1 Environmental Conditions (survival) - Return Periods

1.1 Env 1 - 100 year Wind and Wave, and 10 year Current
1.2 Env 2 - 100 year Wave and Current, and 10 year Wind
1.3 Env 3 - North Sea summer season, H_s = 10 m, T_z = 12 sec, $V_{10min,10m}$ = 30 m/s, Vc = 1.1 m/s (south of 62º), Vc = 1.4 m/s (north of 62º)

2 Design Values of Environmental Parameters

2.1 Wind - $V_{10min,10m}$ (10 minute average at 10m above sea level)
2.2 Current - $V_c = V_{wind} + V_{tc}$ (wind driven current velocity + tidal current velocity)
2.3 Waves - H_s, Peak Period, and Spectrum (" . . . taking short-crested sea into account.")

Notes: 1 10 year $V_{10min,10m}$ = 0.9 x 100 year $V_{10min,10m}$
2 10 year V_c = 100 year V_{tc} + 0.9 x 100 year V_{wind}

3 Analysis - General

3.1 Wind Profile - $V_{tz} = V_{10min,10m} (z/10)^{0.11 \text{ to } 0.14}$, most favourable value can be used
3.2 Current Profile - $V_{cz} = V_{tc} + V_{wind} ((50-z)/50)$, z in metres
3.3 Elastic Modulus - $E_{chain} = 5.6 \times 10^{10}$ N/m²
$E_{wire} = 9.8 \times 10^{10}$ N/m² (7.0×10^{10} N/m² if periodic testing & renewal allows)
3.4 Coefficient of Friction between mooring line and seabed = 1.0 in direction of mooring line, for chain and wire rope.
3.5 Maximum deployed line length allowed in analysis = suspended length (at tension equal to CBS) + 500 m.

4 Analysis - Methods

4.1 Complete dynamic analysis (including transfer functions for actual water depth, effects of mooring system stiffness, thruster damping, LF motions, and line dynamics) may always be used. Detailed guidelines and safety factors will be given in appendix VI of the "Guidelines".

4.2 Quasistatic analysis, line dynamics and LF motions are neglected. Generally applicable for water depth, d, where
(i) d < 200 m
(ii) 200 < d < 450 m, and mooring system is approved for d < 70 m, unless high mooring system stiffness and tension is specified.

4.3 "Incomplete" dynamic methods (partly comply with 4.1) may be used to supplement the quasistatic method (contact NMD on case by case basis).

4.4 The following assumptions/techniques are recommended for use in mooring analyses.
1 Extreme environmental forces are to be taken as coincident in time and collinear in direction, if no other combination of directions yields higher loads.
2 Wave induced motion (WF response) is the estimated maximum in 2 hours (≈ 3% less than 3 hour value), using short-crested sea with a $\cos^2$ spreading function.
3 If long-crested seas are used the maximum WF motion can be reduced by 10%.
4 The maximum WF motion in an arbitrary direction can be found from the maximum WF motions in surge and sway by fitting an ellipse to those values.
5 The line pretensions used in the mooring analysis shall not be optimized beyond what is easily achievable on board.
6 Pretensions may not be modified within a single environmental condition, or for the one line broken condition.
7 For the survival condition the line tensions should normally be optimized to achieve high safety factors in the intact condition.

5 Operating and Survival Condition, and Consequence Class

Operation Condition - when the vessel is performing its intended work at a given location.

Survival Condition - the operations are terminated, extreme values for wind, current, and waves are applied in the positioning calculations

Class 0: Operations where the positioning function is not considered to endanger human lives, or cause major damage in the case of failure.

Class 1: Operations where damage or pollution of small consequence may occur in case of failure of positioning capability.

Class 2: Operations where failure of positioning capability may cause pollution and damage with large economic consequences, or personnel injury.

Class 3: Operations where fatal accidents, or severe pollution and damage with large economic consequences are probable results of loss of position.

Philosophy: The unit shall either be in the survival condition or be able to reach the survival condition after the maximum single failure without exceeding the limiting requirements (factors of safety and allowable motions before and after maximum single failure). Whether or not a failure has occured, operations may be continued only if the consequence analysis shows that any additional failure will not lead to a critical situation. The positioning system, including any non-critical failure will then be regarded as the intact system.

6 Safety Factors and Thrusters

6.1 Failure of thrusters, thruster control, or power supply, is a single failure to be treated equivalently to a single anchorline failure

6.2 For automatic thrusters 100% of available net thrust may be used, for manual thrusters 70% of available net thrust may be used.

6.3 Line Tension Safety Factors - Quasistatic Analysis

Condition	Consequence Class		
	Class 1	Class 2	Class 3
Intact System	2.0		3.0
Damaged System (single failure)	1.4	2.0	2.0
Transient Motion	1.0	1.4	1.4

6.4 For units near to other structures, critical mooring lines shall satisfy consequence class 2 requirements, other lines shall satisfy class 1 requirements.

7 Motions and Offset

7.1 Maximum allowable motions to be determined with necessary safety margin dependent on consequence of exceedance.
7.2 When unit is connected to a (rigid) riser, the transient offset (transient motion + significant WF motion) < allowable BOP ball joint angle - 2.5% of water depth.
7.3 When unit is near to other structures, the minimum clearance (transient motion + significant WF motion) > 10 m.
7.4 Gangway excursion reserve during normal operations > 1.5 m.

8 Line Lengths

8.1 For anchors not specially designed to take uplift forces, zero uplift under the following conditions
(i) Damaged condition, mean offset + sig.(WF motion)
(ii) Maximum transient offset (without WF or LF motions)

1 Environmental Conditions - Return Periods

1.1 Env 1 - 100 year Wind and Wave, and 10 year Current
1.2 Env 2 - 100 year Wave and Current, and 10 year Wind

2 Design Values of Environmental Parameters

2.1 Wind - $V_{10min,10m}$ (10 minute average at 10m above sea level)
2.2 Current - $V_c = V_{wind} + V_{tc}$ (Wind driven current velocity + tidal current velocity)
2.3 Waves - H_s, Peak Period, and Spectrum (" . . . taking short-crested sea into account.")

Notes: 1 10 year $V_{10min,10m}$ = 0.9 x 100 year $V_{10min,10m}$
2 10 year V_c = 100 year V_{tc} + 0.9 x 100 year V_{wind}

3 Analysis - General

3.1 Wind Profile - $V_{tz} = V_{10min,10m}(z/10)^{0.13}$
3.2 Current Profile - $V_{cz} = V_{tc} + 0.02\, V_{1hr10m}((50-z)/50)$, z in metres
3.3 Elastic Modulus - $E_{chain} = 5.6 \times 10^{10}$ N/m^2
$E_{wire} = 9.8 \times 10^{10}$ N/m^2
3.4 Maximum deployed line length allowed in analysis = suspended length (at tension equal to CBS) + 500 m.

4 Analysis - Methods

4.1 Quasi-static or Dynamic analysis

Water Depth (d)	Analysis	Comments
d < 70 m	Q-S/Freq, Dynamic	WF only - mooring system stiffness to be included in calculating WF response
70 < d < 450 m	Q-S/Freq, Dynamic	WF and LF response may be decoupled. For semis only required to consider WF response, for ship shaped vessels both WF and LF responses must be included.
d > 450 m	Q-S/Freq, Dynamic	WF and LF response may be decoupled. For semis and ship shaped vessels both WF and LF responses must be included.

4.2 The following assumption/techniques are recommended for use in mooring analyses.

1 For quasi-static analysis (Q-S/Freq) extreme environmental forces are to be taken as collinear in direction and coincident in time.
2 For dynamic analysis the probability of simultaneous occurrence of extreme values of wind, current, and waves and their directional dependency may be included when satisfactorily documented.
3 For quasi-static analysis, WF response to be based on storm duration of ≥ 2 hours, LF response on storm duration of ≥ 3 hours.
4 For dynamic analysis, both WF and LF response to be based on storm duration of ≥ 3 hours.
5 Maximum excursion = $\sqrt{(\text{Max(Wave Freq.)})^2 + (\text{Max(Low Freq.)})^2}$, to be used for calculation of maximum tensions for intact and damaged conditions. In calculation of maximum transient tension, transient motion to be combined with significant WF motion.
6 Tension optimisation, slackening of leeward lines, allowed for operating conditions I and II (survival and operating) but not for damaged condition.

5 Operating Conditions

5.1 Operating Condition I (survival) - Positional mooring where a single failure (single failure = one line breaks or loss of one thruster) of the positioning system will not lead to a critical situation for overall safety of the unit and those on board.

5.2 Operating Condition II (operational) - Positional mooring where exceedence of position limitations will lead to a critical situation for overall safety of the unit and those on board (single failure = one line breaks, or loss of one thruster, or single failure of thruster control or power system).

Redundancy - If unit is to continue in Operating Condition II after single failure, redundancy of components or systems is required "so that the single failure will not cause critical loss of position or exceedance of anchor line tension". If unit is to transfer from Operating Condition II to Operating Condition I after a single failure, system design is to ensure adequate position keeping for the duration of the transfer.

6 Safety Factors and Thrusters

Operation Condition		Analysis				Thrusters			
		Quasistatic		Dynamic		Manual		Automatic	
		Far	Near	Far	Near	Far	Near	Far	Near
I	Intact System	1.80	2.00	1.50	1.65	0.7(all-1)	0	(all-1)	(all-1)
	Damaged System (single line failure)	1.25	1.40	1.10	1.25	0.7	0.7	1.0	1.0
	Transient Motion	1.10	1.10	1.00	1.00				
II	Intact System	2.70	3.00	2.30	2.50	0	0	(all-s)	(all-s)
	Damaged System (single line failure)	1.80	2.00	1.50	1.65	0	0	1.0	1.0
	Transient Motion	1.40	1.40	1.20	1.20				

Note: (all-1) = net thrust from all thrusters except one, (all-s) = remaining thrust after single failure of a thruster, power supply, or control system.

7 Offset Limits

7.1 Offset < operational service limitations

7.2 When unit is connected to a rigid riser, the transient offset (transient motion + significant WF motion) < allowable BOP ball joint angle - 2.5% of water depth.

7.3 When unit is near to other structures, the minimum clearance (transient motion + significant WF motion) > 10 m.

7.4 Gangway excursion reserve during normal operations > 1.5 m.

8 Line Lengths

8.1 For anchors not specially designed to take uplift forces, zero uplift under the following conditions

(i) Intact mean offset + max(sig.(WF motion), sig.(LF motion))

(ii) Transient offset (without WF or LF motions)

1 Environmental Conditions - Return Periods

MODUs

1.1 10 year - Operations in the vicinity of other structures, all geographic areas. 10-year return environment appropriate for near to pipeline, >10-year for floatel or next to platform, use of risk analysis recommended.

1.2 5 year - Operations away from other structures, all geographic areas.

1.3 1 year - Operations away from other structures, special geographic areas such as the South China Sea, when the following minimum requirements are also satisfied
(i) drilling riser pulled and personnel evacuated
(ii) no nearby structures.

Note: For MODUs return periods are for wind, wave and current.

FPS

1.4 100 year - For permanently connected systems, risk analysis may justify the use of longer or shorter return periods. However not less than 100 year when the event may occur without warning, or when evacuation of personnel is not possible.

1.5 Connect - For a mooring system that permits rapid disconnection of the production vessel, maximum environment in which the vessel remains connected.

Note: For FPS two sets of criteria are to be investigated (1) 100 year waves with associated wind and current, (2) 100 year wind with associated waves and current

2 Design Values of Environmental Parameters

2.1 Wind - $V_{1min,10m}$ or $V_{1hr,10m}$ and suitable wind gust spectrum

2.2 Current - $V_c = V_{tc} + V_{circ} + V_{storm} + V_{loop}$ (vector sum of tidal, circulation, storm, and loop)

2.3 Waves - H_s, Peak Period, and Spectrum (and directionality)

3 Analysis - General

3.1 Wind Profile, $V_{tz} = V_{1min,10m} (z/10)^{0.125}$

3.2 Current Profile, not specified.

3.3 Elastic Modulus, E_{chain} = 7,640 ksi (5.3 x 10^{10} N/m^2), E_{wire} = 9,800 ksi (6.8 x 10^{10} N/m^2)

3.4 Coefficient of Friction between mooring line and seabed, chain 1.0 starting, 0.7 sliding and wire rope 0.6 starting, 0.25 sliding.

3.5 Mean Wave Drift Force, design curves for estimating the mean wave drift force for "small" semis and ship shaped vessels are provided (API RP 2P curves).

3.6 Wave Induced Low Frequency Motions, design curves for estimating the LF motions for "small" semis and ship shaped vessels are provided (API RP 2P curves).

3.7 Wind Induced Low Frequency Motions, LF wind and wave force may be combined to yield LF vessel motions due to both effects, a wind spectra with a simple shape is given.

4 Analysis - Methods

4.1 Quasi-static or Dynamic Analysis

Type of Mooring	Analysis Method	Conditions to be Analyzed
FPS/Permanent Mooring		
• Preliminary design	Quasi-static or dynamic	Intact/damaged/transient
• Final design	Dynamic	Intact/damaged/transient
• Fatigue design	Dynamic	Intact
MOU/Temporary Mooring		
• Away from other structures	Quasi-static or dynamic	Intact
• Mooring lines over pipeline	Quasi-static or dynamic	Intact/damaged
• Vessel next to a platform	Quasi-static or dynamic	Intact/damaged/transient

4.2 The following assumptions/techniques are recommended for use in mooring analyses.

1 Permanent mooring systems should be designed for two primary considerations, overload and fatigue.

2 A storm duration of ≥ 3 hours should be used. For geographic areas with long storms, for example monsoon areas, longer storm periods should be used.

3 For intact and damaged condition, maximum combined mean, WF and LF offsets and tensions may be calculated from the following rule, where X = offset or tension.

If, $X_{LFmax} > X_{WFmax}$, then, $X_{max} = X_{mean} + X_{LFmax} + X_{WFsig}$

If, $X_{WFmax} > X_{LFmax}$, then, $X_{max} = X_{mean} + X_{WFmax} + X_{LFsig}$

4 For the transient condition, maximum combined mean, WF and LF offsets and tensions may be calculated from the following rule, where X = offset or tension.

$X_{max} = X_{mean} + X_{TRmax} + X_{LFsig} + X_{WFsig}$

5 For drilling operations offset limits apply to the intact condition only.

6 Optimization of line tensions, slackening of leeward lines is allowed in the analysis, if the practice is well defined and routinely carried out by trained personnel on board. In general optimization of windward lines should not be used in analysis.

5 Rationale for Safety Factor Format

5.1 Tension limits, and equivalent factors of safety for various conditions and analysis methods are given in Item # 6. This is a departure from previous API practice, and the rationale is given below.

(1) For operations such as drilling where the maximum operating environment is significantly lower than the maximum design (survival) environment, tensions need to be checked for the maximum design environment only. If the criteria are met, tension is not a concern for the milder maximum operating environment.

(2) For operations such as certain floating production operations where production will continue under the maximum storm (survival) condition, the maximum design and operating environments are the same, and the same tension criteria should apply.

Tension Limits and Equivalent Factors of Safety

Condition	Analysis Method	Tension Limit (% of CBS)	Equivalent Factor of Safety
Intact	Quasi-static	50	2.0
Intact	Dynamic	60	1.67
Damaged	Quasi-static	70	1.43
Damaged	Dynamic	80	1.25
Transient	Quasi-static	85	1.18
Transient	Dynamic	95	1.05

6 Thrusters and Safety Factors

6.1 Thrusters may be used to counter the steady environmental forces acting on the unit in the maximum design condition as follows

Available Thruster in the Maximum Design Condition

Mooring System Status	Manual Remote Control	Automatic Remote Control
All lines intact	0.7(all - 1)	(all - 1)
One line broken	0.7(all)	1.0

6.2 Line Tension Safety Factors

Line Tension Factors of Safety and Analysis Required

Mooring System Status	FPS	MOU Next to Platform		MOU Over Pipeline		MOU Away from Other Structures	
	Dynamic	Q-S	Dynamic	Q-S	Dynamic	Q-S	Dynamic
Intact	1.67	2.00	1.67	2.00	1.67	2.00	1.67
Damaged	1.25	1.43	1.25	1.43	1.25		
Transient	1.05	1.18	1.05				

6.3 Safety Factors for Drag Anchors

Mooring System Status	FPS	MOU	
	Dynamic	Q-S	Dynamic
Intact	1.5	1.0	0.8
Damaged	1.0		
Transient			

6.4 Fatigue Safety Factor. A predicted mooring component fatigue life of three times the design service life is recommended. This factor should be used in conjunction with a component T-N curve corresponding to a lower bound of the 95% prediction interval (mean minus two standard deviations). A fatigue curves for wire rope, chain and Kenter and Baldt connecting links are given.

7 Offset limits

7.1 Riser: Mean, S_{mean}, and maximum, S_{max}, allowable offset determined by drilling riser analysis, for drilling operation intact condition only, for FPS intact, damaged, and transient conditions

(i) When operations are discontinued in advance of severe storm and/or riser is disconnectable, use maximum operating environment.

(ii) When operations are to continue under maximum storm conditions use maximum survival environment.

7.2 In the vicinity of other structures, maximum allowable offset, S_{max}, determined to avoid contact of vessel or its moorings with nearby installation, include intact, damaged, and transient conditions.

(i) Use maximum survival environment.

8 Line Lengths

8.1 For drag anchors the line length should in general be sufficient to prevent anchor uplift. For some high efficiency anchors in soft clay field tests indicate high vertical resistance of these anchors, however, caution must be exercised if the vertical resistance is to be used in mooring design.

9 Mooring Test Loads

9.1 If drag anchors are used. the mooring should be test loaded to ensure sufficient anchor penetration and adequate initial holding capacity.

9.2 For permanent moorings, all mooring lines should be test loaded to the maximum storm load determined by a dynamic mooring analysis for the intact condition.

9.3 Test loads for temporary are more difficult to determine because of operational and equipment restraints. Preferably the test load for temporary moorings should be at the same level as the maximum line tension under the maximum design condition. If this cannot be achieved mooring test load should be the greater of the mean line tension under the maximum design condition or the maximum line tension under maximum operating condition.