact.

b) DAMAGED SURVIVAL: Maximum design storm conditions with unit in its equilibrium position following the failure of one mooring system component (i.e. mooring line or thruster).

c) TRANSIENT SURVIVAL: Transient conditions following the failure of any single mooring line during the design storm.

MODUs shall be deemed to be in the survival condition when at survival draft, disconnected from the wellhead and (when applicable) winched the required minimum distance away from the adjacent platform.

3.7.2 Operating analysis

If required, the performance of the mooring system shall be assessed for the following operating conditions:

a) **Intact Operating**: Operating conditions with all mooring lines intact.

b) **Damaged Operating**: Operating conditions with unit in its equilibrium position following the failure of one mooring system component (i.e. mooring line or, if applicable, thruster).

c) **Transient Operating**: Transient conditions following the failure of any single mooring line whilst operating.

MODUs shall be deemed to be in an operating condition whenever a marine riser is connected between the vessel and the wellhead (i.e. the operating condition will include both the drilling and the standby conditions).

3.7.3 Optimisation by winching

In the first instance, survival analyses should be undertaken assuming a passive mooring system i.e. no active modification of the mooring arrangement using winching. If this procedure gives unacceptable line tensions, a simulation assuming slackening of leeward lines should be undertaken. Although this is a relatively standard operational policy, such a simulation should only be undertaken if it models procedures detailed in the mobile unit's operations manual.

The negative aspects of line optimisation should be considered if such a policy is adopted within the analysis. In some instances, optimisation to improve system efficiency in the intact condition leads to a reduction in transient case performance which then becomes critical. This phenomenon is caused by the reduction in overall mooring system stiffness which can lead to excessive vessel excursion during transient motion. Therefore, where line optimisation is applied in the intact condition, its effects upon the damaged and transient conditions shall also be investigated.

Active winching shall not be adopted in the analyses if the operational procedures call for the mobile unit to be abandoned in extreme conditions. In such situations a passive system should normally be considered. Where the direction of the extreme environment can be predicted reliably, the analysis may assume some level of line tension optimisation provided that it is shown that it can be reliably achieved in good time prior to the demobilisation of all personnel.

If the mobile unit's operations manual gives detailed procedures for windward line load sharing for survival conditions as described in (5.5.2) and (5.53), analyses which simulate this capability may be applied. The exact procedure will be equipment- and thus rig-dependent and thus it is not possible to standardise an acceptable, universal analysis technique. The ultimate aim is, however, to reduce maximum line tensions by shedding load from lines heading directly into the weather onto adjacent ones.

It is considered that calculations which indicate that full windward line load sharing (i.e. all windward lines at identical tensions) can be achieved are likely to be unrealistic and are therefore unacceptable. Simulation methods which accept the concept of load sharing but recognise the difficulties in its application due to personnel performance, winch pull/brake capacity, line tension/payout monitoring and weather forecasting are therefore preferred.

Operating analyses should first consider a passive system but if procedures to maintain the mobile unit on location are described in the operations manual, winching to hold station simulations may be used.

3.7.4 Anchor holding capacity

If available, site-specific soil information should be used to determine anchor holding capacity, but where it is not, the assessment should determine the type of soil required to give satisfactory holding with the unit's primary anchors. In this connection reference should be made to Manufacturers' or other relevant data in order to determine the holding capacity of the selected drag embedment anchor. In the absence of credible anchor performance data reference may be made to API RP 2SK (Figures 5.2 and 5.3). Where holding problems are identified, the mobile unit's mooring arrangement shall be modified to attain the required performance.

API RP 2SK (Figures 5.2 and 5.3) may be used to estimate the unfactored holding capacity of anchors but anchor factors of safety shall be determined solely in accordance with this DEP. The characteristic line tension shall be taken as the maximum tension derived from any one of the following survival conditions:

- Intact (including maximum surge/sway motions)
- Damaged equilibrium (including significant surge/sway motions)
- Transient (excluding significant surge/sway motions)

A consequence factor of 1.2 should be applied to the required holding capacity of critical lines as defined by the POSMOOR V requirement and or where it is intended to moor the vessel for a period in excess of five years. A material factor of 1.1 should be applied to the required holding capacity of anchors where credible site-specific soils data are unavailable.

The grounded mooring line may be taken to the anchor(s) in withstanding the total horizontal loadings. In the absence of site-specific information the following coefficients of longitudinal sliding friction may be used:

- Chain cable = 1.0
- Wire Rope = 0.6

3.7.5 Results

The analysis results shall be given in the Mooring Analysis Report as described in (3.2.3). It is important to note that this document not only gives a detailed description of the analytical aspects of the study but also provides useable guidance to the mobile unit's crew in terms of operating limits and procedures.

Operational limits shall be defined in a manner that allows them to be monitored on the mobile unit. If the line tension monitoring system is only capable of measuring mean tensions, analysis results shall also be expressed in terms of mean tensions.

3.8 ACCEPTANCE CRITERIA

3.8.1 General

This section details the assessment criteria applicable to the following:

- Line Tension factors of safety;
- Anchor Uplift;
- Mooring Line Clearances;
- Vessel Excursion.

3.8.2 Quasi-static line tensions

The permissible quasi-static line tension safety factors are given in POSMOOR (Section 3 Table C1). They can be summarised as follows:

a) *Mobile unit in remote location:*

STORM SURVIVAL CONDITION I	Non-Critical lines	Critical lines
Intact	1.80	N/A
Transient	1.10	N/A
Damaged	1.25	N/A
OPERATING CONDITION II		
Intact	2.70	N/A
Transient	1.40	N/A
Damaged	1.80	N/A

b) *De-manned mobile unit in remote location:*

STORM SURVIVAL CONDITION I		
Intact	*	N/A
Transient	*	N/A
Damaged	*	N/A

* This case is not covered by POSMOOR rules. However, API RP 2SK will be accepted for most relevant geographical areas, (see Appendix 7).

c) *Mobile unit within 300 m of another surface installation:*

STORM SURVIVAL CONDITION I		
Intact	1.80	2.00
Transient	1.10	1.10
Damaged	1.25	1.40
OPERATING CONDITION II		
Intact	2.70	3.00
Transient	1.40	1.40
Damaged	1.80	2.00

3.8.3 Dynamic line tensions

Assessments of dynamic analyses results (both frequency and time domain) should be based on the line tension factors of safety given below:

a) *Mobile unit in remote location:*

STORM SURVIVAL CONDITION I	Non-Critical lines	Critical lines
Intact	1.50	N/A
Transient	1.00	N/A
Damaged	1.10	N/A
OPERATING CONDITION II		
Intact	2.30	N/A
Transient	1.20	N/A
Damaged	1.50	N/A

b) *De-manned mobile unit in remote location:*

STORM SURVIVAL CONDITION I		
Intact	*	N/A
Transient	*	N/A
Damaged	*	N/A

* This case is not covered by POSMOOR rules. However, API RP 2SK will be accepted for most relevant geographical areas, (see Appendix 7).

c) *Mobile unit within 300 m of another surface installation:*

STORM SURVIVAL CONDITION I		
Intact	1.50	1.65
Transient	1.00	1.00
Damaged	1.10	1.25
OPERATING CONDITION II		
Intact	2.30	2.50
Transient	1.20	1.20
Damaged	1.50	1.65

Critical lines are those laid within the 180-degree sector facing away from an adjacent installation (i.e. those lines whose failure would cause the mobile unit to move towards the installation). Where movement away from the installation would also have significant consequences (e.g. tender drilling), all lines shall be considered critical.

The POSMOOR rules apply operating condition II to any MOU within 50 m of another installation. POSMOOR V factors apply to any critical line of any installation which is less than 300 m from another one. POSMOOR Figures 5 and 6 incorrectly show this limit at 350 m.

The POSMOOR rules (section 1 A304) state that the 300 m limit applies to semi-submersibles with conventional mooring systems. The risk of collision increases for asymmetric mooring systems with large damaged excursions. POSMOOR V factors should also apply where installation clearances are less than 200 m following single line failure.

The larger the obstacle the greater the risk of collision. POSMOOR factors shall be applied to critical lines where the angular occlusion presented by the adjacent structure is greater that 60 degrees (i.e. the angle between two structures of 150 m length, 300 m apart).

3.8.4 Line tension definitions

Maximum intact and damage tensions shall include maximum surge/sway motions. Maximum transient line tensions shall include significant surge/sway motions.

For anchor lines made up of multiple components (e.g. wire, chain, buoys, clump-weights, etc.) tensions and factors of safety shall be calculated for each element to determine the minimum line factor of safety in the system.

3.8.5 Synthetic Fibre Ropes

The design of moorings which include man-made fibre ropes shall be considered on a case-by-case basis. The safety factors listed above shall be multiplied with a minimum factor of 1.1 for such applications. Larger material factors may be applied following a review of all relevant particulars. Further information on the design and assessment of synthetic fibre mooring ropes is given in (4.3.11).

3.8.6 Anchor uplift forces

Sufficient mooring line length shall be deployed to ensure that gravity embedment anchors do not experience uplift forces at the maximum line tensions defined below. Allowances may be made for anchor types which are specifically designed to accommodate uplift forces, provided that it is demonstrated that they can provide adequate holding capacity.

The maximum line tension for the confirmation of adequate anchor holding capacity shall be taken as the greatest of the following:

a) the maximum transient line tension after single line failure excluding the effect of wave-induced vessel motions;
b) the maximum line tension in the damaged condition including the effects of significant wave frequency induced motion;
c) the maximum intact line tension in the intact condition including the effects of maximum wave frequency-induced motion.

For ship-shaped mobile units this clause shall be modified to the maximum line tension in the damaged condition including the effects of significant wave frequency-induced motion or significant low-frequency motion, whichever is the greater.

3.8.7 Mooring line clearances

Clearance between mooring lines and other items shall be considered for the following cases:

a) Mooring line crossing a pipeline
Where a mooring line crosses a pipeline within the elevated part of its catenary, the following minimum vertical clearance criteria shall be adopted:

CONDITION	CLEARANCE
Intact (mean position - no surge/sway motion)	15 m
Intact (including maximum surge/sway motion)	positive clearance

The above criteria mean that a positive clearance shall be maintained in all intact conditions up to and including the maximum design storm. The selection of the minimum value of “positive clearance” described above shall be based upon a practical risk assessment which takes into account the capacity of the pipeline and the potential consequences of damage or rupture. A qualitative risk assessment performed by competent person(s) shall be accepted in the absence of quantitative data.
In the damaged condition it is always possible that the failure of a mooring line which lies over a pipeline could give rise to mooring line/pipeline contact even when mid-line buoys are used. This is because failure at a critical location can always result in a length of mooring line or even a single link or shackle falling to the seabed. In the worst case an uncontrolled winch run-out could result in a clump of chain being deposited on the seabed. Therefore the potential damage to critical pipelines shall be established in any foreseeable conditions in which a mooring line contact might occur.
Once more a practical risk-based approach shall be adopted which implies that a single initial pipeline-to-mooring-line contact can be permitted in the damaged condition following single line failure provided that:

- the probability of contact is low;
- the pipeline has the capacity to withstand the initial contact;
- the pipeline will not be subjected to repeated contacts and abrasion.

b) Mooring line crossing another mooring line

If two mooring lines cross and the lower line is inactive for the full range of expected line tensions, criteria detailed in a) shall be adopted.

If two active mooring lines cross, a minimum vertical clearance of 10 m is required for the most onerous conditions. (This condition is considered to be represented by the maximum transient condition, including significant surge/sway motion, following single line failure on either of the vessels.)

c) Mooring line passing close to another installation (incl. subsea item)
A minimum horizontal clearance of 10 m shall be maintained between mooring lines and any other installation. This clearance is required in all conditions including transient motion plus significant surge/sway motion.

If mid-line buoys are necessary to maintain the required clearances, the analysis shall model them accurately. Further guidance on the design of mid-line buoys is given in (4.3.8).

3.8.8 Vessel excursion

Criteria for the assessment of transient vessel excursions, including significant surge/sway motions, are as follows:

Operating Condition - Adjacent to installation:	
Minimum Vessel to Installation clearance	10 m
Survival Condition - Adjacent to installation:	
Minimum Vessel to Installation Clearance	50 m
Operating Condition - Remote MODU:	
Maximum excursion	within riser limitations

Riser limits shall be considered when the riser is latched and will normally be defined in the form of maximum allowable lower flex-joint angle and or maximum allowable slip joint extension. If a riser analysis has been undertaken, the correctly defined riser profile shall be used to define the lower flex-joint angle and associated vessel offset for specific environmental conditions. If such an analysis is not available, excursion criteria shall be generated assuming the riser lies in a straight line between the drill floor and the top of the marine riser package. Typical heave motions may also need to be investigated where slip joint extension is limiting as described in (3.8.9).

Riser limits vary depending upon the type of equipment deployed and the stage of the drilling operation, so careful study shall be undertaken in order to identify the limits. Useful guidance on this subject is given in API RP 16Q. The following limits given in API RP 2SK may be used for guidance in preliminary assessments until the actual riser limits have been confirmed:

Maximum allowable mean offset:	
Drilling mode	2% - 4% of water depth
Maximum allowable mean offset:	
Standby mode	8% - 12% of water depth

For a MAU operating with a bridge connected to an adjacent installation, vessel surge/sway motions will be one of the factors which may dictate the environment limit for manual bridge lift. The analysis shall identify these limits and the point where the alarm trips should be set for the automatic recovery of gangway bridges. The analysis shall also identify the transient motion of the unit following single line failure in order to determine if the bridge is likely to impact the installation prior to completing its emergency self-stowing procedure.

In benign areas, the above clearance requirements may be reduced at the discretion of the analyst if their implementation leads to significant operational restrictions.

Practically, account may need to be taken of second-order slow drift motions when considering excursion limitations (e.g. riser and or gangway motions).

3.8.9 Heave

Although not directly linked to mobile unit mooring, heave response of the vessel can have a significant impact on its operability. Operational limitations defined by mooring criteria should thus be supplemented by an appraisal of heave limitations in order to provide an overall assessment of vessel capabilities.

4. MOORING EQUIPMENT

4.1 GENERAL

4.1.1 Aims and objectives

The aim of this section is to confirm that all proposed mooring equipment is fit for purpose. All equipment shall therefore be reviewed to ensure that it:

- has acceptable technical specifications;
- is regularly inspected;
- is adequately maintained;
- is in accordance with the recommendations of the mooring analysis;
- has an adequate reliability for the intended purpose.

4.1.2 Certification and maintenance

Only those mobile units which have been certified to operate in a specific role (e.g. MODUs) shall be used. All mooring equipment shall therefore conform to the relevant certification authority rules. Such rules detail the specifications required for major equipment items (e.g. winches and anchors) and in some cases they also address requirements for thrusters (including their control systems) and anchor line tension measuring equipment. Where the mooring equipment does not have relevant certification it shall be assessed for compliance with POSMOOR requirements. All mooring equipment shall be subject to a comprehensive inspection and maintenance procedure, see EP 93-055 and ANSI/API RP 2P.

4.1.3 Reliability

The potential reliability of different grades and types of mooring equipment shall also be taken into consideration. Risk analyses shall be undertaken for locations where the consequences of station-keeping failure are considered particularly serious or where the reliability of the subject outfit is in question. Typical mooring line failure rates shall be derived based upon the data given in EP 97-5598. Where the historical reliability of subject mooring equipment will not meet project risk acceptance criteria it shall be replaced with an alternative outfit. Guidance on the relative reliability of different types of outfit is given in EP 97-5598.

4.1.4 Site-specific requirements

It is important to note that site-specific equipment requirements may be developed by the mooring analysis. Where this is the case, details of the necessary outfit shall be included in the mooring analysis report as described in (Appendix 4) and a review shall be undertaken to ensure that the mobile unit's proposed equipment complies with these requirements.

4.1.5 Scope

All elements of a mobile unit's mooring system shall be reviewed in accordance with the requirements of this section in order to ensure that the required performance levels are achieved. The following listing indicates the major items that shall be considered:

Anchor line	Chain Wire
Anchors	Primary Piggy-back (secondary)

Anchor and line accessories	Shackles, swivels and connecting links Wire terminations Anchor buoys and pennants Mid-line buoys and pennants Clump weights Fairleads
Winches	Capacity Brakes Speed Control system
Monitoring equipment	Tension meters Payout meters
Thrusters	Control system Power supply
Installation Equipment	Chain/wire chasing equipment Positioning systems

4.2 DOCUMENTATION

4.2.1 General

A detailed equipment quality management system shall be operated by all mobile units so that the specification, location, certification and service history of any item of mooring equipment can be identified. Relevant documentation for all items shall be held onboard the mobile unit at a central location and shall be available for Principal's inspection at all times.

The system shall include detailed technical specifications and maintenance records for all items of mooring equipment, together with Classification Society certificates and failure investigations where applicable.

The following sections highlight the specific areas where documentary information is required.

4.2.2 Technical specifications

Specifications incorporating the following technical data shall be furnished:

Chain cable	Size and type (e.g. ORQ, K4) Total length and useable length Minimum breaking strength Weight in water
Wire rope	Size and construction Total length and useable length Minimum breaking strength Weight in water Termination construction
Anchors (primary and secondary)	Type and weight Shackle size
Connectors	Type and size
Chasers	Type and size
Anchor Buoys	Type and size Weight Pennant size and length
Mid-line buoys	Type (surface, sub-surface rated depth) Net buoyancy (inc. pennant and connectors) Weight Pennant length and size Connector and swivel details
Line make-up	Element types and lengths Connection details
Fairleads	Size and type Locations of unit (plan and height above keel) Horizontal rotation limits
Winches	Type Static brake power (primary and secondary) Dynamic brake power (primary and secondary) Stall capacity (maximum and per layer for wire units) Stopper type Control system (incl. local and remote)

Tension meters	Type Position Calibration accuracy
Payout meters	Type Position Calibration accuracy
Rig position monitoring	Type (primary and secondary) Reference points Accuracy
Thrusters	Type and number (inc. propeller size) Arrangement Thrust per thruster (maximum continuous rating) Control system Power supply arrangement

4.2.3 Equipment location

Sufficient information shall be provided to identify the exact location of each item of mooring equipment. In the case of anchor line make-up, this should be in the form of a drawing with a detailed equipment schedule.

4.2.4 Equipment inspection and maintenance records

Detailed inspection and maintenance records from new shall be provided for all mooring equipment. These shall include calibration and test records for monitoring equipment.

4.2.5 Certification

Official certification (e.g. Classification Society certification) shall be provided for all applicable elements of the mooring system. These should include details of official markings to allow reconciliation of documentation with actual equipment.

Specific items for which certification is required include:

anchor line;
anchors;
fairleads;
shackles and connectors;
thrusters and control systems;
winches.

In certain circumstances additional information may be required in order to confirm the integrity and reliability of critical mooring system components. Further information on these requirements is given in (4.3 and EP 97 5598).

4.2.6 Failure records

A detailed record of all failures suffered by mooring equipment shall be maintained. This shall detail the equipment involved, the circumstances of the failure (including any consequent effects), remedial action taken, subsequent investigations to determine the cause of failure and action undertaken to reduce the possibility of a similar failure re-occurring.

In determining the cause, effect and future risk which might be associated with a given failure the Contractor should access the most comprehensive current information on relevant failure modes as given in (EP 97-5598).

4.2.7 Equipment quality management system

A copy of the mobile unit's quality management and planned maintenance system for all items of mooring equipment shall be provided for the Principal's review. The aim of this document shall be to:

- achieve improved reliability of, and confidence in, mooring systems;
- provide a practical tool which can be used to maintain mooring equipment information;
- provide a system which is robust and impervious to personnel changes;
- provide an efficient system for storage and recall of relevant data.

4.3 MOORING LINE COMPONENTS

4.3.1 General

Mooring equipment shall as a minimum be in accordance with the POSMOOR requirements. This section provides additional requirements for individual items. It is important to ensure that the specifications of all elements of the mooring system are in accordance with those assumed or required by the mooring analysis.

4.3.2 Anchors

Primary anchors shall be of a type and size identified by the mooring analysis. This is of particular importance in cases where site-specific conditions require the mobile unit's standard anchors to be upgraded.

Where the mooring analysis or previous knowledge of the site indicates that anchor holding problems may be relieved by the use of piggy-back anchors, sufficient anchors and pennants of a suitable design shall be available.

4.3.3 Anchor lines

All anchor lines shall be made up according to the requirements of the mooring analysis. Site conditions may require modifications to be made to the unit's existing lines, for example the inclusion of mid-line buoys to meet pipeline crossing clearance requirements.

4.3.4 Chain cables

Chain cable failure modes shall be reviewed as described in EP 97-5598). Particular attention should be paid to the elimination of brittle fracture and for this reason all chain cables should have been manufactured in accordance with IACS Code W22 1993.

Manufacturers of new chain cable should be selected upon the basis of their proven record for the manufacture of high quality-products. This should be established with reference to historical records detailing the rate of proof load and break test failures previously associated with outfit of the same or similar specification.

The reliability and acceptability of outfit which is either more than 10 years old or which has not been manufactured in accordance with the IACS requirements shall be reviewed in accordance with the requirements of (4.1.3).

Outfit which does not meet the required standards of strength and reliability shall be replaced.

4.3.5 Studless chain

Studless chain cable may be used to eliminate some of the risk associated with accelerated fatigue failures in high strength grade 4 outfit. The long-term fatigue performance of studless chain cable has not yet been determined. For long-term moorings fatigue calculations shall therefore be performed in accordance with the recommendations given in EP 97-5598.

4.3.6 Wire ropes

Potential wire rope failure modes should be reviewed as described in EP 97-5598. Sufficient allowance should be made for the effects of in-service degradation due to corrosion, mechanical damage, fatigue etc. The minimum breaking strength should be determined taking into account the current condition of the rope. Any down-rating required shall be applied in accordance with methods described in the "The Inspections and Discard of Wire Mooring Lines" as described in EP 93-0055.

The reliability of outfit which is more than 8 years old shall be reviewed in accordance with the requirements of (4.1.3).

Outfit which does not meet the required standards of strength and reliability shall be replaced.

4.3.7 Connecting elements

Connecting elements (e.g. kenters, shackles, spelter sockets) may be used in line make-up but should not exceed a total of 10 connectors per line and an average of 1 connector per 100 m line length. The use of a large number of connectors in one part of the line should be avoided. All connectors including all wire rope end terminations, spelter sockets etc. shall be proof-tested, fully certified and installed correctly in accordance with the Manufacturer's recommendations.

Connecting elements shall be subject to all those recommendations given for chain cable in this DEP (4.3.4). Particular attention shall also be paid to the elimination of fatigue failures in connecting elements which shall be subject to regular magnetic particle inspection. The frequency of inspection shall be determined by discussion with the relevant classification society. Connectors manufactured from high strength steel such as grade 4, K4 etc. shall be inspected more frequently than other outfit.

Connectors of new or unconventional design shall not be used unless they are supported by a relevant package of certification and structural justification including the results of long-term fatigue testing. Further information on connecting elements is given in EP 97-5598.

4.3.8 Buoys

Surface or sub-surface buoys may be used to meet any mid-line buoyancy requirements. The gross buoyancy of the buoy at its working draught shall equal the net buoyancy required by the mooring analysis, plus the buoy self-weight and the weight of pennants, connectors etc. Buoys should incorporate measures, such as foam construction, compartmentalisation etc., which will ensure that they will not sink as a result of minor damage. Care shall be taken to ensure that all buoys are securely attached to the mooring line in a manner which will not result in local degradation of either the mooring line or the connections.

Surface buoys should be sized to ensure that no more than 40% of the total buoy volume is submerged at the normal operating draft. Surface buoys shall be plastic/foam filled (or equivalent) to minimise the risk of damage to small boats in the event of collision.

Sub-surface buoys shall be rated for use at the required depth of operation identified in the mooring analysis and shall be submerged to a depth which will ensure that they do not represent a hazard to surface shipping.

4.3.9 Pennant lines

Pennant line length shall be as defined by the mooring analysis. Pennant line specification(s) shall take account of both the operating loads experienced in the in-place condition and the temporary phase loads experienced during deployment and recovery. Pennant lines should not include line components with low abrasive resistance such as synthetic fibre ropes.

4.3.10 Clump weights

Clump weights shall be of a weight and type defined by the mooring analysis.

4.3.11 Synthetic fibre ropes

Synthetic fibre ropes may be used for applications where adequate integrity and reliability can be demonstrated by competent persons following a thorough review of applicable failure modes. They shall not be used where they can be subjected to mechanical damage or other forms of rapid degradation. Particular care shall be applied to the design and maintenance of end terminations and fittings.

The scope of design verification, testing and certification required shall be determined by competent persons on a case-by-case basis. The service reliability of prototype designs shall be assessed on a conservative basis. Full-scale tests may be required prior to operational deployment.

Fibre rope moorings shall be designed according to allowable stress methods using the factors of safety given in (3.8.5). The characteristic break load used should be determined from representative break tests for the fibre rope mooring element including the end terminations and any splices. The fatigue failure mode should be investigated for long-term moorings using conventional methods combined with rope/termination-specific fatigue data. Further information on the design of fibre rope moorings is given in EP 97-5598.

4.4 WINCHES

4.4.1 General

The principal objective of all mooring line handling equipment shall be to ensure that mooring systems are deployed correctly and safely with the minimum of handling damage. Basic winch specification in terms of pulling power and braking shall be as a minimum in accordance with the POSMOOR requirements. The actual arrangement of the winch is of particular importance with regard to how it can be used for active winching operations to either reduce line tensions or to maintain the mobile unit on station whilst operating.

All anchor winches shall be capable of slackening leeward lines as the line loads in such a situation should be less than the winch stall capacity and the dynamic braking capacity. Windward line load sharing procedures, however, are highly dependent on the winch capabilities. Specifications shall therefore be reviewed to ensure there is no conflict between the requirements of the proposed operating procedures and the mooring analysis.

4.4.2 Stall capacity

Winches shall have a stall capacity capable of supplying the maximum preload tension required in the mooring analysis. Preload capacity may be provided by multiple winches if this is reflected in the preloading procedures.

Stall capacity is a key element in assessing the feasibility of windward line load sharing procedures. Even if it is described in the operating procedures, winching-in can obviously not occur if line tensions are in excess of the winch stall capacity. Where a chain stopper device is fitted, it may be necessary to undertake a small amount of winching-in to release the line before commencing payout. In such a case, stalling capacity will also limit operations.

4.4.3 Brakes

The capacity of the winch braking systems has a direct influence on how the equipment can be used to carry out line tension optimisation. The capacities of the braking systems shall not be in conflict with any proposed line tension optimisation procedure.

4.4.4 Control system

If operational or survival procedures require active winching to be undertaken, the winches shall be operable both locally and from a central control room.

4.5 MONITORING EQUIPMENT

4.5.1 Tension measurement

Mobile units shall be equipped with an accurate, calibrated system for measuring mooring line tensions. This is important for running out mooring line effectively, testing holding capacity (i.e. preloading) and maintaining minimum tensions when mooring over subsea obstructions. Such a capability is essential for line deployment, anchor installation, test pulling and operations.

Line tension shall be continuously displayed at each winch and shall also be relayed to a second display in a manned control room. A system, preferably automatic, shall be provided for recording all line tensions. This should record at intervals of at least once every 30 minutes during storm conditions.

Systems capable of measuring varying tensions due to vessel motion are preferred and shall be used when operating limits are expressed in terms of maximum line tensions. Systems which measure mean tension levels are acceptable for use during anchor laying procedures and for monitoring line tensions to ensure minimum specified clearances.

4.5.2 Pay-out measurement

Mobile units shall be equipped with an accurate system for measuring mooring line payout. As a minimum, payout shall be continuously displayed at each winch but preferably relayed to a central control room. Where active winching is to be undertaken a log shall be kept recording current payout of all lines.

4.5.3 Position monitoring

All mobile units shall be equipped with a system for accurately monitoring the position of the vessel at all critical times, e.g. MODU with marine riser connected. If a semi-rigid link to a fixed object is available, e.g. link bridge from MAU to platform, this may be used to monitor mobile unit position.

For MODU applications, simple visual measurement of the riser angle is not sufficient and a second system shall be available to provide mobile unit bearing and distance off, in relation to the wellhead or point of riser attachment. This information is critical if winching procedures to maintain station are proposed.

4.6 MISCELLANEOUS ITEMS

4.6.1 Thrusters

If thrusters are included as part of the mooring system, their power and control systems shall be compatible with the procedures detailed for their use in the operations manual. Particular regard should be paid to the details of the control system and the provision of power to the thrusters, such as automatic control and power supply back-up.

4.6.2 Mooring line release

All mooring lines shall be equipped with a system which allows release of the entire line in the event of an emergency. A centrally controlled system is to be preferred but protected, local release arrangements may also be accepted. Evidence that the system is fully functional and is tested on a regular basis shall be available.

4.6.3 Compatibility

All items of mooring equipment shall be compatible with one another. For example, the capacity of installed anchors should be commensurate with the holding power that can be absorbed by the chain. Miscellaneous items such as connectors and chain chasers shall be sized such that they do not damage the overall system or reduce its capability. These aspects shall be given particular consideration when one element of the system has been modified following the mobile unit's entry into service.

4.7 INSPECTION AND MAINTENANCE

4.7.1 Policy

Shell Group policy with regard to mooring systems requires that all mooring equipment is well maintained, is in full working order and is capable of providing the performance levels demanded by the mooring analysis and the operational procedures. All mobile units shall demonstrate that these objectives are achieved. This policy precludes the use of mobile units with defective elements in their mooring systems.

4.7.2 Procedures

All anchor chain, chain accessories, anchor wire and terminations shall be subject to an approved quality management system which incorporates a planned programme of inspection, maintenance and/or replacement. This programme shall be agreed with the vessel's Certifying Authority and shall be performed to recognised industry standards.

The programme shall detail the inspection schedule and methods to be applied to all mooring items. The following list indicates the inspection requirements for specific system elements:

Chain: The maximum interval between 100% inspections shall be 5 years for chain under 10 years old and 3 years for chains over 10 years old. The highly loaded areas of the chain, e.g. at fairlead location, and connecting links shall be inspected more frequently.

Where possible chain shall be inspected onshore but on-board inspection methods in sheltered waters may be considered.

Major chain inspections shall be 100% visual with special attention being paid to areas which exhibit damage or wear. NDT shall be applied to lengths of 5 links every 30 m. Critical areas of wear on items such as anchor shackles, swivels and open links shall also be inspected using a suitable NDT technique. Connecting links shall be opened, removed and NDT performed.

Wire: The maximum interval between 100% inspections shall be 1 year. More frequent inspection may, however, be required for specific applications if recommended by the Principal.

Inspection speeds in the order of 30 m/minute are acceptable provided detailed examination of selected areas is undertaken. Such examination should be scheduled every 150 m and for sections of wire known to suffer high levels of degradation as listed below:

a) outer layer on winch;
b) wire adjacent to winch;
c) wire in splash zone;
d) wire immediately outboard of fairlead;
e) mid-catenary section;
f) wire at touch-down point;
g) grounded line adjacent to touch-down point;
h) wire at end termination;
i) any section where previous damage has been noted.

Wire shall not be cleaned for inspection with the aid of a high-pressure water hose as this has a detrimental effect on wire lubrication.

Where there are indications of local degradation at terminations, the wire should be cut and stripped to allow internal examination. The Contractor's maintenance procedure shall provide for the regular replacement of wire terminations, i.e. not solely as a result of local degradation. Termination replacement shall only be carried out when the operation may be performed satisfactorily and shall be adequately inspected and proof-tested.

NDT of the wire is considered advantageous when used in conjunction with a visual inspection. It can be used to pinpoint sections with internal faults or area loss and these can then be examined in detail. Where NDT is used it is recommended that the same system is used for all inspections and that a test sample of the unused line is available for calibration purposes.

Wire mooring line is prone to wear, particularly in the thrash zone. If wire is used in an area with a rocky seabed, the touch-down point shall be subject to a monthly inspection. If wear is detected, the integrity of the mooring system shall be assessed and action taken accordingly. If such inspections cannot be undertaken, composite mooring lines, employing a chain section in the thrash zone, shall be employed. Care should be taken to ensure that chain / wire connections are located either in the catenary or in the inactive section of the line.

Winches: Winch reliability is a major factor in the assessment of a mobile unit's active winching capability. All elements of the equipment shall be regularly inspected and maintained.

Chain gypsies shall be regularly inspected to ensure that pocket wear remains within allowable limits. Pockets shall be repaired using an approved procedure if allowable wear limits are exceeded.

Mechanical elements such as prime movers, brakes, controls, etc., shall be maintained in accordance with the Manufacturer's recommendations.

Fairleads: Chain pockets shall be inspected for wear as above whenever convenient (e.g. unit repair or survey). Wire fairleads shall be measured at equivalent intervals and replaced if either under-or over-sized.

Monitoring: Monitoring equipment such as tension meters, pay-out meters, and unit location monitors shall be accurately calibrated at the commencement of a charter. They shall also be re-calibrated at regular intervals through the operations period. Such re-calibration shall also occur following extreme events, on noting erratic behaviour of a particular instrument and following the movement of, or damage to, any instrument.

4.7.3 Personnel

All personnel involved in the inspection of equipment shall be fully qualified and experienced to undertake the work. Normally, classification society approved inspectors, working to approved procedures, shall be acceptable but if specific highly skilled operations are required, e.g. for NDT of wire, they shall be undertaken by personnel with specialist training.

5. OPERATIONAL CONSIDERATIONS

5.1 GENERAL

The aim of this section is ensure that mooring analyses are developed in parallel with a thorough review of operational practices and that a clear link exists between the two.

Any mooring analysis shall attempt to model normal offshore practices in terms of both equipment and procedures. Where site-specific difficulties mean that standard mooring techniques are not applicable, the mooring analysis shall be used as a tool to assist in the development of appropriate modifications to the mooring system's equipment and operation.

The assumptions made in the analysis phase and the resultant conclusions shall therefore be reflected by the manner in which the actual mooring system is set up and maintained. In order to achieve this aim, any conclusions or limitations derived from the mooring analysis shall be described in terms of procedures which can be successfully followed offshore.

5.2 DOCUMENTATION

In order to undertake an assessment of a mobile unit's operating and heavy weather procedures with reference to moorings, the following documentation shall be considered:

- mooring analysis report;
- relevant marine operations manual (s);
- Contractor's general and site specific mooring procedures.

5.3 INSTALLATION

5.3.1 Anchor

Required anchor adjustment for the location, e.g. fluke angles, shall be fully defined in the mobile unit's operating procedures. Such adjustment shall be set in accordance with the anchor Manufacturer’s recommendations for the expected soil conditions.

5.3.2 Anchor handling vessels

The selection of anchor handling vessels should be controlled by the Contractor to ensure that their specification meets the anticipated operational requirements. As a minimum anchor handling vessels should be equipped with stern roller(s), shark jaw(s) or equivalent remote-controlled pendant-holding device(s) and have sufficient bollard and winch pull for the intended operation. The Principal may require independent surveys to establish the suitability of anchor handling vessels prior to the commencement of operations.

5.3.3 Anchor handling

If special anchor handling methods are required, these shall be fully detailed in the operating procedures. Particular regard should be paid to the installation of Ultra High Holding type anchors which shall be installed in a specific orientation. In such situations evidence shall be provided to demonstrate that the anchor handling crew is familiar with the necessary techniques.

If it is proposed that piggy-back anchors will be deployed to provide additional holding power in poor soil conditions, detailed procedures for their installation (including sketches of anchor connection method) shall be included in the operating manual or in the location-specific mooring procedures.

Other features which give rise to specific anchor handling requirements are listed below:

Deep water:	Powerful Anchor Handling Tug(s) (AHT) with suitable deck equipment may be required to control a large weight of mooring equipment. Winches or windlasses should be equipped with dynamic brakes for operations in water depths beyond 300 m. Band brakes are not acceptable for deep water operations.
Shallow water:	Powerful AHT(s) may be required during anchor deployment due to friction of the anchor line on the seabed.
Pipelines:	If anchor lines are to be laid across pipelines or subsea obstructions, installation procedures shall be submitted which meet the pipeline clearance requirements given in (3.8.7).
Complex systems:	If the mooring analysis identifies requirements for equipment such as mid-line buoys, clump weights, etc., detailed procedures for their installation shall be given. These shall identify whether pre-laying of mooring system components is required. Procedures for ensuring that connections made on site are fully secured shall be included.
Wire Anchor Line:	Chasing of wire anchor line shall not be acceptable as a primary installation method and shall be used only when other methods are not feasible. Sliding of the wire along the seabed should also be avoided.
Chain anchor line:	Anchor lines should be deployed as straight as possible with even speed and tension to minimize line wear and the possibility of bights forming on the sea bed.

5.3.4 Anchor positioning

At remote locations anchors shall be laid within a line heading accuracy of +/- 3 degrees according to the analysed mooring arrangement. It is expected that mobile unit positioning by satellite navigation array together with radar fixing of the anchor drop location will give an acceptable level of accuracy. This expectation shall not remove the requirement for back-up systems in accordance with normal practice.

Sufficient anchor line shall be deployed to ensure that when anchor pre-loading is complete the fairlead to anchor horizontal distances are in excess of the minimum values required by the mooring analysis and the mobile unit's operations manual. Anchors shall be deployed at a position which takes account of the expected embedment depth for the anchor type and reported soil conditions. Anchors shall not be deployed in exclusion zones even if they lie outside the zone following embedment and proof-loading.

Where anchor positioning is critical, such as adjacent to subsea equipment, a more accurate anchor drop point fixing system shall be used, such as an AHT-mounted real time navigation package. The positioning tolerances given in (3.5.3) apply to final anchor position, thus anchor deployment point should allow for AHT drift etc., which is likely to be of significance in deep water. Accurate anchor positioning also applies to cases where laid anchor line lengths are critical to avoid anchor uplift forces at maximum expected tensions.

The as-laid positions of all anchors shall be determined using an approved procedure to allow comparison with the analysed anchoring pattern. The Contractor shall inspect the results to determine if any anchors need to be re-laid. If necessary, the analyses shall be revised to reflect the actual anchor positions.

5.3.5 Anchor line pre-loading

Anchor lines shall be pre-loaded to test anchor holding capacity and ensure adequate anchor embedment. Anchor lines shall always be pre-loaded as close as possible to the maximum mean load predicted by the mooring analysis in the survival condition, but pre-loading using conventional mooring winches shall in no case exceed 40% of the mooring line break load. Pre-load shall be held for at least 15 minutes during which time there shall be no evidence of anchor drag.

The achieved pre-load value shall be recorded and noted as the maximum value of mean line tension above which anchor integrity has been positively confirmed. No operation which could have serious consequences in the event of anchor drag should be allowed to proceed when mean tensions above this value are recorded.

At critical locations such as a MAU alongside fixed structure or at locations with poor holding conditions, procedures for pre-loading in excess of the above requirements may be required. These should be developed in a manner and to an extent which reflects the consequences of a loss of station-keeping due to anchor drag. Specialist equipment may be required in order to achieve the required pre-loading levels.

5.3.6 Anchor line clearances

Methods used to deploy anchor lines over subsea equipment shall ensure that the minimum required clearance is maintained throughout the installation by use of minimum line tensions or tandem AHTs. Once installation is complete, the vertical clearance shall be verified by reviewing line catenaries with reference to anchor and mobile unit positions.

5.4 OPERATING STRATEGY

5.4.1 Operating limits

If the mooring analysis has determined the mooring system's operational limits in the form of environmental conditions, the mobile unit's site-specific operating procedures shall refer to these limits. This information shall be used to provide assistance when a decision is made to cease operating and move to a survival condition and position.

The limits are not necessarily based on intact condition criteria and may be defined by the mobile unit's behaviour following single line failure. The operating procedures must also recognise the operational significance of extreme heave motions.

5.4.2 Operating procedures

The adoption of a suitable winching procedure can result in a significant improvement to a mobile unit's operating limits when compared with a passive approach. As these limits are generally defined by excursion criteria, any process which assists in minimising vessel offset is likely to be beneficial.

If the mooring systems or procedures do not allow any active winching to be undertaken, the operating limits are defined as a "passive" system.

5.4.3 Operating condition procedures

If the operational limits defined by an active winching simulation are to be applied, it is important to ensure that there is no conflict between the simulation method used and the actual procedures adopted. Thus the mobile unit's operating procedures shall fully define how the mooring system shall be controlled. The procedure shall detail:

a) maximum mean offset allowed before unit is winched back onto station;
b) procedure for selection of lines to be winched-in or paid-out;
c) maximum allowable mean tensions;
d) minimum allowable line tensions (e.g. for pipeline clearance).

Procedures for moving the mobile unit off station in an emergency shall be detailed.

The operating procedures shall also specify the monitoring and recording of the following operational parameters:

a) mean and maximum line tensions;
b) line pay-out lengths;
c) mobile unit position and heading;
d) mean double amplitude heave.

Mooring line damage is often associated with the additional stress induced in the line at the fairlead. The operating procedures should include provision for periodical slipping of lines to avoid continual loading of one section of the mooring line. However, any adjustment procedures should take account of the potential for increased damage associated with line adjustment at elevated tensions.

5.5 HEAVY WEATHER STRATEGY

5.5.1 Survival condition definition

Mooring analyses normally assume that a mobile unit is in survival mode when it is no longer subject to strict operational excursion limitations caused by the presence of other installations or dependent systems, such as marine risers etc. The following are examples of mobile units in survival conditions:

MODU (remote location):	marine riser disconnected;
MAU (close to installation):	gangway disconnected, unit in stand-off position.

5.5.2 Survival policy

The primary aim of a survival policy is to reduce the risk of total system failure by minimising the anchor line tensions. This can be achieved to varying extents by the adoption of different winching procedures.

Immediately on attaining the survival position, it is common practice to slacken all leeward lines to reduce the tensions in the overall system. Depending on the installed equipment, further reductions in line tension may be achieved by optimising the load shared between adjacent windward lines. If the vessel is fitted with thrusters these may be used to partially offset the environmental loadings.

5.5.3 Survival condition procedures

The procedures leading up to the attainment of the survival condition are just as critical as those required once the survival condition is achieved. A detailed procedure shall therefore be provided giving an integrated policy for the staged cessation of operating activities.

In some areas of operation it is standard practice to de-man mobile units prior to the onset of severe events such as hurricanes and tropical storms. Such a procedure can be acceptable if the abandoned mobile unit does not present an unacceptable hazard to other installations and equipment if it suffers a mooring system failure.

If it is the intention to abandon the mobile unit, the procedures shall include details of all facilities such as the helicopters and crew boats required to complete the evacuation within the available forecast period. Additionally it shall be demonstrated that all activities required to secure the unit such as re-ballasting, mooring line adjustment, etc., can be completed prior to abandonment. If it is proposed to move the unit off-station prior to onset of extreme conditions, detailed procedures for the operation shall also be submitted.

Where applicable, the procedures shall identify the pull-back distance which must be attained on cessation of operating activities, in order to achieve the required mobile unit / installation clearances.

The survival condition procedures shall fully define how the mooring system will be controlled to minimise anchor line tensions. If windward line load sharing is proposed, the procedure shall detail how optimisation will be undertaken as the weather deteriorates. The procedures shall indicate at what tensions optimisation by either winching-in or paying-out is no longer feasible. These variables will be dependent upon the mooring equipment specification.

The procedures shall include requirements identified in the mooring analysis for maintaining minimum line tensions over subsea obstructions.

6. REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Facilities optimization study	EP 93-0055
An overview of mooring line failure modes	EP 97-5598

AMERICAN STANDARDS

Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures	API RP 2SK, June 1, 1995
Recommended Practice for Design, Selection, Operation and Maintenance of Marine Drilling Riser Systems	API RP 16Q November 1, 1993
Analysis of Spread Mooring systems for Floating Drilling Units	ANSI/API RP 2P May 1, 1987

Issued by:
American Petroluem Institute
Publications and Distribution Section
1220 L Street Northwest
Washington DC. 20005
USA

NORWEGIAN STANDARDS

DnV Rules for the Classification of Mobile Offshore Units	Part 6 Chapter 2, January 1996

Issued by:
Det Norske Veritas Industri Norge AS
PO Box 300
N-1322 Høvik
Norway

Unified IACS Requirements for the Certification of Offshore Mooring Chain	IACS Code W22 1993

Issued by:
International Association of Classification Societies
Permanent Secretariat
5, Old Queen Street
London SW1H 9JA
UK

FIGURE 1 MOORING ANALYSIS PROCEDURE

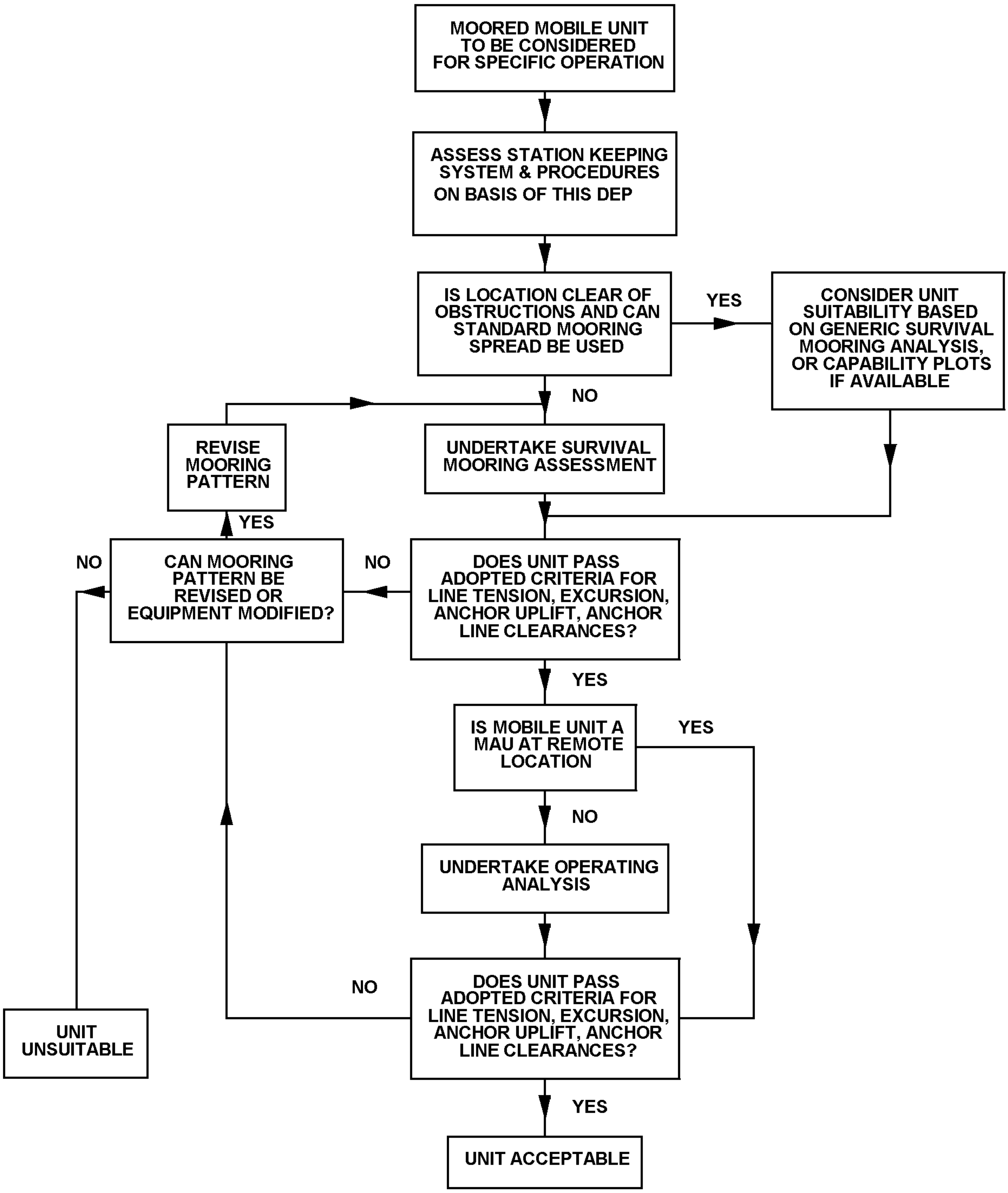


FIGURE 2 SELECTION OF MOORING ANALYSIS TECHNIQUE

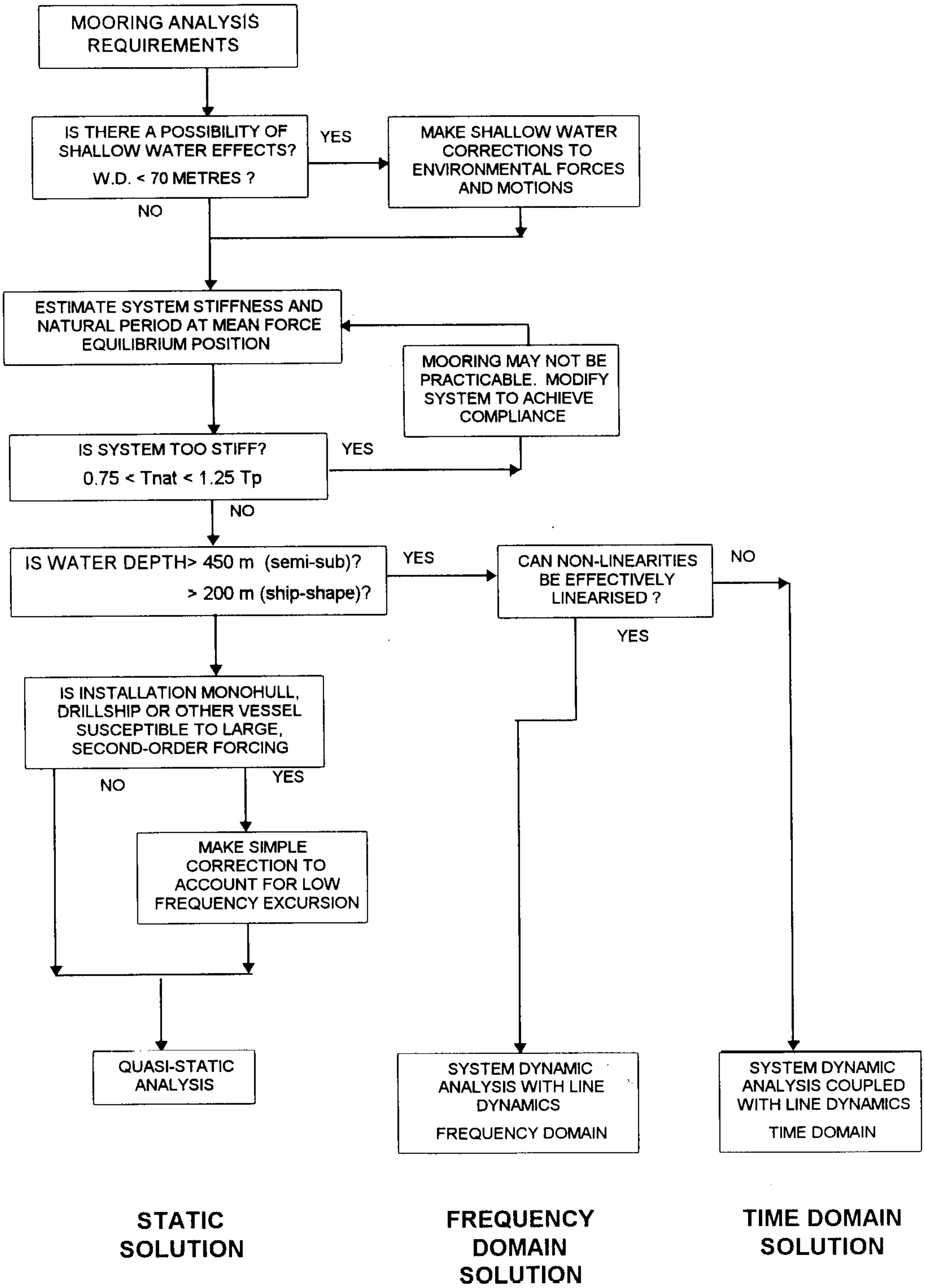


FIGURE 3 ANCHOR EXCLUSION ZONES

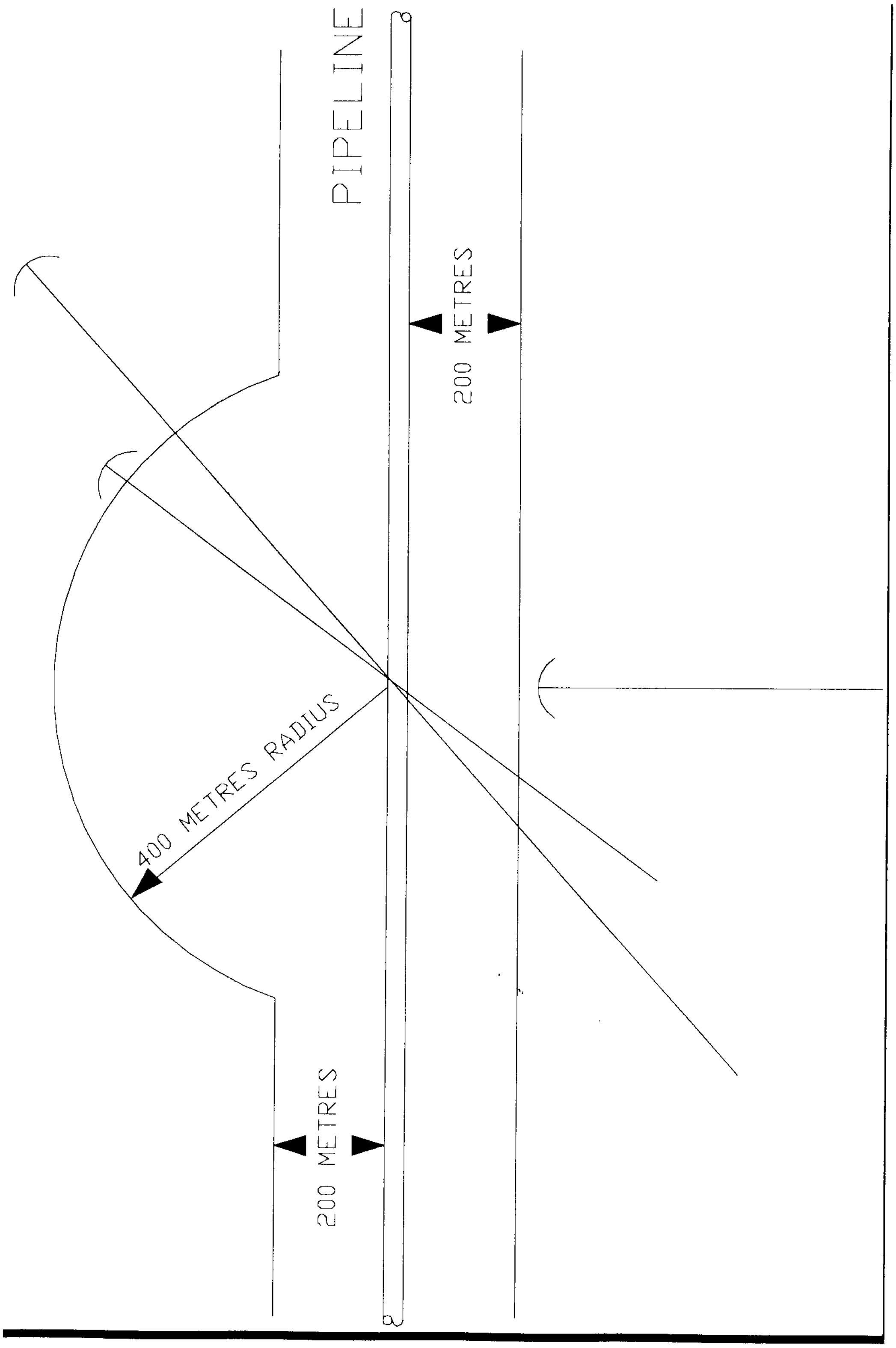
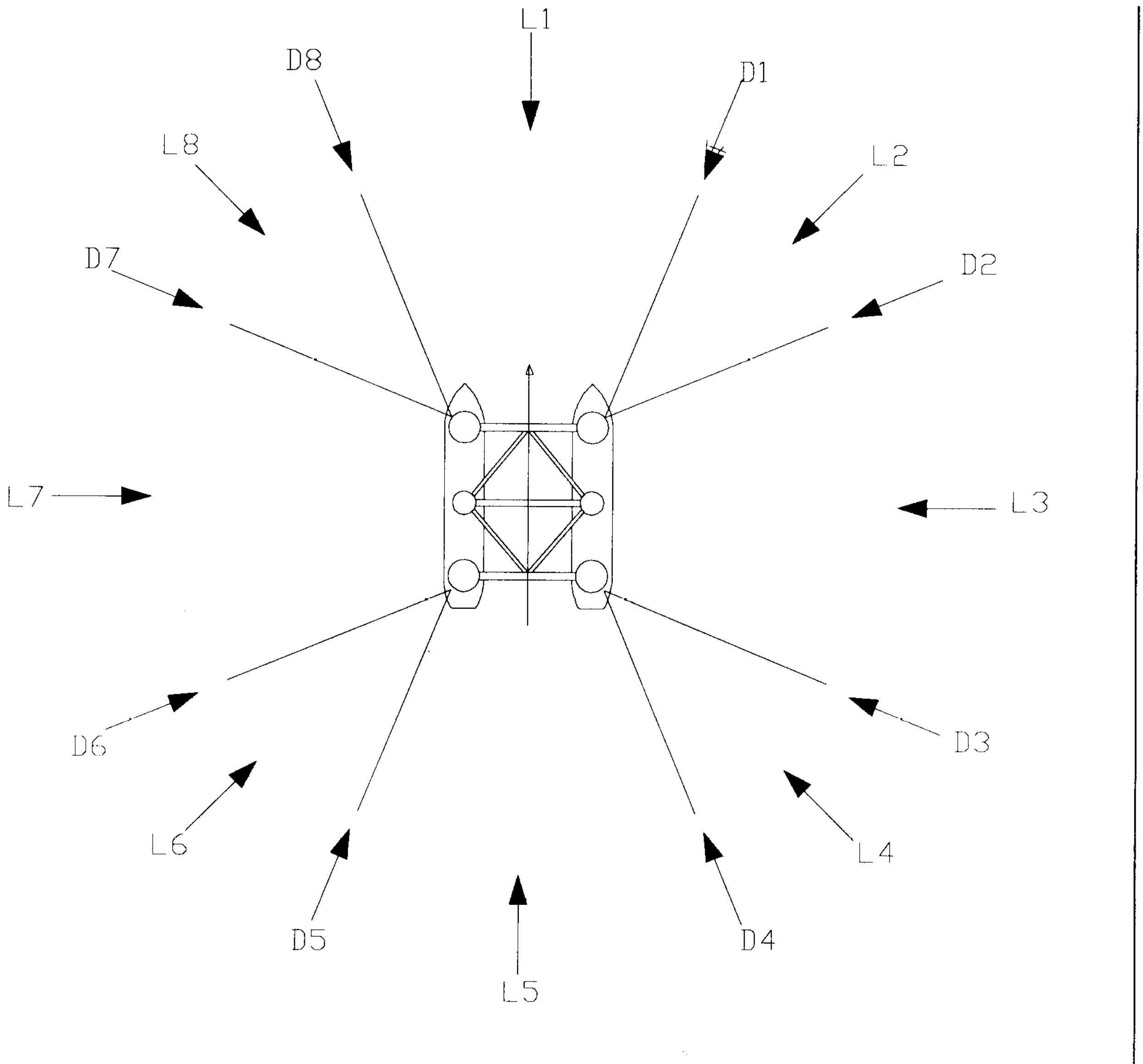


FIGURE 4 LOAD CASES



Load cases L1 to L8 correspond to 'standard' cases (i.e. head, quartering, beam)
Load cases D1 to D8 correspond to 'down the line' cases.

FIGURE 5 SELECTION OF LOADS AND MOTIONS

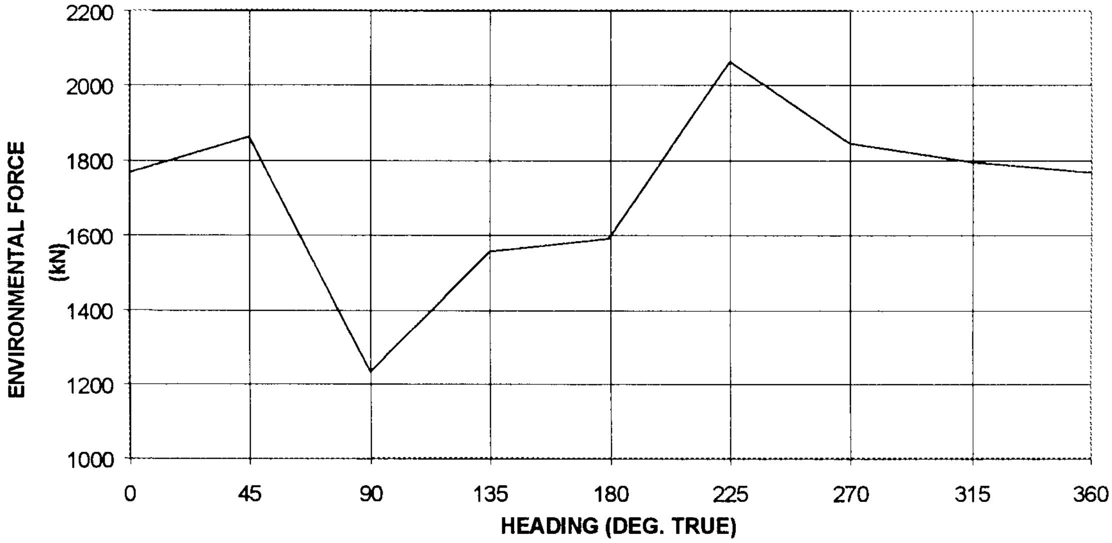
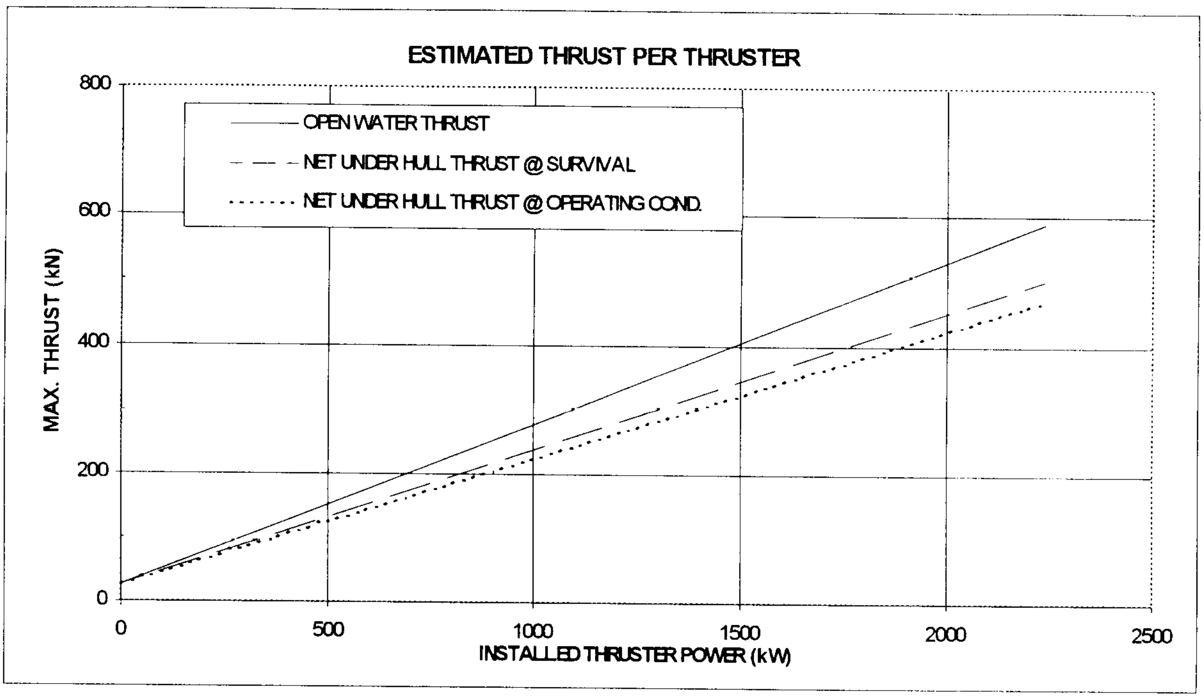


FIGURE 6 THRUSTER THRUST



APPENDIX 1 COMPARISON OF THIS DEP WITH THE POSMOOR CODE

This Appendix provides guidance on the status of all sections of the POSMOOR code with reference to how this DEP has either SUBSTITUTED different requirements, CLARIFIED the POSMOOR text, provided an ADDITION to the POSMOOR text or has resulted in NO CHANGE to the POSMOOR text.

POSMOOR			SHELL REQUIREMENTS		
Section	Sub-Section	Paragraph	Status	DEP Ref.	Comments
1	A.100	101	Substituted	1.1	DEP not applicable to single point moorings
		102	No Change	-	Class Requirements
		103	No Change	-	Class Requirements
	A.200	All	No Change	-	Class Requirements
	A.300	301-303	No Change	-	Class Requirements
	A.300	304	Addition	3.8.2	Additional clearance definitions
	A.300	305	No Change	-	Class Requirements
	A400	All	No Change	-	Class Requirements
	A500	All	No Change	-	Class Requirements
	B		Addition	4.2	
	B.100	101-106	No Change	-	Class Requirements
	B.100	107	Addition	3.8.5, 4.3.11	
	B.200	All	No Change	-	Class Requirements
	B.300	All	No Change	-	Class Requirements
	B.400	All	No Change	-	Class Requirements
	C.100	All	No Change	-	Class Requirements
2	A.100	101	No Change	-	Class Requirements
		102	Substituted	3.4.2 3.4.3	
		103	No Change	-	Class Requirements
	B.100	101	Substituted	3.6	POSMOOR for guidance approved loading coefficients preferred.
		102	Substituted	3.6	POSMOOR for guidance approved loading coefficients preferred.
	B.200	All	Substituted	3.6	POSMOOR for guidance approved loading coefficients preferred.
	B.300	All	Substituted	3.6	POSMOOR for guidance approved loading coefficients preferred.
	B.400	All	No Change	3.6	
3	A.101	101	Substituted	3.1 3.3	
		102	Substituted	3.4.2	50 year return extreme environment.
		103	Substituted	3.4.2	50 year return extreme environment.
		104	Addition	3.6.6	Additional guidance on shallow water effects.
		105	No Change	-	
		106	Substituted	3.4.4	Current depth averaged at centre of pressure.
		107	Substituted	3.4.4	
		108	No Change	-	
		109	Substituted	3.7.4	Different factors applied for chain cable and wire rope.
		110	No Change	-	
		111	Substituted	3.3.2 - 3.3.4	Selection of analysis depends on various parameters.
		112	Substituted	5.3.3	+/- 3 degs. anchor line deviation.
	A.200	201	Addition	3.6.3 d)	Down line load cases to be considered.
		202	Substituted	3.4.4	Load combination according to 50 year return period.
		203	Addition and Substituted	3.6.3, 3.6.4	Load combination according to 50 year return period.
		204 - 206	No Change	3.6.3	
	A.300	301	No Change	3.3.4	
		302	Substituted	3.3.4	Dynamic analysis may often be carried out in frequency domain.
		303	No Change	3.3.4	

POSMOOR			SHELL REQUIREMENTS		
Section	Sub-Section	Paragraph	Status	DEP Ref.	Comments
3	A.400	401	No Change	3.3.5 3.6.2	
		402	No Change	3.3.5 3.6.2	
		403	Addition	3.3.5	Transient line tensions may be determined quasi-statically.
	A.500	501-502	Addition	3.6.3 d)	Down line load cases.
	A.600	601	Substituted	3.3.7	Fatigue analysis to API RP 2SK with modifications to fatigue life factors and allowable S-N curve.
		602-604	Substituted	4.5	Guidance given in Appendix to have priority.
	B.100	101	Clarification	5.4.1	
		102	Clarification	5.4.2	
		103-106	Clarification	5.4	
	B.200	All	Clarification	5.4	
	B.300	All	No Change	-	
	C.100	All	No Change	3.8	
	C.200	201	Clarification	3.8	
		202	Addition	3.8.5 4.3	Additional requirements and clarifications.
	C.300	301	No Change	-	
		302	Substituted	3.8.7	Use of maximum allowable flex-joint angle and reference to API RP 2SK for allowable offsets.
		303	No Change	-	
		304	Addition	3.8.7	In benign areas, bridge clearance requirements may be reduced.
	C.400	401	Substituted	3.8.5	Change in max. line tension condition required for anchor holding capacity.
		402	No Change	-	Max. Line length for line stiffness model and anchor holding.
	C.500	All	Substituted	3.8.6	Guidance given in the DEP shall have priority.
4	A.100	101	No Change	-	
		102	Clarification	3.6.5	Directional thrust factors included. Torque induced in system by thrusters may be ignored in mooring analysis.
		103	No Change	-	
		104	No Change	-	
		105	No Change	-	
	A.200	All	No Change	-	Class Requirements
	B.100	All	No Change	-	Class Requirements
	B.200	All	No Change	-	Class Requirements
	B.300	All	No Change	-	Class Requirements
	B.400	All	No Change	-	Class Requirements
	B.500	All	No Change	-	Class Requirements
	B.600	All	No Change	-	Class Requirements
	B.700	All	No Change	-	Class Requirements
	B.800	All	No Change	-	Class Requirements
	B.900	All	No Change	-	Class Requirements
	B.1000	All	No Change	-	Class Requirements
	B.1100	All	No Change	-	Class Requirements
	B.1200	All	No Change	-	Class Requirements
5	A.100	All	Addition	4.3.1 5.3	Inclusion of anchor handling requirements.
	A.200	All	No Change	-	
	A.300	All	No Change	-	Class Requirements
	A.400 A.500	All	Substitute	3.7.4 5.3.5	
	B		Addition	4.7.2	Inspection procedures.
	B.100	All	Addition	4.3	
	C		Addition	4.7.2	Inspection procedures.
	C.100	All	No Change	-	Class Requirements

POSMOOR			SHELL REQUIREMENTS		
Section	Sub-Section	Paragraph	Status	DEP Ref.	Comments
5	D		Addition	4.4 4.7.2	Mooring analysis shall be consistent with winch capacities. Winch inspection requirements.
	D.100	All	No Change	-	Class Requirements
	D.200	All	No Change	-	Class Requirements
	D.300	All	No Change	-	Class Requirements
	D.400	All	No Change	-	Class Requirements
	D.500	All	No Change	-	Class Requirements
	E		Addition	4.5.1	Tensions to be displayed in a manned control room and recorded at least every 30 mins.
	E.100	All	No Change	-	Class Requirements
6	A	All	No Change	-	Class Requirements
	B	All	No Change	-	Class Requirements

APPENDIX 2 VESSEL INFORMATION REQUIRED FOR MOORING ANALYSES

LINE DATA

- number of elements in line;
- useable length;
- minimum quoted breaking strength for each line element;
- axial stiffness; if unknown use values given in POSMOOR, Section 3, A106;
- underwater weight per unit length;
- number of lines available;
- presence of any mid-line buoys, surface/subsurface, net buoyancy etc.

VESSEL DATA

- load coefficients for mean wind, current, wave drift forces and first-order motions;
- second-order transfer functions and response data if required for dynamic analysis;
- fairleads bearing and distance from unit centre of gravity and height above keel;
- survival and operating displacement;
- principal vessel dimensions;
- survival and operating draught;
- number, type and capacity of thrusters;
- winch stall capacity and brake capacities;
- type and size of anchors;
- RAOs for motion assessments.

APPENDIX 3 LOCATION INFORMATION REQUIRED FOR MOORING ANALYSES

GENERAL DATA

- required mobile unit heading;
- proposed anchor pattern showing stand-off and operating positions when applicable;
- detailed field plan showing subsea obstructions, anchor exclusion zones etc.
- water depth and bathymetry;
- shallow geology, side-scan sonar records, soil strength data etc., if available;
- proposed location duration for environmental data considerations.

ENVIRONMENTAL DATA

- 50 year return:	The season during which the unit is to be on location may be considered when developing these data.
- Wind speed:	10 minute mean at 10 metre elevation above sea level.
- Current speed:	Current speed (depth averaged at the centre of pressure of the underwater hull form).
- Waves:	Significant wave height (3 hour storm)
	Peak period (3 hour storm)
	Appropriate wave spectrum for location.

APPENDIX 4 MOORING ANALYSIS REPORT CONTENTS

1. SUMMARY
   - What was considered in the analysis.
   - The final results of the analysis.

2. VESSEL AND LOCATION DATA
   - Particulars of the unit as analysed, including the vessel heading and mooring spread.
   - Position, water depth, shallow geology of the location.
   - Details of existing structures, pipelines, wellheads, other mobile offshore units etc.
   - Source of the information on the location.

3. ASSESSMENT CRITERIA
   - Survival and operating criteria adopted in the analysis.

4. ANALYSIS METHOD
   - Philosophy behind the analysis, i.e. justified selection of analysis method.
   - Overview of how analysis was performed and any inherent limitations of the approach.
   - Brief description of the program used for the analysis.

5. ENVIRONMENTAL CONDITIONS AND LOADS FOR SURVIVAL
   - General introduction to environmental data and load cases.
   - Description of how environmental loads were calculated.
   - Load and motion coefficients used, together with their source.
   - Factors used for spread seas, shallow water etc.
   - Table of load case, heading, total force, vessel offset, intact/damaged thruster force.

6. ENVIRONMENTAL CONDITIONS AND LOADS FOR OPERATIONS

   As for survival.

7. SURVIVAL ANALYSIS RESULTS
   - Table of results giving max. line tensions and min. factors of safety for all cases.
   - Anchor uplift forces and horizontal forces at anchor should be included.
   - Policy assumed for winching.

8. OPERATING ANALYSIS RESULTS
   - Dependent on the approach required for the particular location, the results should either show the mooring performance with reference to a defined operating condition or should detail the environmental conditions at which the operating criteria are met/exceeded. The following criteria should be considered:
     - horizontal excursion;
     - heave;
     - line tensions;
     - chain / chain or pipeline crossing;
     - winching policy.

9. CONCLUSIONS
   - Summary results of analysis.

REFERENCES

APPENDICES

- Full environmental and soils data where applicable.
- Results of environmental force and motions calculations.
- Relevant computer analysis output.

In addition standard data sheets should be used for the transfer of information between Contractor and Principal and for the use of relevant offshore personnel. It is recommended that these sheets should be included in an appendix to the mooring report. Examples of 8 of such sheets are given in the following pages.

<table>
<tr><th colspan="4">MOORING ANALYSIS REPORT</th><th colspan="2">SHEET: 1 OF 8</th></tr>
<tr><td colspan="6">SHELL</td></tr>
<tr><td>REQUESTED BY</td><td colspan="5"></td></tr>
<tr><td>TITLE</td><td colspan="5"></td></tr>
<tr><td rowspan="3">DEPARTMENT</td><td colspan="5"></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>WORK ORDER</td><td colspan="5"></td></tr>
<tr><td colspan="6">ANALYST</td></tr>
<tr><td rowspan="3">COMPANY</td><td colspan="5"></td></tr>
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<tr><td>DATE</td><td colspan="5"></td></tr>
<tr><td>REFERENCE NO.</td><td colspan="5"></td></tr>
<tr><td colspan="6">LOCATION</td></tr>
<tr><td colspan="2" rowspan="3">NAME:</td><td colspan="2">CO-ORDINATES</td><td colspan="2">UTM (m)
Datum:</td></tr>
<tr><td>LAT</td><td>LONG</td><td>NORTHING</td><td>EASTING</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">MOBILE UNIT POSITION</td><td>SURVIVAL</td><td></td><td></td><td></td><td></td></tr>
<tr><td>OPERATING</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">WATER DEPTH (LAT)</td><td></td><td>m</td><td></td><td></td></tr>
</table>

MOORING ANALYSIS REPORT				SHEET: 2 OF 8
MOBILE UNIT PARTICULARS				
NAME				
TYPE				
MODIFICATIONS				
OWNER				
DRAUGHT	OPERATING		m	
	SURVIVAL		m	
	TRANSIT		m	
HEADING			deg true N.	deg plat. N.
THRUSTERS				
TYPE	NUMBER	THRUST PER THRUSTER *		NOTES
		tonnes		
AZIMUTHING				
STEERING NOZZLE				directional limit: 35 deg, P and S
FIXED				
TUNNEL				

[*] thrust at MCR, including reductions for underwater effects.

<table>
<tr><td colspan="4">MOORING ANALYSIS REPORT</td><td>SHEET: 3 OF 8</td></tr>
<tr><td colspan="5">ANCHOR PATTERN</td></tr>
<tr><td rowspan="3">LINE
NUMBER</td><td colspan="2">MOBILE UNIT FAIRLEADS
(SURVIVAL POSITION)</td><td colspan="2">ALTERNATIVE REFERENCE POINT:</td></tr>
<tr><td>BEARING</td><td>HORIZONTAL
DISTANCE TO ANCHOR</td><td>BEARING</td><td>HORIZONTAL
DISTANCE TO ANCHOR</td></tr>
<tr><td>deg true</td><td>m</td><td>deg true</td><td>m</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
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Sketch of anchor pattern and numbering system:

MOORING ANALYSIS REPORT	SHEET: 4 OF 8
MOORING EQUIPMENT	
LINE NO.	LINE COMPONENTS

Components: chain, wire, primary anchors, surface buoys, sub-surface buoys, clump weights, pennants, piggy back anchors.

Conventions: components listed starting at primary anchor, clump weights - net weight (tonnes) submerged in sea water (sg:1.025), surface buoys - net buoyancy (tonnes) at operating draft in sea water, sub-surface buoys - net buoyancy (tonnes) submerged in sea water, also maximum safe working depth, line lengths in m.

MOORING ANALYSIS REPORT					**SHEET: 5 OF 8**	
SURVIVAL ANALYSIS						
POLICY ASSUMED FOR REDUCING LINE TENSIONS	PASSIVE					*
	LEEWARD LINE SLACKENING					*
	WINDWARD LINE LOAD SHARING					*
LINE NUMBER	MIN. HORIZONTAL DISTANCE FROM FAIRLEAD TO ANCHOR TO AVOID UPLIFT FORCE		MINIMUM REQUIRED PRELOAD TENSION		MINIMUM ALLOWABLE TENSION [* *]	
	m		tonnes		tonnes	

[*] Tick as appropriate.

[* *] Minimum allowable line tension to maintain clearance over a subsea obstruction.

MOORING ANALYSIS REPORT					**SHEET: 6 OF 8**
OPERATING LIMITS					
POSITIONING POLICY:	PASSIVE WINCHING		ACTIVE WINCHING TO MAINTAIN STATION		NOTES
WEATHER (FROM)	WEATHER STATE	CRITERIA NO. [*]	WEATHER STATE	CRITERIA NO. [*]	
N					
NE					
E					
SE					
S					
SW					
W					
NW					

OPERATING CONDITION LIMITING CRITERIA		NUMBER
mooring line tension	intact	1
	damage	2
	transient	3
intact excursion	ball-joint angle	4
	riser stress	5
	umbilical extension	6
transient excursion	installation clearance	7
	ball-joint angle	8
	riser stress	9
	umbilical extension	10
heave	slip-joint scope	11
	tensioner scope	12
other		13

MOORING ANALYSIS REPORT		SHEET: 7 OF 8
CHECK LIST		
PROBLEM	COMMENTS	
EXCLUSION ZONES E.G. PIPELINES		
VERTICAL CLEARANCES E.G. SUBSEA OBSTRUCTIONS		
SOIL CONDITIONS		
ANCHOR UPLIFT		
INSTALLATIONS		
SURVIVAL LIMITS (TENSION REDUCTION POLICY)		
OPERATING LIMITS (ACTIVE WINCHING POLICY)		
EMERGENCY PROCEDURE FOR MOVING OFF LOCATION E.G. SHALLOW GAS		
UMBILICALS		
WATER DEPTH		
OTHERS		

MOORING ANALYSIS REPORT					SHEET: 8 OF 8	
DEFINITION OF WEATHER STATE						
LOCATION SPECIFIC					*	
AREA SPECIFIC					*	
GENERAL					*	
WEATHER STATE BEAUFORT SCALE	WIND SPEED		WAVE HEIGHT		MAX. EXPECTED VESSEL HEAVE	
	m		m		m	
3						
4						
5						
6						
7						
8						
9						
10						
12						

[*] Tick as appropriate.

APPENDIX 5 MOORING ANALYSIS COMPUTER PROGRAM REQUIREMENTS

QUASI-STATIC ANALYSIS

- Capability of the program to perform a quasi-static type analysis which would include an intact condition and a damaged condition. The transient condition would be performed by using a time domain step analysis.
- Capability to compute load extension characteristics for each line type (i.e. catenary profile and length of grounded line for a range of line tensions).
- Capability to compute new equilibrium position of unit after static loads are applied (wind, wave and current) and resulting line tensions at the new equilibrium position.
- Capability to calculate new equilibrium position after the vessel motions resulting from extreme waves are applied to system. Resulting line tensions at new equilibrium position are then calculated.
- Capability to describe the transient behaviour following sudden failure of any single mooring line or station keeping sub-system. The analysis should include an assessment of the maximum line tensions and excursion which occur due to combination of the transient motion and the largest significant wave induced surge/sway motion.
- Capability for allowances of active intervention such as thrusters and line tension optimisation.

ACCEPTABLE QUASI-STATIC MOORING ANALYSIS PROGRAMS

- MECA/DMOOR Noble Denton
- ARIANE Bureau Veritas
- GMOOR Global Maritime
- MIMOSA Det Norske Veritas

APPENDIX 6 EXAMPLES OF LOADING AND MOTION COEFFICIENTS

(* - Includes 0.9 reduction factor for short crested seas. Linearisation of response only valid for T_Z less than 12 seconds)

	HEAD	QUARTER	BEAM
Max. Motions* / Hs (metres)	(0.035xTz+0.1238)	(0.036xTz+0.0655)	(0.0355xTz+0.0415)
Current / Vc² (tonnes)	20.0	43.8	41.5
Wave / Hs² (tonnes)	0.130	0.163	0.247
Wind / Vw² (tonnes)	0.124	0.169	0.134

Friede and Goldman L-907 Enhanced Pacesetter (no mods) - (18 m draught)

	HEAD	QUARTER	BEAM
Max. Motions* / Hs (metres)	(0.035xTz+0.129)	(0.036xTz+0.103)	(0.0355xTz+0.088)
Current / Vc² (tonnes)	23.9	69.1	79.1
Wave / Hs² (tonnes)	0.064	0.096	0.107
Wind / Vw² (tonnes)	0.131	0.148	0.141

Standard Aker H-3 - (18 m draught)

	HEAD	QUARTER	BEAM
Max. Motions* / Hs (metres)	(0.035xTz+0.129)	(0.036xTz+0.103)	(0.035xTz+0.088)
Current / Vc² (tonnes)	26.6	74.0	84.1
Wave / Hs² (tonnes)	0.067	0.100	0.111
Wind / Vw² (tonnes)	0.136	0.155	0.150

Aker H-3 with 4 additional columns and sponsons - (18 m draught)

	HEAD	QUARTER	BEAM
Current / Vc² (tonnes)	30.5	51.9	57.9
Wave /(Hs/Tz)² (tonnes)	13.04	24.22	17.72
Wind / Vw² (tonnes)	0.141	0.153	0.117

Sedco 700 Series - (18 m draught)

Vc : [metres/second]

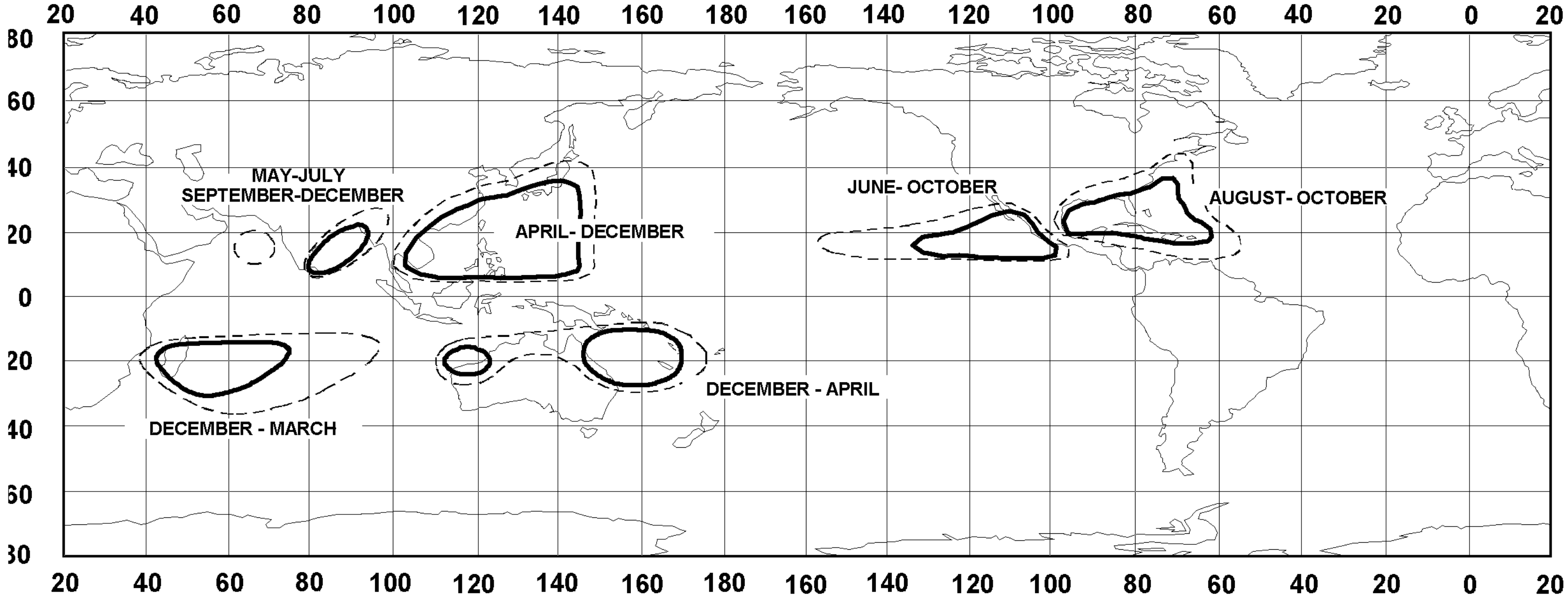
Vw : [metres/second]

Hs : [metres]

Tz : [seconds]

APPENDIX 7 INTERNATIONAL APPLICATION OF API RP 2SK

Figure 1.1 Areas of tropical cyclone activity where assessments to API RP 2SK shall be accepted



(regular occurances are within solid lines. Intermittent occurences are within lighter lines. Cyclone seasons are shown for each area).

APPENDIX 8 ANALYTICAL IMPLICATIONS OF WATER DEPTH (GUIDANCE ON DEEP AND SHALLOW WATER EFFECTS)

1. INTRODUCTION

1.1 This Appendix contains additional supporting information and guidance on analysis methods for extreme water depths.

2. SHALLOW WATER

2.1 MAIN EFFECTS

Shallow water modifies mooring load and motion calculations in the following ways:

a) Increase in current loads due to blockage effects.
b) Modification of vessel motions due to shallow water wave kinematics.
c) Modifications to hydrodynamic factors due to shallow water boundary effects.
d) Modification of vessel motions due to increasing mooring system stiffness.
e) Reduction in thruster efficiency due to shallow water boundary effects.

It should be emphasised that the combination of the above effects can have a significant impact on mobile unit operations in shallow water and thus their evaluation is often critical.

2.2 CURRENT BLOCKAGE

The POSMOOR rules (section 3: A104, figure 2) give some simple corrections for current blockage effects for ship-shape units. These corrections should be applied for depth-to-draft ratios less than 2.5.

No corrections are required for semi-submersible hulls at operating or survival drafts provided that the depth-to-daft ratio is greater than 1.5. This is because semi-submersible hull profiles do not present significant blockages at operating and survival drafts. The corrections given in figure 2 should however be applied for shallow water operations at transit draft where many semi-submersible pontoons are basically ship-shaped.

At inshore locations further blockage effects may occur due to the influence of side walls such as river banks, wharves, etc. Where the current cannot pass between the vessel and the side wall the longitudinal effect is initially equivalent to increasing the drag aspect ratio by a factor of 2. Suitable corrections may therefore be derived from published model test results for standard shapes. This effect will however increase as the ratio of the projected area of the vessel to the channel section increases to the point where the force tends to the full Bernoulli stagnation pressure.

There may also be changes to the side forces on the vessel due to stagnation pressure and fluid velocity differences between one side of the vessel and the other. In practice side wall effects are often difficult to predict owing to uncertainties associated with the upstream velocity distribution and the flow regime actually set up around the vessel. Therefore detailed modelling may be required when conservative mooring solutions are unavailable.

2.3 WAVE FREQUENCY MOTIONS

Fluid particle behaviour, wave height, wave length, wave period, added mass and hydrodynamic damping are all modified by shallow water effects and these in turn may affect vessel motion responses. For a given wave height and period the dominant effect is due to increases in the wave energy associated with a given frequency and as a result amplification factors have to be applied to the wave frequency surge sway responses.

The POSMOOR rules (section 3: A104, Figures 1, 3 and 4) give amplification factors for typical semi-submersible and ship-shaped hulls which should be applied in water depths less than 100 m. However, the fact that the correction factors are different for the two different types of vessel confirms that there will also be variations for unusual vessel types within these groups.

The factors which affect surge/sway responses may also affect heave, but as no empirical correction factors are available these must be calculated when required on a case-by-case basis.

2.4 SECOND-ORDER WAVE EFFECTS

Second-order wave forces are also affected and corrections may therefore be required to the mean wave drift force coefficients used in quasi-static analysis. As wave drift force coefficients are commonly quoted as a function of wave height squared, one approach would be to multiply the coefficients by the square of the factors derived from the POSMOOR rules (section 3: A104, figures 1, 3 and 4). However, if the mooring cannot accommodate the extra forces associated with this conservative approach it may be necessary to re-calculate the coefficient from first principles using a diffraction analysis approach, which takes full account of the shallow water effects. Such calculations are in any case required for dynamic system analysis in shallow water.

2.5 MOORING SYSTEM STIFFNESS

One of the key assumptions of a quasi-static analysis is that the first-order wave responses are entirely independent of the mooring system stiffness. This assumption is valid so long as the net mooring system forces are small by comparison to the total wave forces. However, when mooring systems are deployed in shallow water they can become stiff enough to affect the system inertia and hence the global motion response.

Initially the effect of increasing mooring line loads is to reduce the maximum predicted system excursion and therefore the results of quasi-static analysis are conservative. However, dynamic amplification can occur if mooring system's natural periods are close enough to peak wave energy periods.

The POSMOOR rules (section 3: A104) state that "the stiffness of the mooring system has to be included when the water depth is less than 70 m". This may be a fairly good guide for conventional mooring semi-submersible mooring systems using 3-inch chain cable, but it cannot be relied upon across wider parametric variations of mooring system stiffness and vessel displacement. It is therefore much better to evaluate the mooring system's natural period. As indicated in (Figure 2) of this DEP dynamic amplification of first-order wave frequency responses can be expected where:

$$0.75 < Tnat < 1.25\ Tp$$

Where $Tnat = 2\Pi\sqrt{(m/k)}$

m = vessel mass including added mass in kg

k = mooring system stiffness in N/m at the vessel's mean horizontal displacement

Tp = the peak energy period of the design wave spectrum.

Dynamic amplification factors can easily be determined using standard dynamic analysis techniques. Practically, however, catenary mooring systems are rarely practicable for system natural periods where there is significant dynamic amplification.

2.6 THRUSTERS IN SHALLOW WATER

Problems may arise due to the use of thrusters in shallow water, firstly because entrained sea-bed soil materials may cause local contact damage which results in thruster failure, and secondly because the efficiency of the thruster itself may be affected. The extent to which this occurs varies with the design of the thruster but as a general rule problems can be expected whenever the bottom clearance is less than 3 times the diameter of the propeller.

3. DEEP WATER

3.1 MAIN EFFECTS

Deep water can modify mooring system design and analysis due to the following:

a) Line dynamic amplification due to increased drag and inertia.
b) Second system dynamic response due to reduced mooring system's natural period.

It should be emphasised that the combination of the above effects can have a significant impact on mobile unit operations in deep water and thus their evaluation is often critical.

3.2 LINE DYNAMICS

Line dynamic amplification can occur in deep water when mooring line drag and inertia(s) are so large that the line cannot adopt the quasi-static catenary profile when excited at wave frequency. The result is that the line is stiffer than it would be at low frequency and a line dynamic amplification factor must be applied to correctly predict the maximum line tensions and system excursions.

These effects are increased in deep water due to the increased weight and length of the mooring line. They may, however, also occur in moderate water depths if the mooring line weight and drag increase due to some other reason, such as the inclusion of clump weights, mid-line buoys, etc. They are also affected by the magnitude and the frequency of the maximum fairlead motion with the result that vessels with large roll, pitch and heave motion responses are more likely to be affected. Therefore, whilst the guidance on the limits of quasi-static analysis given in the POSMOOR rules (section 3: A111) is generally helpful, it cannot be relied upon to identify all the cases where line dynamic effects need to included.

3.3 SYSTEM DYNAMICS

Second-order system dynamics are more significant in deep water due to reduced mooring line stiffness. Once more it is the system's natural period and the sensitivity to second-order excitation which are the key issues rather than the water depth. The POSMOOR rules (section 3: A11) recommend that dynamic analysis should be performed for conventional mooring systems in water depths greater than 450 m and for floating production systems in water depths greater than 200 m. Practically, however, system dynamic effects may become increasingly important for installations with natural surge-sway periods in the range 60 m to 200 m.