HSE
Health & Safety Executive

Appraisal of API RP 2FPS

(Recommended practice for planning, designing and constructing floating production systems)

Prepared by **MSL Engineering Limited**
for the Health and Safety Executive

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FOREWORD

This document summarises a study undertaken by MSL Engineering Limited for the Health and Safety Executive to review the final draft API RP 2FPS "Recommended Practice for Planning, Designing and Constructing Floating Production Systems". The API document was compared with the recently updated ISO document ISO/WD 13819-4 "Materials, Equipment and Offshore Structures for Petroleum and Natural Gas Industries – Offshore Structures – Part 4 : Floating Structures", the NORSOK document N-004 "Design of Steel Structures" and the Lloyds Register "Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location".

The purpose of the study was to assess the suitability of the API code for application to the design of FPS's in the UKCS and is a continuation of the previous study undertaken in May 2000 and published by the HSE as OTO 2000 026.

The study was undertaken by Dr David M Osborne-Moss and Dr Adrian F Dier of MSL. HSE input to and management of the study was undertaken by Mr Robert White.

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1. SUMMARY

This study updates OTO 2000 026[1] with a further high level review of the final draft code API RP 2FPS [2] with a view as to whether this code would be suitable for the design of floating production systems on the UKCS. The content and structure of the code has been investigated to determine whether it reflects good practice and the necessary standards required for Floating Production Systems (FPS's) in a harsh environment such as the UKCS.

A measure of this requirement is to compare the API code with other similar documents. In this case the code has been compared with the draft ISO/WD 13819-4 Offshore Structures – Floating Systems[3], the NORSOK Standard N-004 Design of Steel Structures[4] and the Lloyds Register Classification Rules for Floating Offshore Installations[5].

FPS's cover a variety of different floating production concepts together with the associated production facilities, mooring system, riser system and sub-sea system. This wide range of subjects involves an extensive range of specialised products and their associated detailed specifications. The most important aspect of the API design code is that the total FPS arrangement is considered as an integrated unit with consistent levels of production efficiency and safety. The API code covers the design, construction, fabrication and operation principles of such a system but refers to the appropriate sections of existing API codes for the detailed design of components. The suitability of the referenced sections of other API codes has not been established within this high level study.

The API code has merit in providing consistent principles for the safe design of an integrated floating production system. It has also attempted to cover the inherent differences between different regions of the world and the associated variations in environmental loading.

Both the ISO and NORSOK documents are focussed primarily on the structural and naval architecture aspects of floating offshore installations. They therefore do not provide a complete guide to the design issues associated with producing a safe integrated floating oil production installation.

In conclusion the API code in its final version could provide a basis for developing a harsh environment design code for regions such as the UKCS. The references to detail specialised API design codes contained therein should be investigated to ensure they provide the designer with appropriate and consistent rules for the UKCS. The selection of these detailed design rules for reference needs careful consideration to meet the required operational and safety goals.

2. OVERVIEW OF DOCUMENTS

This document follows on from the previous OTO Report No. OTO 2000 026 issued in May 2000. It updates the previous review with the latest evolving documents and includes a review of the NORSOK document.

2.1 API RP 2FPS (Final Draft)

The API document has been totally reviewed in 2000 by a broadly based drafting committee representing all sections of the offshore oil and gas industry. This final version has addressed many of the concerns expressed in written comments on the previous draft, which was issued for comment by industry. As a result the document has been extensively amended and re-written where the drafting committee thought appropriate.

The comments below are items of interest related to the use of the API draft as a complete specification for the UKCS and other similar harsh environment regions. Changes between the earlier May 1999 draft and the final draft are also identified where appropriate and new requirements are marked with an asterix (*). The comments are prefaced by the section references from the API document. Note that many of the section headings are also shown in 3.1 along with relevant section headings in the ISO WD.

Foreword

The final draft of API RP 2FPS has actually removed all reference to the design of concrete hulls and the foreword needs to be re-worded to reflect this.

Abbreviations

The list has been corrected and updated.

1.1 Purpose and Scope

The reference to mooring systems has been changed to station keeping system to cover the use of dynamic positioning.*

The exclusion of TLP's is a major difference to ISO/WD 13819-4 and NORSOK N-004 but it is presumed that the design rules for the hull of the TLP in RP 2T are similar to those contained in RP 2FPS for other FPS's.

1.2 Applicable Codes and Standards

The code is based on working stress design although it allows the designer to use LRFD as an option. However, no further guidance is given in RP 2FPS on LRFD. The code also relies heavily on other API standards for offshore facilities and those issued by Recognised Classification Societies, U.S. Coast Guard, MMS and IMO. This has the advantage of avoiding duplication and re-issuing RP 2FPS whenever one of the referenced standards is revised. It does however present practical difficulties to the designer of FPS's in that many reference standards have to be collated and decisions taken wherever there are design requirement differences between the various organisations involved. For example the historic basis of RCS rules and design methods are clearly different to the highly theoretical design basis of API standards for fixed offshore platforms. A step change in the design basis of FPS's would not be welcomed by the offshore industry but it is equally reasonable for there to be comparable safety margins between different types of platform.

The Responsible Party is required to choose the applicable codes and standards and to ensure that they are not mixed inappropriately. The Responsible Party is defined in Section 1.3m as the legally recognised responsible party of the production lease or leases, concessions, grants, etc., usually the designated operator of the field, e.g. Owner, Duty Holder, Concession Owner, etc.*

*1.3 Definitions**

Additional descriptions are given for:

c. Spar
l. Weak link design
m. Responsible Party
n. Recognised Classification Society
o. Mobile Offshore Drilling Unit.

1.4 Floating Production System Configuration

*1.4.1a Water Depth**

This does not now define FPS types for different water depths but correctly points out that some hull types have minimum water depths.

*1.4.1b Environmental Data**

This adds the comment that short period FPS's will be more prone to fatigue damage.

*1.4.1f New build vs. conversion**

Environmental considerations have been added as a criteria to cover more demanding wave energy or ice conditions.

1.4.1i Well System Configuration

Another consideration of the layout of subsea wells is the optimisation of wellhead location and minimal seabed flowlines against increasing the well deviation and the use of horizontal and multilateral wells (see 9.3).

New sections are added to 1.4.1 for:*

h. Transportation and installation

i. Service Life

k. Hydrocarbon storage requirements

l. Regulatory requirements for re-use

*1.4.2 FPS System Interfaces**

Additional interface considerations are added for:

Ballast and bilge systems
Fuel system and source
Emergency shutdown systems
Life saving appliances
Personnel safety equipment
Production risers

*2.1 Introduction**

A warning is added that using a mixture of design criteria and codes/standards may result in a reduced level of reliability in the design.

*2.3 Categorisation**

The original four categories have been redefined by reversing the order and combining the original categories 1 and 2 into the new category 3. The use of a RCS classed MODU for early, pilot or first-stage field development is excluded from the majority of this API standard providing an acceptable level of safety is confirmed by operation within the specific MODU design criteria and a site specific risk analysis is performed according to API RP 2FPS. Further API RP 2FPS does not apply to a RCS classed MODU, with or without built in crude oil storage capabilities engaged in drill stem testing, extended well or reservoir tests or short term reservoir maintenance.

2.4.2a National Regulations

The title has changed from Host Government and specific references to US outer continental shelf have been removed. The requirements for any 'flagging' of the FPS are included here and the previous section 2.4.2b Flag State has been removed.

2.4.2b Recognised Classification Societies

The list of RCS's has been removed and a reminder added that the services of a RCS may be necessary to obtain or expedite flag state certificates. RCS is defined in Section 1.3n as a classification society that is a member of the International Association of Classification Societies (IACS), with recognised and relevant experience with offshore petroleum activities and established rules and procedures for classification/certification of installations used in petroleum activities.

*2.4.3 Operational Requirements**

Additional requirements have been added for processing equipment performance and personnel comfort and safety.

*2.4.5c Waves**

Reference to consideration of sea swells has been added.

*2.4.5d Current**

Reference to determining the current profile throughout the water column and current scatter diagram has been added.

*2.4.5j Seismic Action/Earthquake**

New section added.

*2.4.5k Subsidence**

New section added.

2.4.6 Design Cases

Section f. Regulatory Requirements removed.

*2.4.6b Project Phases**

Transportation

Fatigue of FPS components has been added.

Commissioning

New section added.

Inspection

Inspection is waived for components specifically designed for no inspection with a corresponding higher fatigue life. Fatigue design is generally required by API RP 2FPS to comply with the appropriate RCS rules but warns that economic considerations may increase RCS rules requirements where they are typically based on a safety level assuming periodic inspection with corresponding repairs. For example Lloyd's Register have a fatigue safety factor of 4 for inspectable structural components and a safety factor of 10 for non-inspectable components.

Marine growth should be removed before underwater inspection.

Decommissioning

New section added.

2.4.6d Environmental Events

*1c Extreme Motions Event**

For a FPS with a rapid disconnection mooring and riser system the maximum design condition for the production configuration is the threshold environment to perform disconnection operations.

*3 Threshold Environment**

These should be captured in the Marine Operations Manual.

2.4.6e Safety Criteria

*Category C**

Increased factors of safety against fatigue failure should be considered for areas that are not inspectable.

*2.4.7b Live Loads**

Mooring and riser loads should be considered in this category.

*2.4.7c Environmental Loads**

Green water effects on deck loading should be considered.

The following sections have been added:*

2.4.7g Accidental Loads

2.4.7h Mooring and Riser Loads

*2.5.1 General**

Critical components should be designed under a weak link philosophy such that a mooring/riser failure shall not compromise the integrity of the unit.

*2.5.1 Accidental Impact Loads**

The operating manual should contain conditions under which the installation should be shut-in and evacuated.

3.1.1 Purpose and Scope

Concrete removed.

Moorings for column stabilised FPS have to be designed according to this RP.*

*3.2.2 Damaged Conditions**

Hydrostatic stability in the damaged condition should be investigated.

*3.2.6 Air Gap**

The air gap is to be designed in accordance with API RP 2T Section 7.2.8 (Deck Clearance)

*3.2.8 Vibrations**

Long slender members are especially susceptible to Vortex Induced Vibrations.

3.3 Design Cases

Previous sections on service loads, fatigue, and accidental loads have been removed as these are covered elsewhere in section 2.

*3.4.1 Hydrodynamic Analysis**

Current loads and damping on mooring lines and risers are to be included in the hydrodynamic response analysis.

3.4.2 Global Structural Analysis

The commentary included at the end of this section has been moved to the end of the document.

3.5 Structural Design -Hull

Simplified to list of API/AISC codes for different structural components.

Section on concrete hulls removed.

*3.6 Fabrication Tolerances**

Special attention is to be paid to interfaces between separately constructed sections.

3.7.2 Intact and Damaged Stability

The specific quoted MODU rules on stability criteria quoting 100 knots wind for intact severe storm, 70 knots for intact operating and 50 knots for damaged condition have been removed and the user is referred instead to national government regulations, MODU Code or RCS rules.

3.7.4 Weight Management

Removed reference to inclining test since it is covered in previous Section 2.4.4b which applies to all FPS concepts.

*4.1.1 Purpose and Scope**

New paragraph drawing attention to the need for the design to consider the varying loads of stored oil and the additional process requirements for safe storage and transfer of crude oil.

*4.2.1 Project Phases**

Turret disconnection may be due to limiting design conditions other than storms.

*4.2.5 Sloshing**

Long swell waves should also be checked.

*4.2.7 Slamming**

Design loads should include slamming as appropriate.

*4.2.8 Fatigue**

Fatigue strength calculations should be based on a site specific assessment.

*4.2.10 Process Equipment Support Structure**

Green water loading has been added to the design condition.

*4.3.2 Global Loads**

FPS environmental loads may be more or less severe than RCS rules.

*4.4.2 Local Strength Analysis**

Support structure for the riser system has been added.

The process equipment supports should be analysed for differential movement between the process deck and hull due to stillwater, wave induced and thermal deflections.

4.4 Vibrations

This section has been removed as covered elsewhere.

*4.5.1 Fatigue Analysis Methodology**

Full history of the vessel to be considered in fatigue especially for converted vessels.

The inspection and repair philosophy should be considered and may increase RCS requirements.

Fatigue limit states should include all significant actions contributing to fatigue damage.

*4.6 Weight and Stability**

Sections 4.6.3 inclining experiment and 4.6.4 weight control replaced with new sections on stability criteria and loading manual.

*5.1.2 Description of a Spar Based Platform**

Definitions of hard and soft tanks added.

5.2.5 Air Gap

The previous paragraph is replaced by a reference to API RP 2T.

5.2.7 Mooring System

This section has been removed as it is covered in section 8.

*5.2.9 Corrosion Allowances and Protection**

Special attention should be paid to corrosion protection in ballast tanks.

5.3 Design Cases

Sections 5.3.2 Safety Criteria, 5.3.4 Environmental Loads, 5.3.4 Service Loads, 5.3.5 Fatigue and 5.3.7 Accidental Loads are all removed as covered elsewhere.

*5.3.2 Loading Conditions**

Loading conditions should include dynamic loads.

5.5.1 Design Basis

Sections 5.5.1 to 5.5.4 are replaced with table of reference design codes for structural members.

Previous section 5.6 for concrete design removed.

5.5.2 Fatigue Design

Reference to using API RP 2T rather than API RP 2A previously.

*5.7.3 Intact and Damaged Stability**

Previous specific design criteria replaced with requirement to meet the required VCG.

*5.7.5 Weight Management**

Construction and operating phases added to design phase weight documentation and tracking.

6.1.1 Purpose and Scope

Model test verification required for unique configurations (moved from former section 6.4.1).

Previous sections 6.2, 6.3, 6.4 and 6.6 removed.

*7.2 Design, Construction and Maintenance**

A site specific structural evaluation using a current condition survey is required.

As the RCS rules used for the original design may have changed the conversion should comply with the current rules depending on the intended mission.

*7.4.3 Ship Shaped Structures**

Additional design conditions include the effects of weathervaning, higher still water levels, partially full tanks and sloshing, permanent moorings, riser system and the production equipment.

*7.6 Inspection and Maintenance**

The inspection of tanks will require emptying, cleaning and gas freeing which may affect the loading on the vessel. Dry-docking of the FPS may not be practical during its service life and underwater inspection may be required. Repair acceptance may limit underwater welding to the secondary structure. Lack of practicable or possible accessibility to inspect, maintain or replace corrosion protection systems will require the design life to be at least twice the service life of the floating structure.

*8.1 General**

A description of a passive mooring system has been added and the use of taut moorings will increase the vertical loading on anchors. Mooring line fairlead locations should consider the hull structure and the loads considered in the structural design.

*8.3.1 Environmental Criteria**

Early field development systems will use a return period 10 times the expected time on location but not less than 5 years or more than 50 years.

*8.3.2 Environmental Design Cases**

Additional design events of earthquakes and tsunamis and joint frequency data of wave height, wave period and wind for fatigue assessment.

Additional environmental parameter of wind spectrum.

*8.4 Analysis**

Damping from risers now included.

8.5 Innovative Deep Water Mooring Systems

Sections 8.5.1, 8.5.2 and 8.5.3 moved to commentary at end of document.

8.6.1 Special Considerations for Mooring Design

Detailed comments moved to commentary at end of document.

*8.6.4 Turret Mooring Systems**

Investigate the sensitivity of FPS dynamic response to the predicted mean heading by undertaking parametric studies.

*8.6.8 Dynamic Positioning Systems**

New section referring to API RP 2SK and IMO MSC Circular 645.

*9.5.1c c) Full Service Production Swivel**

Gas export added to functions.

*9.5.1d Lifting and Pumping Systems**

Subsea multi-phase pumps may also be used to provide energy to the produced fluid stream.

*9.9.2 Testing Requirements for Swivels**

Test requirements should be according to manufacturer's recommendation.

*10.1.1 General Considerations**

New introductory paragraph explains that the RP focuses on unique capabilities that should be considered for production facilities.

Second paragraph introduces the owner's responsibility for identifying all applicable requirements and regulations and resolving conflicts between them.

7. Classification of areas

Consideration to be given to any FPS hull hazardous areas/effects on the process facilities and vice-versa.

8. Piping design

Provide adequate pressure relief systems and shutdown valves to avoid overpressure on the storage tanks.

Consider interfaces between marine and process systems and their differing design codes and practices.

*10.1.2b 1 Motions have significant effect on performance**

Addition of produced water decanting towers.

Additional paragraph on consideration of the effect of motions on the performance of machinery, cranes etc.

10.1.2d Arrangements and Layout

2. The requirement for an A60 firewall if the accommodation is 100ft or less distance from the process facilities has been removed. (See 10.3.2b)

*10.2.2a Bilge System**

Additional requirements for electrical components and adequate ventilation.

*10.2.3a Ballast System**

User is referred to RCS rules for piping arrangements in FPSOs.

*10.2.4 Cargo (Crude Oil) Systems**

Cargo piping passing through hydrocarbon areas have to comply with zone requirements as 10.2.2a above and piping through unclassified areas has to be totally welded without valves flanges or other appurtenances that pose potential leak paths.

A further paragraph allows electrical components to be installed in the cargo pump room providing zone requirements in 10.2.2a are satisfied.

*10.2.7 Inert Gas System**

Alternate over pressure protection is allowed through the use of a 3 way valve venting to a safe surface location.

*10.2.8 Crude Oil Washdown System**

An inert gas system is recommended if a COW system is utilised.

*10.2.10 Production Vent/Flare Systems**

The effects of such structures on the stability and motion characteristics of the FPS should be considered.

*10.2.11a Special Considerations**

Where the flare tower supports the hull tank's inert gas venting system careful selection of the venting point should be made with respect to the possible flare ignition source.

*10.2.11b Flare Configurations**

In certain circumstances more than one type of flare may be utilised simultaneously.

*10.2.11c Design Codes/Requirements**

6. Dispersion analysis is required for the venting of sweet gas. Gas detectors do not need to be installed if it can be demonstrated that hazardous conditions do not exist.

9. Emergency radiation can be considered where gas is continuously flared during online production when compression equipment trips and operational difficulties may result from shutting in the subsea wells.

*10.2.12 Electrical Systems**

Grounding – prohibits use of low voltage systems i.e. less than 1000 volt rms line to line.

Grounded systems are allowed where the return path is provided within the cable system. High resistance ground systems are recommended although low resistance is allowed by some RCS for medium voltage systems.

Integration – Careful co-ordination is required for the marine and industrial systems.

*10.3.1b Means of Escape**

On tanker shaped FPSs it is prudent to install a safe haven at the end remote from the accommodation and escape tunnels along the FPS.

*10.3.2b Structural Steel Protection**

A60 or higher fire protection should be considered on the accommodation sides facing the process facilities.

*10.3.2g Fire/Gas Detection Systems**

Line of sight gas detectors are suitable for open, unenclosed area gas detection.

Installation of flameout detection system for flare systems handling H_2S should be implemented.

*10.4.2a Atmospheric Tanks**

Gas or vapour may be captured in a closed vapour recovery system.

*10.4.3 Produced Water/Well Cleanup Fluids**

Hull tanks may be considered for use in enhanced gravity settling and chemical treatment.

Consideration of the temperature of the produced water and its impact on the tank structure and the possibility of sand carry over from the wells and its accumulation in the tanks.

10.4.4 Product Storage Integrity and Segregation Requirements

Double hull requirements of MARPOL removed since IMO do not apply this requirement to stationary vessels.

*11.3.2 Gas Export**

New paragraph on riser and pipeline export system for hydrocarbon and water transfer operating at higher pressures than low pressure transfer hoses.

*11.5.2 Limitations**

Added condition for the manoeuvrability of the offtaking tanker.

*11.6.2 Limitations**

Limiting wave height also depends on station keeping vessel bollard pull, location of manifold hose connection, ability of operations staff to safely access connection/disconnection area.

*11.6.3 Tandem Floating Hose Design**

Arrangements should be made to flush the hose to a shuttle vessel or back into the FPS tanks for routine maintenance.

*11.6.5 Hawser Design**

The hawser angle with respect to the fairlead may be monitored. Hawsers should be subjected to periodic inspection and testing at regular intervals.

*11.7.4e Submerged Turret Loading (STL) System**

This system allows the STL to weathervane.

*12.2.4 Stiffened Plates and Cylindrical Shells**

Fabrication is now in accordance with API BUL 2U or 2V or equivalent standard.

*12.2.7 Fabrication Details**

The owner shall designate critical locations where flame cutting and mechanical smoothing should apply.

*12.2.8 Other Fabrication Tolerances**

Special fabrication tolerances may be specified for special aspects of the design e.g. mating of a large deck to a spar hull.

*12.3 Mooring System Fabrication**

The mooring line should be manufactured in accordance with API Standards or RCS Rules.

*12.6.7 Commissioning and Start-Up of FPS**

The owner should develop procedures to address all aspects of commissioning, start-up, and associated safety and execution procedures.

12.7 Inspection and Testing

This section has been reduced to a reference to API RP 2A or RCS rules.

*13.2.1 General**

A list of reference standards is now provided.

For high stress connections use of a higher strength and toughness steel should be considered. For connections that load the steel perpendicular, use of through thickness steels would be appropriate to avoid lamellar tearing.

*13.3.1a General**

Structural steel in ballast and drillwater tanks is subject to higher corrosion and should be protected by an appropriate combination of coatings and sacrificial anodes. Exterior hull surface below waterline should be protected.

*13.31b Antifouling**

Use is subject to local regulations.

14.1 General

This section has been re-written.

14.2 Terms and Definitions

Previous section 14.7

14.3 Applications to FPS

This section has been re-written to include previous sections 14.3 to 14.5. Previous section 14.6 has been removed.

2.2 ISO/WD 13819-4

The latest version of ISO/WD 13819-4 (Draft C) has been updated from the previous version to reflect more closely the required ISO format. Thus, Section 1 of the previous version has been edited to become Sections 1 to 5 in the latest version, with a consequential increase in section numbers thereafter. However, the technical changes to the document have been relatively slight, the main areas being affected are mooring systems (Section 9) and riser systems (Sections 10.1 and 10.2) together with a new (informative) Annex B on mooring aspects. Section 9 has been modified by re-wording, adding or deleting sentences, mainly for the purposes of clarification. Section 10.1 introduces look-up tables for existing ISO, draft ISO and other standards with respect to their applicability to production, drilling and workover risers. Section 10.2 lists the referenced standards with their titles. The new Annex, it is stated, is the same as API RP 2SK, 2nd edition.

The comments below made with reference to the ISO standard are extracts from the document and are useful for comparing differences to and omissions in the API code. Significant changes to the latest draft from the previous version are also identified and new requirements are marked with an asterix. The comments are prefaced by the section references from the ISO document which have been renumbered from the previous version.

1.1 Scope

Includes TLP's.

5.3.3 Documentation

All relevant design criteria shall be summarised and documented in a single document (a "Design Basis") at the commencement of the structural design of a FPS.

5.4 Limit State Design

Ultimate, serviceability, fatigue and accidental damage limit states are defined.

6.7 Accidental Actions

The design value for accidental loads are based on an occurrence probability of 10^{-4}.

6.8.9 Temperature Actions

Structures shall be designed for the most extreme temperature differences.

7.1.6.3.3 The Fatigue Limit State

Fatigue life will be a minimum of the design life for non-substantial failure of components accessible to dry inspection through to 10 times the design life for substantial failure of components which are not accessible.

7.4.3.6.4 Fatigue

The minimum fatigue life of a TLP tendon is recommended at 10 times the design life unless a reliable inspection and replacement plan is employed in which case the minimum life is 3 times the design life.

7.6.7 Minimum Fatigue Life to Account for Prior Service

The required fatigue life for substantial non-accessible structural components on a 20 year service life increases from 200 years on a new construction to a maximum of 1200 years on a 20 year old vessel.

9.1 General

ISO plans to include synthetic rope design guidelines when the industry reaches a consensus on the design requirements.

*9.2.8 Atmospheric Icing**

Increased wind area due superstructure icing added

*9.3 Environmental Loads and Vessel Motions**

Spars may be subjected to significant low frequency vibration due to current induced vortex shedding.

*9.4.1.1 Introduction**

Active control of mooring system may be performed for certain operations but should not be considered in the mooring analysis.

*9.4.1.4 Riser Considerations**

Risers may be neglected in the mooring design if it can be shown to be conservative.

*9.4.2.2 Damaged Condition and 9.4.2.3 Transient Condition**

Thruster system failure added.

9.4.3.2 Maximum Offset

The phrase 'When frequency domain approach is used for the simulation of vessel dynamics' has been added to the definition of maximum offset.

*9.4.6 Thruster-Assisted Mooring**

Design guidance is given on the levels of thruster assistance for mooring systems.

*9.4.6.3.1 Mean Load Reduction Method**

More detailed design information given.

*9.5.1 Basic Considerations**

Design fatigue life is better defined.

*9.5.2 Fatigue Resistance of Mooring Components**

Design guidance is given on calculating the fatigue life of mooring line components.

*9.5.3 Fatigue Analysis Procedure**

More detailed guidance given on fatigue summation methods

9.6.2 Line Tension

Transient condition safety factors have been removed from Table 13.

9.6.4.1 Drag Anchor

Transient condition safety factors have been removed from Table 14.

9.6.4.2 Pile Anchor and Gravity Anchor

Transient condition safety factor has been removed form Table 15.

*9.6.4.4 Mooring Test Load**

Added that duration of test load should be at least 15 minutes.

*9.7.2.1 Mooring Wire Rope**

Material, design, manufacture and testing requirements are now to be in accordance with DNV Certification Notes No. 2.5.

*9.7.2.4 Mooring Buoy**

Motions of the buoy should be considered in the design of the connecting links for the buoy.

*9.7.4.1 Line Tension**

Added alternative of a device to detect mooring failure.

*10 Riser Systems**

Section 10.1 has been expanded to include a complete list of reference standards (including draft standards) required for the design of risers.

*10.5.1 Design Loads**

Reference to API 2RD added until ISO Standards are developed.

10.5.4.1 Environmental Conditions

Table 11 references not updated.

10.7.9.2 Crack Growth Rate

Reference to PD6493 removed and general rules given.

10.7.9.4 S-N data; Steel Base Metals

Reference to DOE-B curve removed.

11 Condition Monitoring

This section describes the establishment of a structural integrity management system (SIMS) through the life of the FPS. This specifies the level of inspection and condition monitoring required for various elements of the structure and the frequency required for each action.

*Annex B ISO Mooring Code**

A new section has been added which gives design guidance for mooring systems.

2.3 NORSOK N-004

The NORSOK Standard "Design of Steel Structures" issued in December 1998 is a traditional design guide for offshore structures but includes Annexes covering FPS structures. It does not cover the total scope of designing a FPS unlike the API RP 2FPS and the omissions are identified in the Table shown in Section 3.3.

The comments below made with reference to the NORSOK Rules are useful for comparing differences to and omissions in the API code. The comments are prefaced by the section references from the rules.

Annex L – Special Design Provisions for ship shaped units

L.1.1 General

This annex fulfils NPD rules but the unit also has to satisfy the RCS rules for standard hull design.

Production units will normally have a turret, but storage units may use a buoy.

This annex does not cover the requirements for moorings and risers.

This annex does not cover the requirements for a fixed mooring spread.

L.2.1 Safety format

Design is based on the partial safety methodology.

Units shall fulfil the minimum requirements of the DNV Rules for Ships, Pt.3 Ch.1.

L.3.1 Structural classification

Structural connections are to be designed to Design Class DC3, DC4, DC5.

DC5 are classed as non main loadbearing although the items specified do provide lateral stability to main structural members.

L.3.2 Material selection

Refers to variation in material properties e.g. yield stress with material thickness.

L.3.4 Guidance to minimum requirements

Detailed guidance on Design Class 4 inspection weldments.

L.4.5.3 Green water effect

Design loadings are given for exposed structural members typically 50% greater than Ship Rules.

L.8 Accidental limit states

Over-pressurisation of storage tanks is not mentioned as a hazard.

L.8.3 Explosion

The wording using 'locate hazardous areas' is surely wrong. It would be better to say 'identify hazardous areas'.

L.11 Documentation

This section specifies the requirements for documentation of the design basis and design brief.

ANNEX M – Special Design Provisions for Column Stabilised Units

A review of this document produces very similar comments to those given above for Annex L.

ANNEX N – Special Design Provisions for Tension Leg Platforms

A review of this document produces very similar comments to those given above for Annex L.

2.4 Lloyds Classification Rules

The comments below made with reference to the Classification Rules are useful for comparing differences to and omissions in the API code. The comments are prefaced by the section references from the rules.

Part 1, Chapter 2, Section 2 Classification regulations

The rules cover all types of floating offshore oil production units including semi-submersibles, deep draught caisson units and TLP's in both steel and concrete.

Part 1, Chapter 3, Section 4.3 In-water surveys

The rules allow for special In-water Survey in lieu of a Docking Survey.

Part 1A, Guidelines for Classification Using Risk Assessment Techniques to Determine Performance Standards

Introduces risk assessment techniques into FPSO design.

Part 3, Chapter 1, Section 5 Corrosion control

In-water survey units with hull scantlings derived from the ship rules are to have external cathodic protection and high resistance coatings.

Part 3, Chapter 6, Section 2 Operation in ice

Strengthening of hulls is required for ice loading and iceberg collision.

Part 3, Chapter 8, Section 1.4 Plant design characteristics

Process plant on surface type units is to be designed for an inclination of 22.5 degrees and on semi-subs and TLP's an inclination of 25 degrees.

Part 3, Chapter 10, Section 6 Anchor lines

Minimum factor of safety of 1.67 on anchor lines.

Part 3, Chapter 10, Section 8 Chains

Catenary chains require corrosion and wear allowance of 0.2 mm per year of service and 0.4 mm for touchdown zone and seabed chain sections.

Part 3, Chapter 10, Section 10.2 Drag embedment anchors

Anchor safety factor of 2.0 for static, 1.5 for dynamic and 1.15 for damaged dynamic.

Part 3, Chapter 10, Section 10.3 Anchor piles

Anchor piles safety factor of 2.0 for static and 1.5 for damaged dynamic.

Part 4, Chapter 3, Section 2 Design concepts

Primary structure to be designed using elastic methods unless limit state method is agreed with Lloyds.

Minimum design fatigue life is 20 years.

Part 4, Chapter 4, Section 4 Surface type units

Double hull construction is to be used in the oil bulk storage tank area.

Allowable structural stresses are based on the Lloyds Rules for Ships.

Part 4, Chapter 5, Section 2 Permissible stresses

Allowable axial/bending stress safety factor is 1.67 for operating loads and 1.25 for maximum environmental loads.

Part 4, Chapter 5, Section 5.6 Factors of safety on fatigue life

Structural fatigue safety factors are 2 for dry repairable, 4 for wet repairable and 10 for non-repairable.

Part 4, Chapter 6, Section 8 Double bottom structure

Double bottoms need not be fitted in oil storage units unless required by a National Administration.

Part 4, Chapter 8, Section 2.7 Butt welds

All critical primary butt welds are to be subjected to 100% NDE.

Part 4, Chapter 8, Section 4 Construction details for primary members

Primary steel minimum thickness is 7mm dry and 8 mm wet.

Part 4, Appendix A Fatigue

Fatigue design takes account of UK HSE Guidance Notes for Offshore Installations.

3. COMPARISON OF API RP 2FPS WITH OTHER DOCUMENTS

3.1 Cross Reference with ISO/WD 13819-4

The following table cross refers the sections of API RP 2FPS with the corresponding sections of ISO/WD 13819-4. This provides a high level link between the main sections of the two codes and also highlights some of the major differences.

API RP 2FPS	**ISO/WD 13819-4**
Section 1 – Planning	
1.1 Purpose and Scope	1.1 Scope
1.2 Applicable Codes & Standards	
1.3 Definitions and Terminology	1.3 Definitions and 4 Symbols & Abbreviations
1.4 Floating Production System Configuration	1.1 Scope & 5.3 General Design Requirements
Section 2 – Categorisation and Design Criteria	
2.3 Categorisation	
2.4 Design Criteria	
2.5 Accidental, Fire and Blast loads	6.3 Actions and Global Behaviour 6.7 Accidental Actions
Section 3 – Column Stabilised Units	
3.3 Design Cases	7.2.2 Design Practices
3.4 Global Response & Structural Analysis	6.3 Actions and Global Behaviour
3.5 Structural Design – Hull	7.1 Structural Design and Analysis & 7.2 Semi-submersible Units.
3.6 Fabrication Tolerances	7.1.9 Fabrication and Construction
3.7 Stability & Watertight Integrity	6.12 Compartmentation and Stability
Section 4 – Ship Shaped	
4.2 General Structural Considerations	7.3.1 General 7.3.2 General Design Criteria
4.3 Design Cases	7.3.3 Design Conditions
4.3 Structural Design	7.3.4 Structural Strength
4.5 Fatigue	7.3.4.5 Fatigue
4.6 Weight and Stability	6.12 Compartmentation and Stability
Section 5 – Spar	7.5 Deep Draught Caisson Units
5.2 General Structural Considerations	7.5.2 General Design Criteria
5.3 Design Cases	7.5.3 Design Conditions
5.4 Global Response and Structural Analysis	7.5.4 Structural Strength
5.5 Structural Design – Spar Hull and Deck	7.1 Structural Design and Analysis
5.6 Fabrication Tolerances	7.1.9 Fabrication and Construction
5.7 Stability and Watertight Integrity	6.12 Compartmentation and Stability
Section 6 – Other Hulls	Not covered
Section 7 – Conversion and Re-use	7.6 Conversion and Reuse
7.2 Design, Construction and Maintenance Standards	7.6.2. Minimum Design, Construction and Maintenance Standards
7.3 Pre-Conversion Structural Survey	7.6.3 Pre-Conversion Structural Survey
7.4 Effect of Prior Service	7.6.4 Effects of Prior Service
7.5 Corrosion Protection and Material Suitability	7.6.5 Corrosion Protection and Material Suitability
7.6 Inspection and Maintenance	7.6.6 Inspection and Maintenance

API RP 2FPS	**ISO/WD 13819-4**
Section 8 – Station Keeping and Anchoring Systems	9 Mooring Systems
8.3 Design Criteria	9.1 General, 9.2 Environmental Criteria, 9.3 Environmental Loads and Vessel Motions & 9.6 Design Criteria
8.4 Analysis Method	9.4 Mooring Strength Analysis
8.5 Innovative Deep Water Mooring Systems	Not covered
8.6 Special Consideration for Mooring Design	9.4.6 Thruster-Assisted Mooring & 9.5 Fatigue Analysis
Section 9 – Well and Production Fluid Control	10 Riser Systems
9.4 Well Completion Procedures & Subsystems	Not covered except by reference to API RP 2RD
9.5 Flowpath Systems	10.3.2 FPS Riser System Descriptions
9.8 Operation Inspection and Maintenance	10.8 Inspection, Maintenance and Replacement
Section 10 – Facilities	Not covered
10.1 Process Facilities 10.2 Utility Systems 10.3 Safety Systems 10.4 Product Storage Facilities	
Section 11 – Export Systems	Not covered
11.2 Types of Export Systems 11.3 Export System Design Considerations 11.4 Riser and Pipeline Export 11.5 Alongside Transfer 11.6 Tandem Transfer	
Section 12 – Fabrication, Installation & Inspection	
12.2 Structural Fabrication – Steel	7.1.9 Fabrication and Construction
12.6 Installation Operations	7.1.10 Marine Operations
12.7 Inspection and Testing	5.3.4 In-service Inspection and Maintenance & 11 Condition Monitoring
Section 13 – Materials, Welding & Corrosion Protection	
13.2 Steel	7.1.7 Material
13.3 Corrosion Protection	7.1.8 Corrosion Protection
13.4 Cement Grout	Not covered
Section 14 – Risk and Reliability Methods	5.3.5 Damage Tolerance & 11 Condition Monitoring

3.2 Differences Between API RP 2FPS and ISO/WD 13819-4

The major differences between the two codes are listed in the table below:

API RP 2FPS	**ISO/WD 13819-4**
TLP's excluded – refer to API RP 2T	TLP's included in section 7.4
Working stress design – Section 1.2	Limit State Design – Section 5.4 (see Note 1 below)
Little detailed design guidance since it refers extensively to other API Standards	Contains detailed design information on steel structures with limited reference to other standards
FPS configuration selection criteria – 1.4	Not covered
FPS Categories – Section 2.3 1 – greater than 5 years production system 2 – 60 days to 5 years early development system 3 – up to 120 days drill stem or extended well test	Not covered in this manner
Limited guidance on Mooring Systems	Section 9
Riser Design refers to API RP 2RD	Section 10.5 Design Loads and Design Criteria
Facilities Design – Section 10	Not covered
Export Systems – Section 11	Not covered
Risk and Reliability Methods – Section 14	Limited cover in Section 11
Design rules are specific to structure type and repeated in each section.	General design rules are established in Sections 5 and 6

Note 1. ISO also permits allowable stress design to be undertaken (Section 7.1.6.1).

3.3 Comparison with NORSOK Rules

The NORSOK rules are high level general guidance for the design of structural components and rely totally on other Norwegian specifications. The general guidance given is very similar to that expressed in the API code. The sections on weld inspection and structural design of the FPS are more detailed than API but are not considered significantly different to the corresponding API detailed references.

Major omissions include Spars, other hulls, conversion and re-use, well and production fluid control, facilities, export systems, risk and reliability methods.

API RP 2FPS	**NORSOK N-004**
Section 1 – Planning	
1.1 Purpose and Scope	1 Scope
1.2 Applicable Codes & Standards	2 Normative References
1.3 Definitions and Terminology	3 Definitions, Abbreviations and Symbols
1.4 Floating Production System Configuration	ANNEXs Section 1
Section 2 – Categorisation and Design Criteria	
2.3 Categorisation	Not covered
2.4 Design Criteria	ANNEXs Section 2
2.5 Accidental, Fire and Blast loads	ANNEXs Section 4
Section 3 – Column Stabilised Units	ANNEX M
3.3 Design Cases	3 Actions
3.4 Global Response & Structural Analysis	4 Ultimate Limit States
3.5 Structural Design – Hull	6.6 Design of Plated Structures
3.6 Fabrication Tolerances	Not covered
3.7 Stability & Watertight Integrity	8 Compartmentation and Stability
Section 4 – Ship Shaped	ANNEX L
4.2 General Structural Considerations	3 Structural Classification
4.3 Design Cases	4 Design Actions
4.3 Structural Design	5 Structural Response
4.5 Fatigue	7 Fatigue Limit States
4.6 Weight and Stability	9 Compartmentation and Stability
Section 5 – Spar	Not covered
5.2 General Structural Considerations	
5.3 Design Cases	
5.4 Global Response and Structural Analysis	
5.5 Structural Design – Spar Hull and Deck	
5.6 Fabrication Tolerances	
5.7 Stability and Watertight Integrity	
Section 6 – Other Hulls	Not covered
Section 7 – Conversion and Re-use	Not covered
7.2 Design, Construction and Maintenance Standards	
7.3 Pre-Conversion Structural Survey	
7.4 Effect of Prior Service	
7.5 Corrosion Protection and Material Suitability	
7.6 Inspection and Maintenance	

API RP 2FPS	**NORSOK N-004**
Section 8 – Station Keeping and Anchoring Systems 8.3 Design Criteria 8.4 Analysis Method 8.5 Innovative Deep Water Mooring Systems 8.6 Special Consideration for Mooring Design	Limited cover in ANNEXs
Section 9 – Well and Production Fluid Control 9.4 Well Completion Procedures & Subsystems 9.5 Flowpath Systems 9.8 Operation Inspection and Maintenance	Not covered
Section 10 – Facilities 10.1 Process Facilities 10.2 Utility Systems 10.3 Safety Systems 10.4 Product Storage Facilities	Not covered
Section 11 – Export Systems 11.2 Types of Export Systems 11.3 Export System Design Considerations 11.4 Riser and Pipeline Export 11.5 Alongside Transfer 11.6 Tandem Transfer	Not covered
Section 12 – Fabrication, Installation & Inspection 12.2 Structural Fabrication – Steel 12.6 Installation Operations 12.7 Inspection and Testing	Limited inspection cover in ANNEX's
Section 13 – Materials, Welding & Corrosion Protection 13.2 Steel 13.3 Corrosion Protection 13.4 Cement Grout	5 Steel Material Selection
Section 14 – Risk and Reliability Methods	Not covered

3.4 Comparison with Lloyds Classification Rules

The 1999 version of the Lloyds Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location provide detailed rules for all the different types of floating production systems and their mooring components. Although they make reference to the existing ship design rules the text includes much more detailed design guidance than the API code which generally relies on referring to more detailed specifications such as RCS rules or other API specifications.

Lloyds as a RCS, whose Rules are generically referred to by API, give detailed guidance in those areas where the requirements of their conventional RCS vessel Rules are not considered sufficient. To illustrate these more specific rules a few examples are shown in the table below and directly compared with the more detailed design specifications of the ISO code. The API code detailed design references are also included in the table.

Lloyds Rules	**API RP 2FPS**	**ISO/WD 13819-4**
Part 4 Chapter 3 Section 2 Fatigue life 20 years minimum	Refers to RCS rules	7.1.6.3.3 Life of vessel up to 10 x life of vessel
Part 3 Chapter 10 Section 6 Mooring line safety factor 1.67 intact, 1.25 damaged	Refers to API RP 2SK	9.6.2 Mooring line safety factor 1.67 intact, 1.25 damaged
Part 3 Chapter 10 Section 10.2 Drag anchor safety factor 2.0 intact static, 1.5 intact dynamic, 1.15 damaged dynamic	Refers to API RP 2SK	9.6.4.1 Drag anchor safety factor 1.5 intact, 1.0 damaged
Part 3 Chapter 10 Section 10.3 Anchor piles safety factor 2.0 intact, 1.5 damaged	Refers to API RP 2SK	9.6.4.2 Pile anchor safety factor 2.0 intact, 1.5 damaged
Part 4 Chapter 5 Section 5.6 Riser fatigue safety factor 4 accessible, 10 non-accessible	Refers to API RP 17A	10.5.9 Riser fatigue safety factor 3 accessible, 10 non-accessible

4. APPLICABILITY OF API RP 2FPS TO UKCS

4.1 Omissions in API RP 2FPS

The table below lists the major omissions of the API code when compared with the ISO code. In some cases the API code relies on other API standards but in some areas the ISO code provides more detailed information.

TLP structures covered in API RP 2T	See ISO Section 7.4 Tension Leg Platforms
Fatigue Resistance of Mooring Systems	See ISO Section 9.5 Fatigue Analysis
Design of Mooring Components	See ISO Section 9.7 Mooring Hardware
Riser Design covered in API RP 2RD	See ISO Section 10 Riser Systems
Condition Monitoring	See ISO Section 11 Condition Monitoring

4.2 FPS Design Considerations for UKCS

The table below lists some of the major design considerations for a recent harsh environment FPSO. The list is by no means inclusive particularly for the detailed decisions within each discipline but highlights the areas of concern considered in establishing the primary design principles of the FPS. The third column judges whether these subjects and criteria are adequately covered by the draft API.

Design Subject	**Relevant Criteria**	**Covered by API RP 2FPS**
Subsea System optimisation	Location of well templates, length of flowlines, common flowline sizing, multi-lateral wells, process requirements	Covered in section 1.4.1i and section 9
Flow assurance	Integrated team design from wellhead to offloading tanker, component and system reliability	Limited cover in section 9
Hull configuration	Double bottom, double hull, collision protection, oil leakage detection, waxing	Limited cover in sections 10 and 14
New build or conversions	Design life, safety levels for environment, internal corrosion, conversion cost, original specification	Covered in section 7
Material selection	High strength steel, fatigue limited working stresses, local impact strength, weldability, toughness, ice resistance	Limited cover in section 13
Turret location	Balance mooring and riser forces against weather vaning	Partially covered in section 8.6.4
Turret or bow mooring	Number of risers, well co-mingling, disconnectable?	Limited cover in sections 2 and 8
Mooring design	Chain or wire or hybrid, fatigue life, anchors or piles	Partially covered in section 8
Dynamic positioning or thruster assist	Long term reliability, redundancy, energy consumption	Partially covered in section 2.4.8
Accommodation location	Bow – environmental loads, helicopter access, proximity to turret hazards Stern – downwind of fire and smoke	Partially covered in section 10.1.2d
Flare type and location	Radiation on accommodation, dynamic motions and ship stability	Covered in sections 10.2.10 and 10.2.11
Green water effects	Bow design and height, facilities deck protection	Covered in section 4.2.6
Integrated control systems	Ship control, process facility control, level of instrumentation, training of operators	Limited cover in section 10

4.3 Other Aspects

The API document is well structured with a consistent level of design guidance throughout based on a working stress approach to design. It deals with the main principles of each subject covered and in many cases makes references to the specific sections of other established API codes for detailed design guidance. It deliberately omits guidance on TLP and riser design by relying on the existing API RP 2T and API RP 2RD. The review showed few areas of disagreement with the principles expressed and most of the comments above related to clarification or a desire for further detailed guidance. There have been several improvements to the API document as a result of the recent revision and it now reflects a broad range of industry experience.

The review of the ISO document shows a more limited document which primarily deals with the structural and marine engineering aspects of FPS's using a limit state design approach. The ISO document is more complete in these areas than the API code due to the inclusion of more detailed guidance information. Again there were few areas of disagreement with the principles expressed and the detailed design guidance was consistent with corresponding fixed installations. The structure of the ISO document differs to the API and Lloyds documents in that general design principles are established for all floating vessel types at the beginning of the code in Sections 5 and 6.

The 1999 Lloyds design rules are the most comprehensive design guide reviewed in this study. They include a wealth of detail and reflect the recent experience of Lloyds in Classifying harsh environment FPSO's. The scope of the Lloyds Rules is broader than the ISO code and very similar in the range of subjects covered to the API code. A limited number of direct detailed design rule comparisons showed similar design requirements to the ISO code. It is understood that both DNV and ABS have also recently produced design rules similar in detail to Lloyds.

The NORSOK rules are general design documents which only give detailed guidance in the structural design of FPS's. They rely on the range of other Norwegian Specifications in a similar manner to the API document but the design subjects covered are less extensive and therefore less complete than API. A detailed list of omissions is given in Section 3.3.

An important aspect of a FPS design code for the UKCS is the combination of two different design cultures i.e. traditional merchant ship design and construction with the high technology, quality and safety culture of the offshore oil and gas industry. A successful outcome will be the retention of the economy and speed of construction of the world's leading shipyards with the highly automated, safety conscious production facilities of the North Sea.

The API code is therefore more suitable than the ISO or NORSOK documents for developing a UKCS guidance document. The ISO document has some useful additional guidance in the areas listed in the table in section 4.1 above. Many of the harsh environment design considerations listed in the table in section 4.2 above are mentioned in the API code. The suitability of the detailed references to other API standards would need to be investigated for compliance with harsh environment design practice.

The authors believe that there is merit in producing a specific UKCS guidance document for FPS's since the existing documents do not completely cover the harsh environment requirements of such installations. A combination of the API code with such a guidance document would produce a more workable document together with appropriate references to the more extensive details within the classification rules such as Lloyds. Risk assessment is a UK requirement and its rigorous application to all the safety critical elements would allow the duty holder to discharge his regulatory responsibilities. Section 14 of the API document addresses risk and reliability methods in some detail and Part 1A of the Lloyds rules introduces the principles.

5. RECOMMENDATIONS FOR FURTHER INVESTIGATIONS

The final draft version of API RP 2FPS is due to be published at this time and will become the basis for the design of FPS's in US coastal waters. MMS and the USCG were represented on the drafting committee and it is expected they will both issue guidance notes for the benefit of operators using the new code.

A similar guidance note for the UKCS would be beneficial to ensure that development applications for FPS's can be approved more quickly through potentially reducing the requirement for detailed HSE safety assessments of each application. The guidance note would only identify those areas of the API code which require further special consideration due to the hostile North Sea environment and to historic specific operational concerns from existing UKCS FPS installations.

The guidance note would require two specific items of investigation as follows:

1. A systematic review of the detailed API code references to ensure that these cover the current practice and experience of existing North Sea design standards and specifications. This may lead to the requirement to comply with other codes or specific RCS rules where appropriate.

2. A review of operating experience and incidents related to existing North Sea FPS's to ensure that the lessons learned are incorporated into the initial design process.

Following MSL's experience in being a member of the drafting committee developing the final API code and their extensive experience in North Sea design and repair it is anticipated that the guidance note could be developed to a first draft within three months subject to the assistance of HSE. The document would then require circulation and comment from North Sea operators, designers and constructors before final issue to the industry.

6. CONCLUSIONS

API RP 2FPS is a reasonably complete high level design philosophy document for most types of FPS's and the associated components. It excludes TLP's and makes extensive reference to many other API standards for detailed design rules. On the other hand ISO/WD 13819-4 in its interim version concentrates mainly on the detailed structural and marine engineering design aspects of various FPS's including TLP's and as such it is a more complete design guide in this more limited aspect. Similarly NORSOK only covers the structural engineering design aspects of FPS's and has major omissions of specific FPS types and components. API uses a working stress design approach and ISO and NORSOK a limit state approach, although ISO does allow the use of a working stress design format. All codes allow the designer to use Recognised Classification Societies Rules for the naval architecture design of the floating vessel.

The final draft API code provides the most suitable design basis for the UKCS subject to a more thorough examination of the specific cross references in the text to detailed API design guides. The practical design requirements of harsh environment FPS's should receive more detailed discussion and guidance, if the API code were to be used in the UKCS.

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