Guideline for managing marine risks associated with FPSOs

Report No. 377
April 2006
Global experience

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Report No: 377
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Acknowledgements

This report was produced by a task force of the OGP Safety Committee/
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I Introduction

Scope

Floating structures for production, storage and offtake have been used safely and reliably throughout the oil industry for many years. Early installations were primarily floating storage and offtake vessels, “FSO”, but today the modern floating production, storage and offtake vessel, “F(P)SO” includes processing equipment and a higher level of sophistication. Consequently, the F(P)SO becomes an offshore producing installation, storage facility and loading terminal all rolled into one unit.

The F(P)SO and the FSO present many of the same hazards to personnel and the environment, although the inclusion of production facilities on the F(P)SO increases the risk associated with any marine incident. This guide considers both types of installation using the term F(P)SO and only distinguishes between the two when the difference from a marine perspective is significant.

There are many different types of F(P)SO, including, for example, weather-vaning designs with internal or external turrets, or spread moored designs that maintain a fixed position and orientation. Early F(P)SOs in the 1980s, taking advantage of a severe downturn in the tanker market, were converted from relatively new tankers. More recently, the tendency has been to use new, purpose-built, generally ship-shaped hulls, particularly for F(P)SOs associated with long field-life projects. However, conversions of tankers – both old and new – continue to take place.

The F(P)SO allows oil companies to produce oil in more remote areas and in deeper water than would have been economically possible with other technology. The F(P)SO allows storage of crude oil and loading of tankers in the field rather than requiring a pipeline to transport oil to an onshore terminal facility. The provision of storage and loading has introduced additional hazards, however, which require the wisdom and experience of both oil field and marine experts to manage the associated risks.

Approach

These guidelines are intended to introduce project personnel, operators, and managers to the marine hazards associated with all types of F(P)SOs irrespective of configuration and geographic location. Such hazards include:

- Long-term exposure to environmental conditions without access to economical repair facilities
- Additional motions and stresses induced by a floating ship-type structure
- Potential collision with offtake tankers and field support vessels
- Potential pollution associated with frequent transfers of crude oil

Notwithstanding these hazards, F(P)SOs have proven to be very safe, low-risk operations. These guidelines describe the considerations necessary to maintain marine risks at very low levels.

The guidance contained has been collated from operating and design experience contributed from committees and individual experts and also much information contained in reports in the public domain and published national, international and industry standards. These have been referenced in the text where appropriate and for illustration a single standard may have been cited, the reader should be aware that other references (some are contained in the bibliography of this document) may be used and will contain similarly useful information.

References

A selection of references is available from the OGP FPSO website – http://info.ogp.org.uk/fpso

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2 Definitions

The following terms and acronyms are used throughout this publication and are defined here for clarity:

API
American Petroleum Institute

ANSI
American National Standards Institute

AWS
American Welding Society

BHAB
British Helicopter Advisory Board

BOP
 Blow Out Preventor

BS&W
Basic Sediment and Water, measured from a liquid sample of the production stream. It includes free water, sediment and emulsion and is measured as a volume percentage of the production stream.

CAA
Civil Aviation Authority (UK Agency)

CAP
Civil Aviation Practice

CoF
Certificate of Fitness

COLREGS
International Regulations for Avoiding Collisions at Sea

Control Station
Point of control designed on installation where control of key process variables may be undertaken

Conventional Market Tanker
Same as a General Trading Tanker

COWed
Crude Oil Washed

Dedicated Shuttle Tanker
A vessel designed for offtake of cargo from an F(P)SO. Such a vessel would normally have a bow loading system and a means of station keeping relative to the F(P)SO, without the aid of tugs.

DP
Dynamic Positioning

DSV
Diving Support Vessel

E&P
Exploration and Production, the stages of field development from reservoir identification and assessment (type and extent) up to and including the development options for producing from the fields.

EER
Escape, Evacuation and Rescue

EIA
Environmental Impact Assessment is a report or exercise that considers the potential of the development to affect its environment. Effects may arise from, changes in waterway or associated shore/terminal use, the introduction of new features to the seabed and emissions to land, water or air.

EPIRB
Emergency Position Indicating Radiobeacon

ERP
Emergency Response Plan

ERS
Emergency Response Strategy

ESD
Emergency Shut Down

F&G
Fire & Gas (Detection)

F(P)SO
Term used in this Guide to designate either an FSO or an FPSO when the discussion could apply whether or not the unit has production facilities on board

FEED
Front End Engineering Design

Fish tailing
Where the relative heading of the offtake tanker to the F(P)SO changes rapidly and often, the offtake tanker moving from one side of the F(P)SO to the other.

FPS
Floating Production System is a floating facility which is designed to receive crude oil from producing wells and process it, but has no facilities for storage. Export would be usually via pipeline to shore or to a nearby FSO

FPSO
Floating Production, Storage and Offloading System includes, in addition to storage and offloading capability, facilities for receiving crude oil from producing wells and processing it for export by separating water and gas.

FSO
Floating Storage and Offloading System consisting of a ship or barge-shaped floating hull incorporating tanks for storage of produced oil, and a method of loading the oil onto offtake tankers.

FSU
Floating Storage Unit is a floating facility intended only for storage of oil. Export would generally be via pipeline to an onshore facility. Sometimes used synonymously with FSO.

FSV(s)
Field Support Vessel(s)

General Trading Tanker
A typical tank vessel commonly available in the market for worldwide trading. The vessel should be fitted with an OCIMF bow mooring arrangement for mooring to a single point mooring, and a midship manifold arrangement for connecting to floating hoses.

GMDSS
Global Maritime Distress and Safety System
HAZID
Hazard Identification (process or exercise)

HOF
Human and Organisational Factors

Hs
Significant Wave Height

HSE
Health, Safety and the Environment, generally pertaining to issues causing adverse effects.

ICP
Independent Competent Person

ICS
International Chamber of Shipping

IMCA
International Marine Contractors Association; the international trade association representing offshore, marine and underwater engineering companies.

IMO
International Maritime Organization, a UN agency headquartered in London with the goal of developing international conventions to promote marine safety and prevent damage to the marine environment by shipping

INMARSAT
A global mobile satellite communications operator, formed from an intergovernmental organisation, providing a range of voice and multimedia communications services.

ISGOTT
International Safety Guide for Tankers and Terminals

ISM
International Safety Management code

ISO
International Standards Organization

Ku
Ku-band satellite technology, broadcasting at ultra-high frequencies

MARPOL
International Convention for the Prevention of Pollution from Ships

MODU
Mobile Offshore Drilling Units

OCIMF
Oil Companies International Marine Forum

Offtake Tanker
A tank vessel receiving the cargo from an F(P)SO. The vessel may be a dedicated shuttle tanker or a general trading tanker.

OIM
Offshore Installation Manager

OSPAR
Oslo Paris Commissions, a Ministerial meeting in 1992 that adopted a new Convention for the Protection of the Marine Environment of the North-East Atlantic (the “OSPAR Convention”)

PLEM
Pipe Line End Manifold

POB
Personnel On Board

PTW
Permit To Work (system)

ROY
Remotely Operated Vehicle (subsea)

ROYSV
Remotely Operated Vehicle (subsea) Support Vessel

SCE (s)
Safety Critical Element(s)

SI
Statutory Instrument, a regulatory instrument in UK law.

SOLAS
International Convention for the Safety of Life at Sea

SPM
Single Point Mooring

SRB
Sulphate Reducing Bacteria

STL
Submerged Turret Loading, STL technology was a result of a demand in the market for loading systems with high availability in harsh environments

STS Loading or Operation
Ship to Ship Transfer, whereby the offtake tanker is brought alongside the F(P)SO and cargo transfer is through a manifold to manifold connection.

Tandem Loading
This arrangement describes the mooring of the offtake tanker by the bow to the stern or bow of the F(P)SO.

TEMPSC
Totally Enclosed Motor Propelled Survival Craft

Tp
Time period between wave peaks

TR
Temporary Refuge

TVP
True Vapour Pressure

UNCLOS

VOC(s)
Volatile Organic Compound(s)

WG
Water Gauge, used as a measure of low pressure.

WSE
Written Scheme of Examination
3 Risk Assessment

Scope

The section presents a general methodology for undertaking the risk assessment, that is identifying the hazards and their associated consequences and probabilities, which may be encountered during the lifetime of the F(P)SO. The overall aim being for an organisation to be able to demonstrate to itself and the regulator that the risks are understood and that adequate measures have been taken to manage the risks.

The Operating Parameters of the F(P)SO are in part determined by the risk assessment. All activities should be governed by safe systems of work which include the requirement for appropriate preparation, procedures and processes, competent and properly trained people, and plant and equipment that has been designed and constructed for the task.

Optimising production uptime whilst achieving safe operation will be the aim; ensuring that there are steady, reliable and predictable operating conditions to match the plant and F(P)SO design specification.

A major constraint on F(P)SO operation is to recognise the balancing demands of achieving optimal plant throughput and allowing timely off-take before the storage on the F(P)SO is full and production has to be curtailed.

F(P)SOs operate in an extremely wide range of areas, weather and sea conditions, and with quite different support functions available from their support bases. To achieve an appropriate and accurate risk assessment and implement effective hazard management measures, it will be necessary to develop “local rules” to cover such marine and production activities, eg access to the main deck during severe weather, restricting the draft in preparation for storm conditions, etc.

Risk evaluation and management

The OGP report Guidelines for the development and application of health, safety and environmental management systems (Ref. 4) describes an overall methodology for undertaking a risk assessment, and developing a risk management strategy. The methodology is applicable to all forms of offshore installation.

This section considers the risk evaluation and management strategy which can be adopted for field development through the use of an F(P)SO. However, it is important that an appropriate risk evaluation is undertaken at the concept selection phase to demonstrate that an F(P)SO and its associated offloading and support systems is an acceptable development option compared to other structural forms.

The stages in the risk evaluation and management process are shown in Figure 3.1.
Identify hazards and effects

The first stage involves the systematic identification of the hazards and their effects which are expected to be encountered during the lifetime of the F(P)SO.

The identification should include consideration of:

- Planning, construction and commissioning phases
- Routine and non-routine operating conditions, including shut-down, maintenance and start-up
- Incident and potential emergency situations, including those arising from:
  - Product/material containment failures
  - Structural failure
  - Climatic, geophysical and other external natural events
  - Sabotage and breaches of security
  - Human factors including breakdowns in the HSE Management System
- Decommissioning, abandonment, dismantling and disposal
  - Potential hazards and effects associated with past activities

Personnel at all organisational levels should be appropriately involved in the identification of hazards and effects.

On an F(P)SO, marine based systems interface with E&P systems. As a result hazards may arise which are not usually addressed on fixed installations. It is essential that these hazards and their effects are recognised. This can be achieved by ensuring that the personnel involved in the hazard identification stage include individuals with experience in both E&P and marine based systems.

The Hazard Identification exercise (HAZID) should be rigorous, it should build on previous industry experience and should propose a methodological process. There are strengths and weaknesses of adopting a generic checklist, these are described below;

The strengths of a generic hazard checklist are:

- It makes use of experience from previous risk assessments.
- It helps to prevent past accidents from recurring
- It promotes standard hazard categories, and facilitates comparison between HAZIDs
- It requires minimal information about the installation, and so is suitable for concept design

Its weaknesses are:

- It is limited to previous experience, and thus may not anticipate hazards in novel designs or novel accidents from existing designs
- It does not encourage intuitive / brainstorming thinking, and so gives less insight into the nature of the hazards on the installation.

Overall, a generic hazard checklist is useful for most risk assessments but should not be the only HAZID method, except for standard installations whose hazards have already been studied in more detail.

Reference should be made to Appendix 2 for a generic and comprehensive checklist of potential hazards.
Evaluation
Procedures should be maintained to assist the evaluation (assessment) of the risks and effects from identified hazards against appropriate screening criteria, the assessment should take account of probabilities of occurrence and the severity of the consequences for:

- People
- Environment
- Assets

It should be noted that any evaluation technique provides results which may be subject to a range of uncertainties in data or method. Consequently formal risk evaluation techniques are used in conjunction with the judgement of experienced personnel, regulators and the community.

Risk evaluation should:

- include effects of activities, products and services;
- address effects and risks arising from both human and hardware factors;
- solicit input from personnel directly involved with the risk area;
- be conducted by qualified and competent personnel;
- be conducted according to appropriate and documented methods; and
- be updated at specified intervals.

Evaluation of health and safety risks and effects should include, where appropriate, consideration of:

- fire and explosion;
- impacts and collisions;
- drowning, asphyxiation and electrocution;
- chronic and acute exposure to chemical, physical and biological agents; and
- ergonomic factors.

Evaluation of acute and chronic environmental effects should include, where appropriate, consideration of:

- controlled and uncontrolled emissions of matter and energy to land, water and the atmosphere;
- generation and disposal of solid and other wastes;
- use of land, water, fuels and energy, and other natural resources;
- noise, odour, dust, vibration;
- effects on specific parts of the environment including ecosystems; and
- effects on archaeological and cultural sites and artefacts, natural areas, parks and conservation areas.

Recording of hazards and effects
Procedures should be maintained to document those hazards and effects (chronic and acute) identified as significant in relation to health, safety and the environment, outlining the measures in place to reduce them and identifying the relevant HSE-critical systems and procedures.

In addition, a record should be kept of the statutory requirements and codes applicable to the HSE aspects of operations, products and services to be used on the F(P)SO and to ensure compliance with such requirements.
**Objectives and performance criteria**

Procedures should be maintained to establish detailed HSE objectives and performance criteria at relevant levels.

Such objectives and performance criteria should be developed in the light of policy, strategic HSE objectives, HSE risks, and operational and business needs. They should be quantified, wherever practicable, and identified with defined timescales; they should also be realistic and achievable.

As a follow-up to risk evaluation procedures should be maintained to set performance criteria for HSE-critical activities and tasks, which stipulate in writing the acceptable standard for their performance. It should also, at specified intervals, review the continuing relevance and suitability of the criteria.

**Risk reduction measures**

Procedures should be maintained to select, evaluate and implement measures to reduce risks and effects. Risk reduction measures should include both those to prevent incidents (i.e. reducing the probability of occurrence) and to mitigate chronic and acute effects (i.e. reducing the consequences). Preventative measures such as ensuring asset integrity should be emphasised wherever practicable. Mitigation measures should include steps to prevent escalation of developing abnormal situations and to lessen adverse effects on health, safety and the environment and, ultimately, emergency response measures to recover. Effective risk reduction measures and follow-up requires visible commitment of management and on-site supervision, as well as the understanding and ownership of operations personnel.

In all cases consideration should be given to reducing risk to a level deemed “as low as reasonably practicable” reflecting amongst other factors local conditions and circumstances, the balance of cost and benefits and the current state of scientific and technical knowledge.

Procedures should be in place to:

- Identify prevention and mitigation measures for particular activities, products and services which pose potential HSE risks.
- Re-appraise activities to ensure that the measures proposed will reduce risks from those activities and that other relevant objectives of the activities (i.e. some measure of functional success) can still be met.
- Implement, document and communicate to key personnel the interim and permanent risk reduction measures, and monitor their effectiveness.
- Develop relevant measures such as plans for emergency response to recover from incidents and mitigate their effects.
- Identify hazards arising from risk prevention and mitigation and recovery measures.
- Evaluate the tolerability of consequent risks and effects against the screening criteria.

Note that within the context of the measures above, prevention should be considered to include inherent safety approaches of elimination and avoidance of the hazard wherever possible.
4 Design considerations

Scope

This section describes the risks from marine activities that should be considered at the F(P)SO design stage in order to achieve an overall safe and reliable F(P)SO design with minimum risk to health, safety and the environment. Principal design considerations covered in this section include overall layout of facilities, hull and mooring design, and arrangements for safe and efficient operation. Factors and recommendations associated with the F(P)SO cargo handling system are included in section 6, Hydrocarbon Handling and factors associated with offtake arrangements are covered in section 7.

All of the sections in this chapter describe aspects of design that should be implemented to achieve a good working product. It should be emphasised that preparation and planning to implement these considerations is a common theme. A cost-effective, safe and productive F(P)SO will be developed from enshrining common objectives across all parties contributing to its development and at the design stage this can be achieved by choice of contract and project management style. The development of F(P)SOs has been particularly challenging as development practices and contract familiarity has had to accommodate two quite separate industrial cultures, namely marine and offshore oil and gas. The issues arising from contract and project management style should be faced squarely, based on a distinct decision-making process that recognises the issues surrounding each form of arrangement and puts in place measures to address the shortcomings. The decisions should be based on the type of development, geographic location, technology available, level of lifetime support sought or required, commercial judgements and contract risk, and the decisions should be taken at the outset of the project.

Regulatory regimes for F(P)SO operations.

Offshore installations throughout the world are subject to a variety of International, National (coastal state), Flag and Classification Society Rules and Regulations covering their basic integrity and safe operation. The requirements are usually governed by the laws of the local coastal or territorial waters' National Authorities, but particularly where no relevant legislation exists, they may also be influenced by the requirements of the Insurance Underwriters or Operator’s company policy. Where legislation exists, these requirements commonly take the form of formal Certification or Verification Regulations, both of which may include the requirement for a Safety Case and may also specify Flagging and Classification of the vessel. There may also be an Operator policy for implementation of a voluntary Certification or Verification regime.

It should be noted that the governing National Authorities may include not only the Marine Administration but also Government departments concerned with Mines, Energy or Safety, each with their own separate requirements. The legislation they enforce may be simple one-line requirements or complex, and may not strictly be intended for floating installations, leading to a requirement for close liaison with the administration.

This guide points to some sources of regulatory requirements. It is also important as part of the Front End Engineering Design (FEED) to maintain a dialogue with national and local government bodies to assure that the installation meets the requirements of the host government.

Safety, health and welfare of people both on the F(P)SO and in the local communities, together with the demands of environmental management must remain in the forefront of management’s attention when planning and implementing an F(P)SO project.

The following notes are intended to be a general guide to what may be expected.
Certification

Generally speaking, Certification implies a prescriptive regime, associated with a set of Regulations or “Guidance Notes” (e.g., the now superseded 4th Edition Guidance for Statutory Instrument 289 (SI289) in the UK). The extent and nature of the requirements do however vary considerably, from comprehensive and specific stand-alone rules to simple sets of one line requirements or cross-references. It may cover all aspects of the installation or certain parts only (for instance, sometimes only the structural integrity is covered). Certification will require examination of the installation by an independent third-party body and frequently there are requirements for selection of this body. In recent years, many Certification regimes have been complemented by Safety Case Regulations, following the lead of the UK, post Piper Alpha.

Certification generally has its roots in compliance with recognised oil and gas industry codes and standards such as AWS D1.1, ANSI B31.3, etc. Indeed, where the Certification rules are not extensive, this is likely to be entirely the case. Where Safety Case regulations also apply, the analyses performed may be used as supporting justification for concessions to codes and standards. Certification generally requires the issue of a “Certificate of Fitness” (CoF) by the independent third-party body. There may be a requirement to maintain the validity of a CoF throughout the life of the installation, requiring a system of periodical surveys by the independent third party.

Verification

This approach (sometimes known as Validation – e.g., in Australia) is focussed on the Safety Integrity of the installation and is based on a formalised approach to risk assessment and management such as a Safety Case regime and is at its most developed in UK waters. There is no requirement for a CoF; in general, the law places the responsibility for Verification with the operator or Duty Holder, who is required to have a “Written Scheme of Examination” (WSE) for the installation, which is verified by an “Independent Competent Person” (ICP). The Safety Critical Elements (SCEs) of an installation must be identified by a formal hazard identification exercise and standards of performance must be set to ensure that these SCEs are designed and built to perform their required role throughout the life of the installation. The WSE specifies the initial and periodical Verification activities of the ICP, which are intended to verify that each SCE remains in a satisfactory condition.

Verification requires that scrupulous records are kept at all times by the Duty Holder and ICP of the various activities described above. Although recognised codes and standards frequently remain the cornerstone of design and construction for installations, this regime requires the Duty Holder to think beyond slavish compliance and instead investigate all risks. Thus, whilst novel approaches which do not meet the requirements of codes and standards are allowed, equally, a need for standards well in excess of these may arise.

Role of the classification society

The concept of “Classification” has developed within the marine industry to provide interested parties (insurance companies, cargo owners, etc.) with a degree of assurance that a ship has been designed, constructed and maintained in accordance with sound principles.

Classification societies provide this assurance on the basis of published “rules” that are derived from a combination of empirical requirements based on service experience and engineering first principles. The rules define how a ship is to be designed, constructed and inspected throughout its life to assure the safety of both the cargo and the crew. A classification certificate is issued and Class is maintained through a series of annual and special (5-year cycle) surveys, which are intended to ensure that the vessel is being maintained in a suitable condition to the intent of the Rules.

F(P)SOs evolved initially from converted tankers and several classification societies have modified their ship rules to reflect the specific requirements of F(P)SO service. Although the concept of “Classification” is not strictly necessary for offshore installations, classification societies’ long history of establishing and assessing design standards for ship structures and machinery systems has provided them with unique expertise. This is particularly so in the design and fatigue assessment of stiffened-plate structures. In this regard, they
have established themselves as credible independent verifiers of structural design and operational adequacy, which may be required by a local government.

It is recommended therefore that F(P)SO operators involve a classification society in the design and construction (or conversion) of an F(P)SO hull and associated marine systems. Considering, however, that an F(P)SO differs in several key respects from a tanker, the operator should be careful to select a society that has significant experience with F(P)SOs. The operator should also reach an early understanding with the classification society on such key issues as project life and environmental conditions, and on the scope of the verification effort that will involve the society.

Classification societies are evolving a risk-based approach applied to verification. This allows the operator of an F(P)SO to demonstrate equivalence (or better) to the requirements prescribed in “traditional” rules. This feature is particularly suitable for novel designs, unusually harsh environments or unusually benign environments where conditions may be outside of those normally encountered.

If the classification society is intended to have continued involvement with in-service inspection, the operator should develop a complete understanding with the society on how and how often inspections will be carried out.

**Flagging**

Strictly speaking, there is no general requirement for a permanently moored F(P)SO installation to be flagged or to comply with international maritime law, as it is not a vessel *undertaking international voyages*. However, in cases where an F(P)SO will proceed to site under its own power or where it may be taken off station a flag may be desirable or necessary. In addition, some Coastal states require that F(P)SOs operating in their waters be Flagged, either under their own jurisdiction, or under another Flag State and that they are issued with international statutory certification as if they were on international voyages.

Flagging a vessel places the responsibility on the operator of ensuring compliance with international marine standards as required by the administration of the Flag State. The regulations are generally those imposed by the International Maritime Organization (IMO), an agency of the United Nations. Flag administrations apply international statutory requirements directly or through national agencies, which may ask for additional requirements. For example, a US Flagged vessel must comply with the prescriptive requirements of the US Coast Guard and a UK Flagged vessel must comply with the prescriptive requirements of the UK Maritime and Coastguard Agency.

For compliance with Flag state requirements, F(P)SOs may require the issue of at least the following certification:

- Safety Construction Certificate (SOLAS 974)
- International Oil Pollution Certificate (MARPOL 73/78)
- International Loadline Certificate (1966)
- International Tonnage Certificate (1969)
- Shipboard Safety Management Certificate (ISM Code)
- Certificates for Masters, Officers or Ratings

These certificates would be issued by the Flag State or by Class on behalf of the Flag State. The Flag state would also expect the following certificates to be issued by the Class Society supported by appropriate yard and manufacturers’ documentation:

- Certificate of Class (hull, machinery, etc)
- Certificates for Lifting Equipment/cranes
- In Europe, compliance with applicable directives (F(P)SOs will generally be considered to be offshore installations and not ships)

National administrations may also have requirements for compliance with environmental and occupational health/safety codes eg ISO 14001 and ISO 18001.
Metocean considerations

The ability of the F(P)SO to meet safety, environmental and performance targets during the range of weather and sea conditions that may affect it requires planning and modelling based on reliable metocean data. This represents significant difficulties in newly exploited areas where wind, wave & current data are limited.

Weather and sea conditions at the site affect:

- Type and strength of the mooring system to assure that the F(P)SO remains safely moored under all expected environmental conditions
- Global strength of the hull required to resist wave-induced stresses and fatigue as well as hull loading due to stored cargo and process facilities.
- Structural design of the hull to minimise repairs and prevent hydrocarbon leakage due to fatigue cracks or to green water damage on deck
- Strength of the topsides supports
- Topside arrangements to prevent operator exposure to hydrocarbon vapours and equipment exposure to vessel accelerations
- Arrangement of the offloading system to assure safe, pollution-free transfer of crude oil to offloading tankers

For new locations, global environmental models can be used early in the design process to approximate site conditions. In established areas such as the North Sea and the U. S. Gulf of Mexico, extensive data are readily available. However, it is important to gather site-specific data on winds and sea states during early exploration of the location and to refine continually these data as the development progresses.

Currents are more difficult to predict and the associated data are more expensive to obtain; however, the characteristics of currents and the forces associated with them are important for the design of the F(P)SO mooring system, the offloading system and the various risers and umbilicals attached to the F(P)SO. Currents may include ocean circulating currents, tidal currents, wind-driven currents and river outflow. Strong tidal currents have been known to cause an F(P)SO to swing beam to the sea, causing severe rolling. Currents may vary in both strength and direction with depth, season and time of day. Some current data are usually available from early exploratory drilling operations. These usually relate to currents well below the ocean surface and are relevant to the design of risers. However, currents in the top 10 to 20 meters of the water column are the most significant for the marine design aspects of an F(P)SO. Attention paid to early gathering of current data over the full range of depth during exploration drilling will pay design dividends later.

Important sources of both local weather and current information are other offshore installations and marine activities in the area. It is recommended that as early as possible in development planning marine experts visit the area to discuss local conditions with mooring masters, harbour masters and pilots, commercial fishermen, etc.

F(P)SOs have been installed in water depths varying from a few tens of meters to in excess of 1000 meters. Water depth will impact on the type of mooring system and loads that both the mooring system and risers impart to the F(P)SO hull.

It is important that structures are tested in representative multi-directional waves, especially when evaluating the extreme roll response. This may result in having to consider larger vessel movements, but may lead to benefits by allowing moorings of a lower capacity to be used. Tests carried out have also indicated some dependency on spectral shape and content of the wave field, and possibly on the loading condition.

The following conclusions regarding greenwater loading may be drawn, however, it must be noted that greenwater events are vessel specific and therefore the findings of reference studies can only be regarded as indicative of the relevant vessel shape:

a) Long crested sea conditions seem to give rise to the highest number of greenwater occurrences.

b) The main areas of susceptibility are the bow, just aft of the bow bulwark where the freeboard is lower and aft of amidships.
c) Compared with the nominal 100-year design condition, significantly more greenwater events may occur with the steeper wave conditions (even within the nominal 1-year event).
d) The loading condition may have an effect on the number of greenwater events and the distribution of the susceptible areas along the vessel’s hull.

In design calculations and model tests of new F(P)SOs the important aspects to focus on are:
- Establishing green water zones in order to plan the layout of equipment and placing the safety equipment.
- Establishing forces and the capacity of structures and equipment placed in the green water zones.
- Establish contour lines for Significant Wave Height (Hs) and time between wave peaks (Tp) and perform evaluations of green water for a full range of relevant sea states.

**Field layout**

The layout of surface and subsea facilities must be carefully considered early in the design to account for hazards associated with:
- Passing ships and local community activities, such as fishing
- Supply and maintenance vessels in relation to anchoring or dropped objects,
- Anchor mooring patterns of drilling rigs during locating and moving
- Safe access by offtake tankers, avoiding interference with other moorings, flowlines and risers as well as other field operations

The field layout must be clearly defined, in particular the areas delineated by the extremities of the field. Knowledge of the extremities including, flow-lines, umbilicals, well heads, manifolds, and anchoring pattern must be made clear to all parties involved with the movement of craft in or near the field. This knowledge is essential to ensure that risks to people, the environment and the asset are minimised and movement of craft within the area is properly controlled.

**Safety distances around F(P)SOs**

In co-operation with the host country government a safety or restricted zone should be established around the facility. This will provide the basis for limiting activities such as fishing and other vessel traffic that could damage facilities. The United Nations Convention on the Law of the Sea (UNCLOS Article 60.5), provides for designers to make provision for a reasonable safety zone around fixed platforms. UNCLOS (Article 60.5) states that such zones shall be designed to ensure that they are reasonably related to the nature and function of the “installations or structures” and shall not exceed a distance of 500 metres around them measured from each point of their outer edge. Similar considerations should be made in establishing a safe zone around an F(P)SO installation, considering that a turret-moored F(P)SO with other surface production facilities may occupy a much larger “footprint” than a platform.

Submission of field layout to the relevant hydrographic office or offices is important to assure that mariners are notified of potential obstructions to navigation and that the field facilities are noted on any updates to nautical charts.

**Tanker manoeuvring areas**

The field layout must also consider the need for offtake tankers to approach the F(P)SO, moor, load their cargo, unmoor and proceed to open waters, always in safety. The parameters for achieving this, which will include manoeuvring areas and weather limits on operations for the tankers, may be derived by means of a risk assessment study as described in OCIMF Offshore Loading Safety Guidelines – With Special Relevance to Harsh Weather Zones [Ref. 10]
For the purpose of determining the manoeuvring areas for offtake tankers operating to and from an F(P)SO, designers should take the following factors into account:

- **Approach** – the distance required for the tanker to safely approach the loading point on a straight course. Necessary allowances should be made for slowing down of the vessel during the final approach; for turning into the straight course; and for aborting the manoeuvre. Allowance should also be made for the presence of another tanker in the area, either departing or on standby.
- **Departure** – the distance required for the tanker to safely let go and clear the area at any time and in emergency.
- **Access route** – a safe route of adequate water depth must be provided from the loading point to deep water.
- **Anchorage or waiting area** – an area should be designated where arriving tankers can safely wait and remain clear of other tankers approaching or departing the loading point and avoid risk of damage to pipelines, moorings, and other facilities on the seabed.

The distances required will depend upon a number of factors including but not limited to:

- Prevailing winds, currents and/or tidal streams at the location;
- Availability of tugs/support craft (number and horse power);
- The station keeping and manoeuvring characteristics of the tanker(s) – bow and/or stern thrusters, dynamic positioning etc.
- Size of tanker to be accommodated

Berth utilisation, production rates, and storage capacity are other considerations. For example, can delays or downtime be accepted awaiting suitable conditions for berthing a tanker? This may determine whether the manoeuvring area is circular around the F(P)SO or remote loading point, so that the tanker can approach from any direction, or whether the approach will be restricted to a particular sector. The departure area should normally be a full 360 degrees to allow departure at any time and in any direction.

**Hydrocarbon characteristics**

Storage and transfer of hydrocarbons present hazards to personnel and the environment which are not generally present on a production platform. These include:

- The need to vent continuously hydrocarbon vapours during loading presents a potential hazard to personnel due to toxic vapours and a potential for structural damage due to over-pressure.
- Water and other contaminants in the crude can accelerate corrosion of the F(P)SO structure and systems resulting in premature failure and, potentially, escape of hydrocarbons to the environment.
- Crudes with high viscosity or a high pour-point require heat to permit efficient transfer of the crude and to avoid damage to transfer equipment.
- Hydrogen-Sulphide (H₂S), if present in the crude, may disassociate as a gas and present a hazard to personnel both on the F(P)SO and on the offtake tanker. Additionally, the gas and sulphate reducing bacteria will increase corrosive effects and design allowances should be made; also see section 6, Hydrocarbon Handling.

It is expected that the crude oil process facilities will deliver crude to the F(P)SO tanks that is of export quality. That is, vapour pressure will be suitable for the intended delivery destination (generally in the range of 10-11 TVP @ 100˚F) and water and sediment (BS&W) content will be minimal.

It is important that the venting system be designed to accommodate the maximum volume of volatile organic compounds (VOCs) vented from storage. Allowance must be made the higher temperatures experienced at maximum production rates and for possible process upsets. In some areas, local regulations or guidelines limit the amount of VOCs that may be released to the atmosphere. Consequently, it may be necessary to adopt loading practices that will minimise VOC emissions.
At times, the crude loaded in F(P)SO storage tanks still contains significant quantities of water and the tanks become, in effect, the last stage of separation. Produced water can be very aggressive and may, in addition, contain sulphate-reducing bacteria. The quality of coatings and cathodic protection within the cargo storage tanks is therefore important to prevent penetration of the tank structure due to corrosion. Slop tanks should be fully coated and fitted with sacrificial anodes. The cargo storage tanks should be coated on the bottom to protect from water dropout. Positioning of sacrificial anodes within the cargo tanks to provide back-up protection in the event of local coating breakdown is recommended. The most vulnerable area is the bottom plating and as such, the anodes should be as low as possible and in any event within 30 mm of the bottom.

The top surfaces of storage tanks should be coated to protect against condensation, particularly if the crude contains large amounts of H$_2$S or inert gas is produced from fuel containing significant amounts of sulphur.

Temperature is an important parameter. Equipment manufacturers must specify the maximum temperature that their equipment is designed for, in particular, pump seals, valve seals and tank coatings.

**Turret and riser systems**

As with other offshore systems, F(P)SO turret systems can be subject to degradation in service. Anecdotal information on damage or failures in F(P)SO turret and riser systems has come from a number of sources. The generic failure topics are reproduced below to provide guidance when selecting and specifying turret systems.

- Failure of swivel seals
- Turret – cracking of elastomeric riser bend-stiffeners
- Flexible riser connections – slippage of internal layers
- Vessel structure – cracking around turret cavity and moonpool
- Greenwater damage
- Gas swivels – leakage
- Drag chain systems - flexible riser leakage
- Sudden rotation of turret
- STL turret-buoy
- Effects of excessive roll
- Cracking of pipe supports
- Production pipework - corrosion and weld root erosion
In-Service Life

The design life of an F(P)SO for its planned use in any one location should be defined at the outset of a new F(P)SO project. Failure to do so could result in the following:

- Premature structural failure due to fatigue or corrosion
- High maintenance and repair costs due to lack of access to dry-docks and other repair facilities
- Lower production volumes due to equipment problems

A significant possibility is that field developments may extend the life of an F(P)SO beyond the original design intention. This could result from a field being more prolific, with a longer producing life than originally anticipated, or from in-fill drilling and tying-in of new discoveries. Consequently, consideration should be given to allowing a substantial margin when defining design life.

The definition of the intended design life will impact the following areas of F(P)SO design:

- Structural fatigue (see next section, Hull Design Criteria)
- Extent of structural repairs (for conversions)
- Corrosion protection features and quality, both inside the hull and externally
- Provision for access to sea valves and other underwater equipment without access to a dry-dock
- Provision for access to structure and equipment for periodic inspection and maintenance
- Maintenance and overhaul of any propulsion or heading control units. A number of these units are now available which can be removed for overhaul whilst the F(P)SO is in service
- Redundancy of key operating equipment
- Provision of spare parts and on-board repair facilities

Hull design criteria

Storage capacity

Adequate storage capacity for the F(P)SO must be established to reduce hazards associated with:

- Frequent production shut-in or possible overfilling of tanks due to inadequate storage
- Frequent mooring and un-mooring of offtake tankers due to small parcel sizes

A study of offloading requirements should be undertaken, possibly using modelling techniques, and should incorporate the following considerations:

- Design production rate or production profile
- Parcel size range expected for the target sales market
- Wind and sea conditions at the F(P)SO site
- Offloading method and its limitations
- Type of offloading tanker and its operating limitations
- Unpumpable oil quantities or minimum draft limitations

The operator will need to examine the trade-off between the cost of incremental storage and the possibility of production shut-in or the cost of tanker delays while considering the overall safety of the operation.

Stability

An F(P)SO must maintain adequate positive intact stability at all times. Like tankers, single skin FSO’s usually are very stable owing to their low centre of gravity, wide beam and subdivision of tanks. F(P)SOs may have a higher centre of gravity with their large topside loads. F(P)SOs with double bottoms or double hulls are more susceptible to stability problems particularly if the arrangement of ballast tanks gives rise to large free surface areas. It should be emphasised that the movement of liquids in both ballast and cargo tanks may give rise to significant free-surface effects. This problem is exacerbated in F(P)SOs due to the constantly changing levels as production is pumped into and out of the tanks.
Stability can also be affected by loss of ballast control and dependent upon the vulnerabilities of the system and subsequent consequences of failure, this system should be considered as a Safety Critical Element. In addition, the consequences of accidental flooding into large machinery spaces should be considered in the HAZID and ERPs (Ref. 34).

Loss of stability can give rise to violent movements from side to side which may injure personnel, damage equipment or upset processing. Stability conditions need to be examined and assured under the full range of ballast and crude loading cases.

Emergency response preparedness will require the ability to evaluate stability in damaged scenarios in order to avoid taking action that might further endanger the situation. Damage stability calculations are complex and it is recommended that arrangements are made to secure rapid specialist assistance.

**Strength and fatigue**

Structural design of an F(P)SO must consider the strength requirements to accommodate loads due to the environment, stored crude and topside facilities. The design must also allow for long-term fatigue damage due to wave loads and hull motion. Hazards that can be avoided with proper structural design include:

- Structural failure due to overloading
- Hull cracks and potential crude leakage due to accumulated fatigue damage

The basic strength requirements for F(P)SO structures are well covered by the principal classification societies, who have decades of experience in the design of similar structures for ships. However, F(P)SOs also must accommodate a number of localised loads that are not encountered in ship design. These include:

- Facilities/topsides support loads
- Flare tower
- Mooring loads from turrets or mooring lines
- Loads from turret-mounted or side-mounted risers
- Greenwater loading on both forward structure and deck mounted facilities
- Towing loads on hull structure
- Potential collisions with workboats and other small craft

These loads need to be considered taking into account vessel loading and motions both at the permanent site and during the tow to site.

Furthermore, while ships have access to dry-docks and repair yards at regular intervals F(P)SOs must be designed to operate without access to dry-docks and on-shore repair facilities for their entire design life, which may be as long as 20-25 years. Consequently, much higher emphasis needs to be placed on design of structural details, fabrication quality, and fatigue life with particular emphasis on accessibility of the structure for inspection and repair.

Environmental loading is another aspect where F(P)SOs differ from ships. Ships are expected to operate throughout the world’s oceans. F(P)SOs, however, make only one long distance voyage (usually under tow) and then are expected to survive extreme environmental loading at the production site (unless the F(P)SO is designed to disconnect at some lesser condition). Site conditions may be less severe than normal ship design criteria, as they would be in West Africa, or they may be significantly more severe, eg in the North Sea.

For F(P)SOs converted from existing tankers, an assessment must be made of the fatigue damage accumulated by the hull in its previous tanker service. Most classification societies have developed methods of assessing this damage and assessing the future structural loading imposed by site-specific conditions.
Collision damage and impact scenarios

The methods used to assess collision are often simplified due to the complexity of the transformation of the energy prior to collision into rotational, translational and strain energy after the collision. One method of simplification considers the time duration of impact, when the duration of impact is short compared to the natural periods of vibration of the system, the collision event is essentially dynamic. However, if the duration of impact is long compared to the natural periods, as is normally the case, the impact can be treated as quasi-static. Complexities also occur with internal mechanics when the distribution of strain energy between the struck and striking vessel is to be determined.

Facilities Arrangement

Arrangement of facilities on the F(P)SO should be made to minimise hazards to the operating personnel and facilities due to:
- Potential fire and explosion
- Cargo and inert gas vapours
- Potential greenwater on deck
- Potential contact with the offtake tanker
- In some locations, unwanted visitors

The physical arrangement of the F(P)SO will generally be determined by the topsides facilities, however there are a number of marine considerations that should be kept in mind:
- Providing safe access to machinery and equipment located in or on the hull
- Access to a safe refuge with blast and fire protection as well as access to sufficient covered lifeboat or escape capsule capacity for the entire complement at the quarters end of the F(P)SO
- Provision of unobstructed passages for escape to a temporary refuge - in harsh environments the passages may be enclosed tunnels, whereas in mild climates they can be open walkways on the hull deck set to the side of and below the process deck
- For large F(P)SOs consideration should be given to providing a smaller temporary refuge with access to an escape capsule at the opposite end
- Provision to prevent any oil spills to the hull deck from reaching the water by leading them to a slop tank
- Location of the Quarters with due consideration to protection from cargo vapours
- Location of the flare to prevent exposure of personnel and equipment to excessive temperatures and to avoid damage to or by offtake tankers
- Provisions of overside lighting to monitor hoses and other in-water equipment
- Provisions to limit access

The future changes and growth of equipment on the F(P)SO should be considered and a positive judgement made on the strategy followed (rather than being left to a default position). It is important to consider the growth and upgrade potential of the F(P)SO at the design stages eg topside modifications and withdrawal route for deep tank submersible pumps.
Mooring system

An F(P)SO mooring system must be designed to minimise the following hazards:

- Possible failure of the vessel’s moorings under maximum anticipated environmental conditions
- Excessive movement of the vessel and possible damage to risers and flowlines

The codes and recommended practices for the design and analysis of stationkeeping and mooring systems should be followed (eg API RP2SK). The established codes provide a well-recognised basis for the design of mooring systems, covering preliminary design of moorings using quasi-static methods and final design approaches using dynamic analysis methods. The factors of safety reflect the accuracy of the analysis method. For deepwater applications, it is important to include the contribution of riser loads, stiffness and damping in the mooring analysis.

F(P)SO size, environmental conditions, water depth, number of risers and seabed conditions will govern the type of mooring system used. In many areas, directional variability of wind, waves and current will require that the F(P)SO be connected to its moorings by means of a turret in order to minimise the loads imposed on the mooring system.

Turrets may be internal to the hull or mounted on an extension of the hull. Internal turrets may be either passive, where the hull position responds to the environment without assistance, or active, where thrusters are required to align the vessel to the environment. Selection of the type of turret requires the consideration of all of the design factors noted above and should include an assessment of the risk of thruster failure if an active turret is considered.

In certain areas where the environmental conditions are very mild and, for the most part, uni-directional, an F(P)SO can be moored in a fixed orientation with a so-called spread mooring. This avoids the complications of accommodating a turret in the hull structure and the operational issues associated with maintaining a turret and swivel. However, it may also make other issues, such as direct offloading, more difficult to accommodate.

Modelling may be considered to identify mooring system and offtake tanker behaviour and understand if modifications are necessary for the expected maximum weather conditions established in the environmental criteria.

Make up of the mooring lines will be dependent on water depth but will, in general, be chain or chain/wire combinations. Recently operators have considered polyester mooring lines, but so far little experience exists with these lines. It appears, however, that great care needs to be exercised to assure that laying on the bottom during installation does not contaminate the lines.

Anchors that have been successfully used for long term moorings for F(P)SOs include:
- Drag anchors.
- Piled anchors.
- Suction anchors.
- Gravity anchors

Anchor and mooring systems should be designed for “life of field”. Piled or suction anchors are generally the preferred system as these can be pre-installed and moorings pre-laid. With these anchors, modern survey equipment can allow moorings to be pre-cut, which allows attachment to the F(P)SO with greater ease and less risk.

The system with all components intact should be checked in the 100 year storm environment. Acceptable factors of safety are 1.67 against breaking strength if a dynamic analysis is used or 2.00 if a quasi-static analysis is used.

If thruster assisted moorings are used, then the system should be checked in the 100 year storm environment. The system should exhibit appropriate factors of safety for either dynamic or quasi-static analysis. The generally recommended factors correspond to an equivalent case where a mooring line is broken.
The dynamic behaviour of a damaged system should be analysed to check that the maximum excursion is within flexible riser limitations. Again, the system should exhibit an appropriate factor of safety for both dynamic and quasi-static analysis.

Although thrusters may be used for mooring assistance, they may be fitted to F(P)SOs for several different reasons:

a) To maintain a heading in vessels fitted with an amidships turret that do not have natural weathervaning.

b) To provide a major part of station-keeping capability in a deeper water application.

c) To fine-tune the heading to minimise roll motions so that the process is settled, the crew remain comfortable and to assist shuttle tanker operations.

Thrusters may also be useful in fire or platform abandonment scenarios where the vessel can be rotated to clear fire or smoke from around production areas and living quarters and to provide a lee side for survival craft launch.

Thruster redundancy will depend on the duty requirement and will require an assessment of the probability and consequences of failure and the reduced capability of the system. The thrusters type selection should take into account the maintenance at sea requirements and allow working parts to be withdrawn into the hull for inspection and repair rather than diver-assisted keel hauling. It should also be noted that thrusters may well be Safety Critical Elements.

In category (a) above, the thrusters are transverse, normally tunnel-mounted with sufficient power to unwind the vessel before the limits of the drag chain hose transfer system on the turret are reached.

In category (b), the thrusters are a combination of transverse thrusters to maintain heading and longitudinal thrusters (which could be the main propulsion in a converted vessel) to reduce the environmental load transmitted to the mooring system.

In category (c) the thrusters are transverse stern-mounted, either tunnel or azimuthing. The power requirements are relatively small, since the thrusters are used only to fine-tune heading in moderate sea-states, and not to achieve major weather vaning. They may be used where the wind and current are not co-linear with waves or swell, resulting in heavy rolling.

During shuttle tanker connection and loading, the thrusters may be used to reduce fish tailing and slow down changes in F(P)SO heading following a change in tidal strength or direction.

Thruster sizing and type selection is a function of the duty requirements above, and the environmental loads the thrusters have to overcome. The environmental loading and thrust requirements must be assessed using accepted and proven methods or more accurately from wind tunnel and model tank testing. Thrust requirements will need to be increased for the effects of water inflow speed due to high currents.
Design of offloading equipment

Chapter 7 (Offtake Arrangements) provides a detailed description of various methods and arrangements for offloading of an F(P)SO. Except for loading through a remote Single Point Mooring (SPM), these methods require some means of connecting an offloading tanker to the F(P)SO (usually a hawser or hawsers) and a means (usually a hose) of transferring crude oil from the F(P)SO to the offloading tanker.

The risks during this operation include:
- Loss of mooring between the F(P)SO and the offtake tanker
- Breakage of offloading hose

Offtake tanker moorings

Mooring hawser(s) and associated equipment should be designed to take into account the maximum expected loads imposed by the operational environment and by relative vessel motions. OCIMF Publications Mooring Equipment Guidelines, Second Edition, 1997, [Ref. 15] and Recommendations for Equipment Employed in the Mooring of Ships at Single Point Moorings [Ref. 16] provide background on the type of equipment that is standard on industry tankers. It is advisable to conduct model tests or dynamic simulations to fully evaluate mooring loads under various environmental conditions.

Consideration should be given to providing the following features in the offtake tanker mooring system:
- Hawser tension monitor
- Alarm system advising of high and very high loads with defined actions in the event design loads are exceeded
- Emergency release of the hawser under load, for example by hook or a patented stopper

Hose strings

The transfer hose may be a floating hose string of a length to reach the manifold of the offtake tanker from the offtake point on the F(P)SO, taking into consideration the criteria as laid down in the OCIMF publication [Ref. 16]. Alternatively, the hose may be deployed from the F(P)SO to the offtake tanker bow connection. In either case, the diameter of the hose string should be commensurate with the designed discharge rate of the F(P)SO and the fluid velocity limits recommended by the hose manufacturer.

In the case of a floating hose, a single hose string of a larger diameter may be more practical than two strings of smaller diameter. The tanker rail hoses should be of a size that can easily be handled by the lifting equipment on expected market tankers considering dynamic loads, end fittings, etc. In any event, they should not be greater than about 400mm (16 inch) diameter. It may thus be necessary to have twin tail hoses from a single hose string.

Emergency shutdown and release

Offloading systems must be designed so that they can be easily connected to a shuttle tanker and released very quickly in an emergency situation without any pollution or damage to the equipment. Emergency Shut Down (ESD) facilities should be installed so that by pressing one button, pumps will stop and valves will close.

If the offloading system is designed to operate with shuttle tankers with bow loading systems, emergency shutdown can be extended such that by pressing only one button, pumps will stop, valves are closed and hose is released in correct sequence to avoid any pollution. After the hose end is released, the mooring hawser can be released automatically. The system must be designed so the mooring hawser and the offloading hose can be retrieved back to the F(P)SO without any damage and ready for use again after an emergency release.

If the offloading system is designed to operate with conventional market tankers, safety devices, such as breakaway couplings and shut-off valves can be built-in to the floating hose string to prevent pollution if emergency disconnection takes place. Often, a monitoring system on the F(P)SO monitors pressure in the
offloading hose and the tension in the hawser connection to the tanker. Higher readings than the pre-set values will alarm or automatically initiate pump stop and closing of offloading valves on the F(P)SO.

**Line flushing**

Whether for operational or maintenance reasons there will be a need to flush the cargo from the hoses with sea water from time to time, and arrangements should be made to receive the contents into the F(P)SO.

The seawater line flush may be made by the F(P)SO, by the offtake tanker, or by a support craft. Modern tankers carry only segregated ballast with no permanent cargo system connection to the sea; consequently, it is becoming more difficult to rely on them to provide the line flush. Thus the F(P)SO should be fitted with a seawater pumping arrangement and hose connection for the tanker end of the hose. Alternatively, the support craft can be fitted with a seawater pump and hose connection.

If the F(P)SO is fitted with a circulation system for flushing the hose, this may also be used to charge the hose with cargo following maintenance. This will avoid passing seawater to the next offtake tanker, with the attendant commercial problems.

**Communications**

It is important to maintain good communications between an offtake tanker and the F(P)SO. For harsh environments such as the North Sea when using dedicated shuttle tankers, telemetry communication between tanker and F(P)SO gives both vessels the ability to initiate any emergency shutdown or emergency release of offloading systems and mooring system. For facilities using conventional market tankers, this communication is usually provided by means of portable radio equipment carried by a mooring master who boards the tanker prior to connection and remains aboard until cargo transfer is complete.

**Logistical considerations**

**Mooring arrangements for support vessels**

The F(P)SO design must be compatible with the requirements, mooring arrangements and intended operating philosophies of all support vessels that attend on a regular basis. These may include mooring support vessels, supply/service vessels, standby vessels, maintenance/diving support vessels, crew boats, and bunkering vessels. The need for such vessels to come alongside and tie-up before beginning their work should first be considered within the overall hazard assessment of the F(P)SO, particularly in the context of risks from vessel to vessel impact or from vessel to riser impact. For example, spread-moored F(P)SOs may have fixed risers along one side and require all regular vessel activity to take place along the other side. Consideration should be given to providing these vessels with Dynamic Positioning (DP) capability in accordance with the principals established in Ref. 17, IMCA M103 – Guidelines for the Design and Operation of Dynamically Positioned Vessels.
Cranes for over-side working

Crane(s) onboard the F(P)SO should be designed to be of sufficient capacity and reach to enable the lifting/backloading of maintenance materials, containers and supplies etc from/to the support vessels. Such capacity and reach should be determined within the framework of the operating environment, the weather working limits, and combined motions of both the F(P)SO and support vessels. Generally, cranes designed for offshore platforms may not be able to accommodate the vessel motions associated with an F(P)SO. The well-established available standards for cranes applied to offshore structures should be considered as a basis for crane design, these include API Recommended Practice 2C, Specification for Offshore Cranes and EN 13852-1, Cranes: Offshore Cranes Part 1, General Purpose Offshore Cranes.

Crane(s) onboard the F(P)SO should also be designed to be of sufficient capacity and reach to support the maintenance activities of the onboard process equipment, minimising the need for manual handling tasks and/or the use of free standing materials handling equipment.

If diving support is to be provided from the F(P)SO, consideration should be given to the role and additional design requirements of the onboard crane(s) that diving activities may require. Space should also be provided for lay-down of diving support equipment and other diving related material.

Materials handling onboard

The lifting and stowage of cargo containers, loose items of equipment, and bulk tanks introduces the risk of a swinging load or a “dropped object” to both the F(P)SO as a vessel and the process equipment. Layout design for any transit and storage areas on deck should therefore minimise:

- The distance that containers must be carried at height by the crane
- The need to travel over process and piping or other hydrocarbon-containing equipment
- The location of lay-down areas close to any sensitive or safety critical equipment

Accommodation and marine cultures

The accommodation represents the common area where Marine and Operational crews come together and also where all of the crew return to relax and rest. Several design issues that should be considered early in accommodation design are:

- Locating the accommodation for motion sickness as well as production support and for major accident hazards
- Considering the mix of crews and ensuring that the best of either traditional marine or offshore is included in the facilities provided
- Ensuring that marine equipment does not generate high noise levels due to high transmissibility of low frequency noise and vibration from slow moving rotating equipment
- Provision for additional crew required during commissioning and later periods of maintenance and anticipated upgrades
5 Delivery, installation and commissioning

Scope

This section covers marine activities and events from the time the F(P)SO leaves the fabrication site to its commissioning at its final location. It discusses some of the risks that are faced during this critical period in an F(P)SO’s life and suggests mitigating measures.

These risks include:
- Damage to the F(P)SO hull or topsides structure during transit due to unfavourable weather conditions.
- Loss or damage to the F(P)SO due to inadequate towing vessels and/or equipment
- Injury to personnel during transit, installation, or commissioning
- Damage to other field facilities during installation

Planning & execution of delivery

An F(P)SO is usually delivered from the shipyard or an integration site to its field site by either towing or self-propulsion. At the time of writing, both methods have been used successfully with no major incidents reported. Careful planning is required to achieve successful delivery by considering the issues described in the following sections.

Preparation for transit

In preparing an F(P)SO for transit, particular attention must be paid to the structural loading of the process deck supports as the towing period may represent the most severe loading that these supports will experience.

Strict limits on pitch, roll, etc. should be documented to assist the Tow Master’s decision-making process. Any or all of the following strategies may be used to limit structural loading during the transit:
- Beam Seas Avoidance
- Sea Fastenings
- Temporary Bracings
- Unique Ballast Patterns

Towing

For F(P)SOs without self-propulsion, towing is the only practical option available to bring the vessel from the shipyard to the production field. Even for vessels capable of self-propulsion, towing may be selected dependent upon propulsion capacity and readiness at time of relocation. Towing is usually slower and takes a longer time than self-propulsion.

F(P)SOs may be towed either manned or unmanned, but this decision should be made during the design stage to ensure that adequate provisions are made for the selected method.

Manning the vessel during the tow may provide early warning of any problems developing, such as ingress of sea water or structural damage. Manning also permits the testing and operation of certain equipment, such as ballast pumps, during the tow. It requires, however, that the necessary accommodation facilities be provided, including shelter, power supplies, food, potable water, and sewage. International regulations will require that adequate life saving appliances are available and ready to be deployed.

In many respects, an unmanned tow is simpler, but provision must be made to allow personnel to board the vessel at sea in the event that it becomes necessary to operate some of the vessel’s equipment.

The towing operator and towing vessels should be carefully selected to ensure that they will be able to reliably tow the F(P)SO at the desired speed, within the schedule and during an acceptable weather window. The operator should be able to demonstrate prior successful experience with similar tows and the qualifications of key officers and crewmembers should be also checked.
The underwriters’ usually require review and approval of the proposed towing plan. This should be co-ordinated sufficiently ahead of time to allow proper time for review and approval.

In addition to an independent review by the underwriters, the operator’s qualified mariners and other supporting personnel should carry out an in-depth investigation of the condition and history of the towing tugs. This should include all items such as adequacy of supplies, condition of equipment, telecommunication equipment, spares, condition of class and any other regulatory bodies, proper charts for the voyage route and condition of all safety equipment. All equipment that will be used in the towing operations, such as wire ropes, should be checked for adequacy and condition. Strength and quality of the towing brackets on the F(P)SO and tug should be confirmed. The condition of spare or emergency towing wires should be checked. Spare or emergency rope deployment method should be confirmed.

**Self-propelled transit**

Self-propelled transit to the production field is an option for F(P)SOs that have been converted from conventional tankers. It is also an option for newly built F(P)SOs that have been fitted with adequate thruster capacity, although this is less common.

Self-propulsion usually offers the advantage of shorter transit time due to higher attainable speed. It also eliminates the expense of chartering powerful ocean-going tugs. Offsetting these advantages is the need to maintain the F(P)SO as an operating ship, meeting all requirements of the vessel’s flag state and international regulations for safe operation. It is also necessary to employ a qualified marine crew to man the vessel during the transit and to arrange provision for disabling the vessel’s propulsion and steering equipment after arrival at the site, if the propulsion is not required to maintain the vessel on station.

In summary, long transits will tend to favour self-propulsion (where feasible) whereas short transits will favour towing.

In the cases where the F(P)SO has a detachable turret, the thrusters will be required to move the vessel safely off station in potentially quite severe sea and weather conditions. It is essential to define a very clear protocol for these manoeuvres so that the designers have precise criteria for sizing the thrusters and defining their reliability and robustness as under such circumstances they will certainly be defined as Safety Critical Elements.

Thus, when fitting and sizing thrusters, it is essential to consider all aspects of thrusters use during the various life cycles of the F(P)SO.

**Transit planning**

A comprehensive transit plan should be prepared with the objective of getting the F(P)SO and the tug boat(s) safely to their destination. The plan should include at least the following:

- Routing with respect to adequate water depth, potential for safe havens, and avoidance of hazards
- Expected weather, including extreme conditions, over the voyage route
- Preservation of equipment on board the F(P)SO from extreme weather (eg freezing) and sea conditions
- Reviewing all emergency scenarios, contingencies and countermeasures to mitigate emergencies
- Communication procedures during the transit and periodic reporting formats
- Availability of fuel and supplies and a restocking plan if necessary

The towing plan should include the appointment of an experienced Tow Master. The Tow Master carries a key responsibility for delivering the F(P)SO to the installation site. His key role is the safe co-ordination of the towing operation and he is responsible to the operator for the safe execution of marine activities.

The towing plan should take account of heavy weather that may be encountered on the passage, which may be incorporated into the F(P)SO structural design criteria for both towing as well as structural survival. In certain heavy weather areas, areas close to land or for large F(P)SOs, consideration should be given to the use of multiple tugs both for an F(P)SO being towed or as a tug escort for F(P)SOs under self-propulsion.
The transit plan must recognise areas for shelter and “Ports of Refuge” in the event of severe or unseasonable bad weather. It must be recognised, however, that keeping an F(P)SO under tow at sea may be less of a risk than entering a safe area or a “Port of Refuge”. This decision must rest with the Tow Master but clear criteria and guidance must be provided.

For an unmanned tow or tow of significant duration, all equipment on board must be adequately secured and preserved. For tows expected to go through areas susceptible to pirates, anti-piracy measures should be provided in co-operation with the responsible naval or coastguard authorities. Adequate ballast quantities should be taken on board for safe towage and to prevent damage from rough weather. Proper lighting to conform to COLREGS should be provided on the F(P)SO and the tug.

**Planning & execution of installation**

It is highly likely that the operator may have several contracts in place to execute the overall project works as well as other field activities such as drilling and exploration. To prevent conflicts and to ensure safe separation of all equipment operating in the area and to ensure co-operation and harmonisation between all affected parties, the operator or his designated contractor must produce contract interface and co-ordination procedures. These procedures should be prepared sufficiently ahead of time and in turn reviewed, understood and accepted by all concerned parties.

For executing the installation works of an F(P)SO, the operator has three discrete tasks to manage:

- Installation of mooring anchor legs
- Hook-up of the F(P)SO with its anchor legs
- Installation of riser and subsea systems

It is important that responsibility for interfaces during installation should be established at a point when the information on the F(P)SO design, seabed conditions and field layout have been defined; this should take place at a very early stage in the project. This allows the installation contractor to interface more closely with the hull fabricator and incorporate installation aids into the design.

Quite often, the subsea part of the mooring system such as anchors or piles, anchor legs and pipeline end manifold (PLEM) are pre-installed prior to F(P)SO arrival. This reduces the installation time after the F(P)SO arrives at the site and thereby, reduces the risk of F(P)SO time at site in a condition where the F(P)SO is under tug controls and not hooked up to secure permanent moorings.

**Installation vessels**

The type of vessels used for installation will depend largely on location, the environmental conditions prevalent in the area, water depth, mooring and riser systems design. A sufficient number of vessels should be available to ensure that the F(P)SO can be maintained in the desired position and heading under all likely environmental conditions. In the case of freak storms, the vessels should be able to sufficiently control the F(P)SO to prevent the risk of running aground or hitting other facilities/vessels that may exist in the vicinity. Contingency planning should be part of the installation planning.

Mooring systems on F(P)SOs are specific for each installation and are usually heavy. As such, the vessels recovering, handling and transferring the mooring systems will almost certainly be required to be specially adapted for the task. There may be a requirement to use different vessels for different tasks and it is recommended that a thorough investigation of vessels’ condition, capability and suitability be carried out to determine vessels’ fitness for these tasks.

All vessels must be crewed by persons who are briefed on the requirements of the operation and in particular on their specific scope and responsibilities. All towing and installation vessels should be inspected to ensure proper management of the vessels, competent crewing and fitness for the task.
Adequate fuel and other consumable stocks on the installation vessels should be confirmed. In the event of a protracted installation, which often occurs, fuel can be rapidly depleted; this risk must be recognised and avoided by either fully stocking the vessel prior to the start of the work and/or having reasonable means for restocking.

The vessels should be under the direct control of the person responsible for performing the installation. This responsibility may revert to an installation contractor.

**Weather limits**

At the installation planning stage, the operator and responsible contractors should determine the limiting environmental conditions for installation, they should ensure that weather windows for each work activity is clearly identified. The person responsible for making the final decision to proceed with work should also be clearly identified.

Wind speed/direction, current speed/direction, significant wave height, swell height, direction and period must be within the determined parameters for a sufficient duration to allow:

- Pre-laid moorings to be safely retrieved from the sea bed and transferred to the F(P)SO mooring system.
- The F(P)SO to be held within a pre-defined envelope until sufficient moorings are connected.
- The F(P)SO to be held on location should the weather conditions deteriorate.

A weather forecasting service should be provided to give the latest weather information to the site. This service provider must have a full understanding of the risks and deliverables. It may be possible and advisable to have a competent meteorologist on site for the duration of the installation. If possible, a weather watch should be established with help from other facilities and vessels within a 50-mile radius to monitor development of local ‘freak’ storms. Such storms are not normally forecast by weather services.

**Communications**

Prior to departure from the fabrication site all communications systems should be fully commissioned and operational.

Communications systems should in the main consist of the following:

- Ku Band main bearer segment.
- INMARSAT station
- GMDSS station
- Airband station to meet national aviation authority requirements.

The above equipment should meet all operational and emergency response requirements.

Equipment within the GMDSS station will meet the requirements of routine communications with installation and support vessels. The installation contractor should give serious consideration to providing additional hand held radios on dedicated private channels to ensure that a clear communication route is always available.

It must be recognised that in addition to the installation activity, other works will be taking place simultaneously on the F(P)SO. These will include, completion of outstanding work, commissioning and routine operations and all these activities will require a certain level of radio communications.

All lines of communications, both written and verbal should be outlined in the co-ordination procedures and detailed in the installation procedures. In addition to this, the language being used must be agreed and all persons involved in the communications chain must be sufficiently fluent in that language.
Roles and responsibilities define the order and level of communication required on an individual basis. This should be outlined in the installation and co-ordination procedures. They must also consider the interfaces with any pre-established field communication network already in place. The operator has the responsibility for providing a field network communications system to allow a central point of contact for vessels and aircraft arriving, departing and moving within field limits.

**Commissioning**

**Timing**
From a marine perspective, it is highly desirable to complete satisfactorily the commissioning of hull and marine systems as much as possible whilst the hull is in the shipyard rather than defer the work to offshore. The full resources of the shipyard should be applied to achieve satisfactory commissioning and avoid costly offshore work.

For those projects where the topsides facilities are fitted at a different location to the hull fabrication (build or conversion), the commissioning of the hull and marine systems will probably need to wait until the combined units are successfully fitted at an integration site, when, for example, high voltage power is available and piping systems are complete.

The bulk of topsides commissioning is typically carried out on completion of the topsides installation onto the hull with the balance of commissioning completed offshore after the F(P)SO has been installed at the final location. It is important to remember that entire systems should be fully commissioned and that this may only be achievable after the topsides and mooring equipment has been installed.

**Commissioning requirements**
The commissioning of hull and marine systems may be approached in two ways ie:

- “Marine” style commissioning as traditionally carried out by shipyards for sea going oil tankers. In such cases the shipyard is the primary driver of the commissioning standards and practices based on its own experience. Typically, comprehensive testing is carried out but the provision of final hand over documentation is limited to specific pre-commissioning checks and measurements taken during actual commissioning runs.

- “Offshore” style commissioning whereby the commissioning practices used by the offshore industry are applied. In such cases, the owner frequently is the primary driver for setting and specifying the desired commissioning standards. Typically, pre-commissioning and commissioning requirements are specified in considerable detail. The results from all stages of pre-commissioning and commissioning are recorded and a comprehensive dossier is compiled for the future owner/operator.

Whichever commissioning system is adopted it is important to be clear from the outset what the expected standard will be so as to avoid confusion and potential commercial impact.

Increasingly hull and marine system commissioning in shipyards are adopting the offshore commissioning practices in order that interconnected systems between the hull, topsides and other hydrocarbon handling equipment are subject to the same specification of commissioning and the same standards of final documentation.
Pre-commissioning

Prior to actual commissioning both individual equipment items and complete systems are pre-commissioned. Typical pre-commissioning activities include:

a) For instrument and electrical:
   - Cable continuity checks
   - Instrument calibration
   - Equipment installation verification
   - Loop checks
   - Functional checks
   - Cable meggering
   - Grounding verification
   - Motor rotation

b) Mechanical
   - P & ID (Piping and Instrumentation Diagrams) installation verification
   - Cleanliness
   - Line flushing
   - Hydrotesting
   - Chemical cleaning and/or flushing

The results of each phase of pre-commissioning are typically recorded for inclusion in the final commissioning dossier. The extent to which this documentation is to be completed and its form should be clearly agreed in advance between the parties concerned.

Commissioning

Actual commissioning will comprise a series of working tests agreed in writing, in advance between the equipment manufacturer, shipyard, classification society and future owner/operator. Representatives of the key parties involved should witness all such tests or as a minimum clearly assign responsibility for witnessing to another key party with a clear expectation of what the test should achieve. It should be noted that commissioning tests and endurance runs may be used to supplement training for operational staff but they should not be considered a replacement for proper training.

Prior to commencement of the tests, the appropriate safety precautions should be clearly identified, communicated (including induction of visitors) and implemented.

During commissioning trials, it is important that both individual equipment items and whole systems are tested. The commissioning process should adequately reflect the actual operational condition and should be of sufficient duration to provide a meaningful test. The relevant safety devices should be checked prior to any endurance runs to provide confirmation/assurance that they are in full working order.

All key operational outputs (temperatures, pressures, flows, amperage etc.) should be recorded at pre-agreed intervals throughout the test and recorded on preprepared record test sheets.

On completion all commissioning test data will be included in the commissioning documentation package handed over to the F(P)SO owner/operator.
Post commissioning

It is frequently the case with F(P)SOs that considerable time can exist between the completion of commissioning in the shipyard and final offshore start up. This “delay” can be as great as 12 months where the hull has to go to an integration site for installation of the topsides and then followed by a protracted tow to the field.

In such cases, it is important to take adequate precautions in accordance with manufacturers recommendations to protect and preserve systems and equipment from possible mechanical or corrosive damage and degradation during this dormant phase. Typical measures to be taken include systems draining (particularly of stagnant water) and mothballing of equipment and dehumidification of machinery spaces may need to be considered in extreme cases.

Establishing an appropriate Preventative Maintenance schedule including routine greasing and rotation of equipment should also be considered during this dormant period.

Dependent on the time and extent of mothballing, a repeat of certain key commissioning activities may be appropriate prior to actual operations commencing.

There should be consideration of post-commissioning and early operation demands at the earliest possible opportunity, ideally when contracts are placed. This will help the operations team significantly when coping with the upsets, wear-outs and change-outs that are so common at this stage. Ensuring that suppliers and contractors can supply retrospective documentation to provide assurance and support to the rectification of problems will save time and money. Often, carrying out repairs on equipment that is out of guarantee is disproportionately expensive and presents a “built-in” safety and commercial risk.
6 Hydrocarbon cargo handling

Scope

This section outlines the activities for receiving produced oil from the process facilities; distributing it to the storage tanks under controlled conditions and discharging the final product to the offtake vessel. The process facilities may be above the deck of the storage vessel as they would be on an F(P)SO or they may be on a remote platform or at shore facility as they would be for an FSO. In any case, it is assumed that the process facility delivers “export quality” oil to the storage facility, i.e. that most produced water and gas have been removed consistent with normal specifications for crude oil transportation.

Although crude handling on an F(P)SO is similar in many respects to crude oil handling on a tanker, an F(P)SO is a dynamic facility, continuously loading product whilst carrying out a multitude of other operations. Concurrent operations and the sequences of these operations can differ greatly from conventional tankers and result in the greatest risks to be managed through procedures and system design.

The hazards that need to be managed during hydrocarbon operations include:

- Maintenance of acceptable hull stresses while loading and discharging cargo
- Adequate venting and maintenance of a non-explosive atmosphere in cargo tanks
- Minimising exposure of personnel to hazardous cargo vapours
- Inspection and maintenance of storage tanks whilst continuing normal loading and discharging operations
- Potential environmental pollution through accidental or operational discharges

General safe handling requirements

There are a number of general procedural issues that must be followed to ensure the safe handling of cargo. They should be checked and confirmed in place prior to and during cargo handling operations. It is therefore essential to ensure that:

- Any equipment to be used is in a safe condition to operate and is fit for intended use.
- There are no outstanding work permits or isolations pertaining to the loading or related equipment that compromise safety.
- All involved personnel are fully aware of the cargo handling plans and have been briefed on their role in the event of an emergency arising.
- All personnel are fully aware of the guidance contained in ISGOTT, section 7.14 relating to over and under pressurisation of cargo and ballast tanks.
- Where relevant, the guidance contained in ISGOTT, section 7.4 relating to the hazards of static electricity when handling cargo should be understood and observed by all personnel.
- Acceptable hull stresses and vessel stability are maintained while loading and discharging cargo.
Stress

A poor loading or offloading sequence can cause hull stress levels that are well above the design limits and can lead to major structural damage. The stress within the hull structure is dependent upon the following factors:

- Vessel weight distribution including topsides equipment, ex-crude (lightship)
- Buoyancy distribution
- Environmental conditions
- Crude oil & ballast distribution

The first three factors are outside the control of the operator and are determined by the facility’s design and its geographical location. However, the crude oil and ballast distribution is entirely within the control of the operator.

Operators should be provided with a loading computer with design limits preinstalled to assist them to maintain structural stress components within acceptable limits. These stresses include:

- Longitudinal Bending Stress
- Longitudinal Shear Stress
- Torsional Stress

Longitudinal bending and shear stress components are normally controlled by appropriate distribution of oil and water ballast over the length of the vessel. Torsional stress components would normally be managed by symmetrical loading of cargo and water ballast.

The loading computer should be able to perform structural stress calculations in real time and for loading plan development. Ideally, real time stress calculations should be performed by directly integrating the loading computer analysis with the tank level sensors’ output.

Loading cargo tanks

General

After the processing operation, crude oil is delivered to the storage tanks via a “common” loading header and individual tank branch lines. Each branch line should be fitted with an isolation valve, which may be remotely operated and monitored from a Cargo Control Room. Double isolation to individual tanks or groups of tanks should also be provided as there will be a periodic requirement for tank inspection and maintenance.

Prior to and during loading the following should be ensured:

- All cargo tanks must be inerted to less than 8% O₂ by volume with a positive pressure of greater than 300 mm WG.
- The valve control hydraulic system should be in operation
- The ballast pump system should be in operation
- The tank level gauging system, including the independent “high level” alarms, should be in operation, with manual level gauging devices available as backup.
- The tank primary and secondary venting system including individual tank pressure alarms if fitted, should have been proven to be operational as per ISGOTT prior to commencement of loading.
The following additional conditions should be met as far as practicable when concurrent operations, such as loading / deballasting the vessel, are underway:

- Operating draft may be optimised in order to reduce windage area and thus environmental force impacts.
- Draft variations should be kept to a minimum where possible by matching ballast & loading rates with the discharging rate to the offtake vessel.
- Trim variations should be kept within limits agreed with the process designers.
  
  Note: Sufficient trim (nominally 2 meters) may have to be maintained to ensure efficient Crude Oil Washing, stripping and draining operations.

**Cargo loading plans**

Except for first oil, importing oil to the cargo tanks should be carried out to a loading plan designed to meet the operational cycle for exporting oil to a shuttle tanker. The actual order of loading the cargo tanks will depend on whether all tanks are available, the size and make up of the next intended offload parcel, and any restrictions imposed on the operators by equipment or tank non-availability. In general the following should be observed:

- The loading plan should take account of all allowable stress components. An approved loading computer with pre-installed design limits should be used by the operators to verify plan suitability.
- Hull draft should not exceed the draft established under the Load Line Rules.
- Tank loading pattern should be prepared to minimise free surface, which is detrimental to vessel stability, and "sloshing" which can lead to tank internal damage.
- During the preceding 2 hours prior to the top-off of any tank, the accuracy and operation of the remote level gauging and independent high level alarms should be verified.
- The operation of the loading valves to the next tank to be filled should be checked and flow proven prior to any topping-off of cargo tanks.
- In order to minimise the risk of pollution due to over-filling, filling should be planned to stop when any tank reaches 98% full. Consideration could be given to providing automatic valve closure when the tank reaches 98% full.

**Cargo tank venting**

Cargo tank venting systems must be designed to protect the tanks from over or under-pressure during tank filling and discharging. They should also be so arranged as to efficiently disperse tank vapours.

Prior to and during cargo operations it is essential that vent systems be thoroughly checked to ensure that they are correctly set for the intended operation and that they work correctly.

If isolating valves are fitted to vent lines, a strict procedure should be in place to ensure a proper control and monitoring of the position of these valves. It is recommended that these isolating valves be regularly inspected and maintained.

It is also recommended to provide each cargo tank with independent protection against over or under pressurisation in the event that the tank is inadvertently isolated from normal venting arrangements or in the event of primary vent system malfunction. Consideration should be given to the installation of pressure sensors in the head-space of each cargo tank to provide high and low-pressure alarm functions.

Pressure/vacuum relief valves and devices fitted to mast risers and vent stacks to prevent the passage of flame must be regularly checked to confirm they are clean, in good condition and correctly installed. Special care should be given to the pressure/vacuum relief valves and devices fitted to mast risers and vent stacks to prevent the passage of flame (wire gauze screen). During cold weather, their functioning should be checked to detect any seizing or blocking due to freezing.
Loading plan, discharging plan, cargo handling procedure and checklists should clearly address tank venting taking into account the specific design of the venting system.

Further information is available from referring to:
- ISGOTT [Ref. 9] item 7.6.3, 2.15, 10.6.2 and 10.6.5.
- OCIMF Information Paper on the Prevention of Over and Under Pressurisation of Cargo Tanks on Oil Tankers [Ref. 14].
- SOLAS II-2 [Ref. 6] Regulation 59 and 62, which set out arrangements and procedures for venting, purging, gas-freeing, ventilation and inert gas system operation for tanker cargo, tanks. Although not statutory for F(P)SOs, the issues relating to cargo tank venting should at all times comply with SOLAS to ensure lessons learned are adequately captured for all F(P)SOs.

**Hydrogen sulphide (H$_2$S)**

Crudes may contain a significant quantity of H$_2$S, even after processing. If this is the case, vent systems should be designed to ensure that tank vapours are vented well away for the deck. Section 4, Design Considerations, also recommends both fixed and portable H$_2$S monitoring systems be installed. These systems should be monitored continuously and appropriate precautions taken in the event that environmental conditions make it likely that personnel could be exposed.

**Water discharge**

Most produced crude entering the storage tanks will contain some amount of produced water, which will settle out at the bottom of the storage tanks in varying degrees depending on the quantity of water, the residence time, and the crude characteristics. If significant quantities are present, this water may present corrosion problems on the tank bottoms and may result in complaints about crude quality. In addition, some produced water contains sulphate-reducing bacteria (SRB) that can lead to severe corrosion problems. If this situation is anticipated, consideration should be given to providing an independent system for stripping water from under the crude before discharge. On an F(P)SO, this water can be fed back to the process facilities for separation of oil and discharge. On an FSO it will be necessary to provide separation facilities for processed water.

From time to time, it will also be necessary to wash the tanks with seawater to remove crude residues in preparing the tanks for personnel entry for inspection and maintenance. This water will also require proper disposal. In most instances, it is not advisable to mix produced water and seawater, their differing chemistries may produce significant quantities of precipitates that will cause operating problems in separators and other equipment. Consequently, it will be necessary to provide separate separation and oil monitoring equipment.

Discharge of water from the tank section of an F(P)SO must be done in strict accordance with local and applicable international regulations.
Offtake/discharging

General
This section describes the basic considerations and requirements for handling crude oil during offtake from an F(P)SO.
The offtake can be made by purpose built or converted vessels to “shuttle” the cargo from the F(P)SO to the shore. Such vessels tend to load over the bow.
The second method is by a general trading tanker, which is not equipped with the specialised fittings of the shuttle tanker and generally loads by means of a hose attached to the tanker’s mid-ship manifold.
See section 7, Offtake Arrangements, for a description of the various methods of offtake.

Cargo pumping system
The cargo pumping system on an F(P)SO is usually one of two alternatives, as follows:
- A centralized gathering system consisting of a piping system with suction points in each tank and the pumps in a pump-room at one end of the vessel. This is similar to a tanker offloading system and is usually the choice when converting an existing tanker for F(P)SO service.
- A system consisting of individual pumps submerged in each tank, interconnected only on the discharge side at the upper deck level. This is often the choice for a purpose-built F(P)SO as it minimises the amount of valving and piping within the cargo tanks.
Regardless of which approach is chosen, the crude pumping system should have the following characteristics:
- Offload crude at the fastest economical rate consistent with the capabilities of anticipated offtake tankers and design limitations of the F(P)SO equipment, in order to minimise the offtake tanker residence time.
- Deliver crude to the loading point (whether an SPM, tandem hose connection, or vessel-side manifold connection) with sufficient pressure to load the off-take tanker at the desired rate.
- Allow isolation of the intended offload parcel while continuing to load other tanks from production in order to ensure quality of the offloaded crude and permit independent confirmation of the offloaded volume.
- Allow positive isolation (usually double valve) of individual tanks in order to permit tank entry for maintenance and inspection while continuing to load or offload remaining tanks.
- Allow efficient stripping of tanks in order to permit periodic bottom crude washing to avoid sludge build-up in the tanks.
- Permit emergency shut-down of the entire system in the event of problems on the offtake tanker, with the loading system or on the F(P)SO. The offloading system should also be designed to accommodate possible surge pressures in the event of accidental or deliberate closing of the offtake tanker’s loading valves.

VOC return lines
The issue of VOC return lines and their use during offloading represents a key safety issue. The operation of VOC reclamation represents a highly hazardous situation where flammable mixtures of hydrocarbons are returned to the F(P)SO. An added complication to the VOC reclamation process is that the offloading and reclamation systems may often be combined as a dual hose system, adding to the hazards generated by offloading. For those F(P)SOs with stern accommodation, the offloading and reclamation point may be located close to the accommodation and TEMPSC.
Discharge plan

While the processed product loading is a continuous process, export may be performed within a relatively short time (typically less than 36 hours). Therefore, detailed loading, discharging and ballasting plans, including any non-routine operations, must be compiled prior to each export.

The discharge plan of the F(P)SO should take into account the following:

- Hull stresses
  - The discharge sequence should be arranged such that the hull stresses, bending moments and shear force remain within acceptable limits.

- Discharge rates
  - From a safety point of view, it is preferable that the offtake tanker be alongside the FSU for the shortest time possible. The bulk discharge will therefore in all probability be at the maximum capacity of the offloading system, although the start up and topping-off on the export tanker will be at reduced flow rates. As such the F(P)SO will not normally strip the cargo tanks, unless this is necessary for other reasons such as tank cleaning etc.

- Sequence of cargo tank discharge
  - The sequence of discharge should be arranged such that the bulk discharge can be maintained and the other limiting factors are satisfied.

- Sequence of filling of ballast tanks
  - Ballasting of tanks should be done to maintain the other limiting factors (discussed earlier, see “Loading Cargo Tanks”).

- Trim and list
  - It will be necessary to maintain the vessel in an upright condition especially if carrying out an STS operation, or if the F(P)SO is weather vaning. The trim should be monitored to ensure the F(P)SO trim is by the stern, yet with sufficient draft at both the bow and stern to limit the movement of the F(P)SO and within the limits of any topside equipment.

- The stowage of the incoming produced oil
  - The stowage of the incoming oil should be into tanks that will not be used for export prior to the crude being of export quality. On older installations, time will be required for the crude to “settle”. With more modern process plants, this is less of a consideration.

- Segregation between the produced oil and the export quality oil.
  - The export ready crude and the incoming crude should be segregated. This is achieved by careful manipulation of the cargo valves and cargo lines.

Custody transfer

During offloading, custody of the crude oil transfers from the F(P)SO to the offtake tanker. This transfer must be carefully regulated in accordance with agreements between interested parties in the venture and in particular in accordance with the requirements of the host government customs authorities. Custody transfer therefore requires accurate determination of the quantity of oil offloaded and accurate determination of its quality. The API Manual of Petroleum Measurement Standards provides a good basis for implementing a satisfactory custody transfer system.

The usual means of determining quantity is a metering system on the F(P)SO meeting the accuracy standards specified by the parties or the host government. An alternative means could be direct manual ullaging of tanks to be offloaded. In any case, direct ullaging is recommended as a backup means to confirm accuracy of the metering system.
In addition, it is usually necessary to collect and analyse samples of the oil in order to document the quality of the oil being offloaded, particularly the water content. Sampling may be by means of an in-line automatic sampler or by means of direct sampling from each tank to be offloaded.

In order to facilitate manual ullaging and sampling of tanks, each tank should be fitted with a vapour-lock sampling connection that will allow crewmembers to safely ullage tanks and obtain samples while maintaining a continuous positive inert gas pressure in the tanks.

**Crude oil washing**

Crude oil washing may be carried out periodically on the vessel to reduce the build up of sludge in the tanks and prepare tanks for entry or maintenance. Crude oil washing may be carried out during a discharge, especially of the upper parts of the tank. It may be preferred to carry out bottom washing between offtakes when a tank is available.

It must be noted that not all crude oils are suitable for crude oil washing, and thus COW may not be an option in every case. Personnel supervising crude oil washing should be qualified and experienced in the operation.

The vessel is to ensure that the crude oil washing takes into consideration all of the precautions as laid out in Chapter 9 of ISGOTT [Ref. 9].

**Cargo tank inert system**

The atmosphere in the F(P)SO tanks is to be maintained in a "non explosive" condition. The normal method is to supply low oxygen content combustion products to the tanks from boiler uptakes or from an independent oil or dual fuel (oil or gas) generator.

The inert gas is cleaned, cooled and distributed to the tanks by means of system of piping with branches leading to each tank. Although SOLAS does not apply to F(P)SOs, it is recommended that the inert gas system comply in all respects with the requirements of SOLAS and the relevant IMO guidance notes. Prudent operators may also consider maintaining 100% redundancy for this critical component.

The vapour spaces of all tanks containing crude oil should be rendered inert with an oxygen content of below 8% at all times. Any cargo space should be purged of hydrocarbon vapours prior to gas freeing to ensure that the atmosphere contained does not pass through the explosive range when the tank is ventilated with air.

The inert gas system can also provide the primary means of venting the tanks (see section "Cargo Tank Venting"). In this case, the system will be pressurised at all times due the venting of gas caused by the incoming crude. Consequently, the inert gas line may not be effective when purging specific tanks for other reasons, ie prior to or after aerating the tanks. For this reason, it is often necessary to have a second inert gas line on the deck which is independent of the incoming crude vent line and it should be possible to positively isolate individual tanks from the system by positive shut off devices.

Section 10 of ISGOTT [Ref. 9] provides a detailed description of the Inert Gas system operation.

**Cargo oil heating**

Due to high pour-point, wax content and/or high viscosity it may be necessary to maintain the crude at a certain minimum temperature. To compensate for heat losses to the surrounding environment, the stored cargo may require heating in order to maintain the required export characteristics. Specific equipment start-up, operating and shut down procedures should be adhered to at all times. Tank heating by coils or circulation method should be kept to a minimum and only until the required temperature has been stabilised. At no time should the maximum recommended storage temperature be exceeded.
7 Offtake arrangements

Introduction

This section describes the hazards and safety requirements to be considered for the offtake of cargo from a Floating Storage Unit.

It is appreciated that there are a number of methods of mooring the F(P)SO; there are a number of methods of transferring cargo to the export vessel from the F(P)SO; and that export tankers may be dedicated shuttle tankers or general trading tankers.

This section discusses all methods, but where the hazards and safety precautions to a specific system are covered in other publications, reference will be made to those publications.

Offtake hazards

Although F(P)SO operations are subject to all marine hazards such as grounding, weather, fire, collision, piracy, the principal hazards considered in this section are those associated with the close proximity of the F(P)SO and the offtake tanker during the export, together with the hazards in transferring hydrocarbons.

The hazards are discussed under the broad headings of:

- Collision.
- Fire and Explosion.
- Pollution.
- Breakout of the export tanker from the F(P)SO.

Types of F(P)SO operations considered

There are a number of mooring and cargo transfer arrangements that can be considered and can be any combination of mooring of F(P)SO with offtake method and with type of offtake vessel. These are as follows:

Offtake Tanker;
- General Trading Tanker
- Dedicated Shuttle Tanker

Method of Offtake;
- SPM - Remote loading buoy
- STS - Alongside Ship-to-Ship transfer
- Tandem – Offtake ship moored to the F(P)SO bow-to-bow or bow-to-stern

Mooring of F(P)SO;
- Weather Vaning – F(P)SO free to rotate around the anchor point.
- Spread Moored – F(P)SO moored on a fixed heading with a pattern of anchors

General trading tanker

General trading tankers are the most common type of tanker for offtake of oil from all types of F(P)SO. They are available in a wide range of sizes, are fitted with a variety of equipment and are manned by crews of varying skill and experience.

For these reasons, care should be exercised to assure that the offtake tanker has bow arrangements for connecting to a single hawser, and manifold arrangements for lifting and connecting a floating hose. Prior to accepting a general trading tanker to load at the F(P)SO, confirmation should be received that the tanker complies with the requirements for loading at an SPM as described in OCIMF’s Offshore Loading Safety Guidelines: with special reference to harsh weather zones (Ref. 10).
The berthing of a general trading tanker will require a skilled pilot and tugs to position the tanker at the mooring location and to supervise the mooring and connection of transfer hoses. Support craft will be required to assist the handling of the hawser during the mooring and unmooring operations, and to handle the floating hoses. In tandem position, the tanker will not be able to maintain position relative to the F(P)SO without the assistance of a pull back tug.

Finally, provision of emergency release and shutdowns should be made by the F(P)SO, since usually they will not be provided by the general trading tanker.

**Dedicated shuttle tankers**

Dedicated Shuttle Tankers, such as those in the North Sea, tend to be used when weather conditions require special features in order to assure reliability of offtake. In order to be practical, they also require a limited number of discharge locations that are relatively close to the F(P)SOs that they serve.

Typical features include:

- Dynamic Positioning (DP) capability. Some vessels use DP to control the load on a mooring hawser ("taut hawser") while others are able to maintain the relative position with the F(P)SO without reliance on the hawser ("slack" hawser).
- Bow mooring arrangement and bow loading system with an emergency shutdown and a disconnect system compatible with F(P)SOs in their trading area.
- A suitably qualified Master to act as the pilot for the berthing and unberthing manoeuvres, the officers will be able to monitor and maintain the ship position.

Such vessels generally offload with tandem mooring method to weather-vaning F(P)SOs or specially designed loading buoys and are able to pick up the mooring (if used) and hose coupling arrangements without the use of support craft. Furthermore, the offtake tanker can maintain position astern of the F(P)SO by use of the tanker’s engines without the need of a pull back tug.

The operation and safety considerations for such vessels is covered in the OCIMF publication Offshore Loading Safety Guidelines [Ref. 0] and that publication should be referred to for further guidelines.

**Single Point Mooring (SPM)**

This method uses a single point mooring system (generally a buoy) so that the offtake tanker will be loading at a distance from the F(P)SO. The loading point will be connected to the F(P)SO with a submerged pipeline. The vessels do not come into close proximity and as such there are reduced risks of collision and of an escalation of a fire/explosion from one vessel to the other.

The buoy mooring should be positioned such that the offtake tanker has sufficient room for a safe access to and from the mooring in all weather conditions. The unobstructed distance between the loading point and other field facilities would be typically more than 1 nautical mile, (see section 4, Design Considerations – Field Layout).

The loading of tankers at single point moorings is a well established practice and that operation in conjunction with an F(P)SO presents no greater risk of pollution than that from any other buoy mooring, OCIMF Offshore Loading Safety Guidelines (Ref. 10) should be consulted for further advice.

When SPM facilities are operated with dedicated shuttle tankers, the offtake tanker should be fitted with an emergency shut down capable of stopping the F(P)SO cargo transfer pumps and closing offtake valves. When operated with general trading tankers, a trained mooring master should be onboard the offtake tanker throughout the loading. The mooring master should be in frequent radio communication with the F(P)SO and emergency response measures should be well established.
Ship-to-Ship Transfer (STS)

General
Ship-to-Ship cargo transfers from an F(P)SO to an export tanker are suitable for sheltered areas with restricted sea room and are not suitable for exposed locations where heavy seas and/or strong winds are a feature.

The offtake tanker is moored directly alongside the F(P)SO, separated by floating rubber fenders, and cargo transfer is through flexible rubber hoses directly connected to the manifold of each vessel.

It must be stressed that this system is more common with FSO operations. The STS system of cargo transfer is less appropriate with F(P)SOs, particularly those with a flare stack on the deck. The reason being that the loading tanker will be venting the cargo tank vapours to atmosphere whilst loading, with the inherent risk of combustion of the gases in the flare stack. Although having a vapour return line from the tanker to the F(P)SO can reduce the risk, the possibility of gas venting to atmosphere, controlled or otherwise, will remain.

The OCIMF/ICS publication Ship to Ship Transfer Guide (Petroleum) (Ref. 13) provides an excellent reference for this operation. Moored F(P)SOs, however, present specific problems that are not common in general ship-to-ship transfers. One principal difference is that the F(P)SO is permanently moored and the mooring manoeuvre cannot be made "underway" – i.e. both vessels steaming. A second difference is that the mooring chains of catenary anchored F(P)SOs tend to extend beyond the hull and are a consideration for berthing and unberthing the offtake vessels.

Collision
There is a risk of contact between the tanker and the F(P)SO during the mooring procedure, but once the vessels are moored, the risk of contact damage is greatly reduced. To prevent hull contact between the vessels, it is necessary to employ adequate tug support to safely position the offtake tanker alongside. In addition, the number and size of fenders together with their positioning should be stipulated, eg as in the Ship to Ship Transfer Guide (Ref. 13).

There is also a possibility of the upper parts of the vessels "touching in a beam" swell, where the roll between the vessels is large. The contact would typically be in the region of the bridge wings. If the F(P)SO is a converted tanker, removing a section of the bridge wing on the F(P)SO so that it does not extend to the extreme breadth of the vessel can prevent this.

Oil pollution
The risk of oil pollution during an STS transfer is relatively low. The cargo hose is relatively short, and there is direct contact between the two ships’ personnel. As with any oil transfer operation, however, there must be adequate preplanning and emergency response procedures must be in place.

Fire/explosion
Due to the vessels being in very close proximity, the risk of a fire or explosion on one vessel affecting the other is greatest with this system of transfer.

It is important that the F(P)SO is equipped with emergency shutdown and release equipment that will allow the vessels to part in the event of an emergency with either vessel, (see section 4, Design Considerations - Emergency Shutdown and Release).
Breakout
The mooring lines during an STS operation tend to chafe in the fairleads, with the risk of the ropes parting. The lines should be monitored at all times and any chafed ropes replaced.

The mooring operation requires a certain expertise in seamanship. F(P)SOs tend not to have a full complement of seafarers and handling the moorings of the offtake tanker should take this into account. The F(P)SO may be equipped with traditional mooring bits and winches to allow the handling and securing of the offtake tanker moorings or it could be equipped with mooring hooks and combined winches.

STS transfer – weather vaning F(P)SO
In conducting STS cargo transfer from a weather vaning F(P)SO, the offtake tanker will berth alongside the F(P)SO with the assistance of tugs whilst heading into the prevailing weather or current. The arrangement should always be such that the offtake tanker will berth port-side-to.

The berthing manoeuvre must be carried out when the F(P)SO is on a steady heading. The F(P)SO should be equipped with a compass that will allow staff on the F(P)SO to provide the approaching vessel with the heading and with information of the yawing (swing) motion. If necessary, a tug can be attached to the stern of the F(P)SO to assist the F(P)SO to maintain a steady heading.

If the vessel is swinging onto a new heading (shift of wind or change of tide) or yawing beyond the pre-set limits, the approach should not be attempted.

Under normal weather conditions, or in an emergency, the offtake tanker should be able to depart from the F(P)SO without the aid of tugs, although there may be circumstances where the anchor chains of the turret may impede the departure of the offtake tanker, these circumstances should be understood and assessed in emergency preparations.

If the F(P)SO is moored with an external turret having a catenary anchor leg mooring, the chains may extend beyond the beam of the F(P)SO. This will be even more pronounced when the F(P)SO is in a light condition (as would be the case on completion of a cargo transfer). In these cases, the choice of offtake tanker should be limited to a size that would be able to manoeuvre clear of the F(P)SO without the aid of tugs. Alternatively, tugs should be retained on standby to assist the departure of the vessel.

STS transfer – spread moored F(P)SO
The spread moored F(P)SO presents a number of problems for STS, principally as a result of the anchor pattern.

The spread moored F(P)SO is held in a position on a fixed heading with a pattern of anchors. The pattern of anchors will be from each quarter of the F(P)SO - port and starboard bow, and port and starboard stern quarters, which can in effect “trap” an export tanker within the mooring pattern. This is certainly the case if the anchor chains pass through leads at the deck edge.

To prevent the offtake tanker being hampered by the anchor chains of the F(P)SO, these may be passed from the deck to leads situated on the bilge. This is, however, only appropriate in deeper waters where a catenary can be maintained in the anchor chains.

The offtake tanker must be of a length that will be accommodated within the moorings. Tugs will be required to manoeuvre the offtake tanker into position and will be required for unberthing.

Due to the fixed heading, the weather and current may not necessarily be from ahead, and the offtake tanker may be “pushed” onto the F(P)SO by the prevailing conditions, making an emergency departure impossible without the aid of tugs.
Tandem moored offtake

General

Tandem Mooring an offtake tanker to an F(P)SO is common in open seas and allows cargo transfers to be carried out in weather conditions more severe than the STS mooring would allow. When using dedicated shuttle tankers, the system can be used in harsh weather areas. This section discusses principally tandem moored offtake with General Trading Tankers.

The offtake tanker is moored by the bow directly to the stern (or bow) of the F(P)SO by a mooring hawser. The separation between the tanker and the F(P)SO is maintained for the most part by the environmental conditions of wind and current, although, it must be appreciated, that these cannot always be relied upon.

The potential for “loss of station keeping events” incidents should not be under-estimated. The experience in the UK has been to develop guidelines to help reduce incidents against a baseline of seven events per shuttle tanker per year. Reference should be made to guidelines produced by UKOOA and the Health and Safety Executive in conjunction with the UK industry’s “Step Change in Safety” initiative. Part one addresses performance standards for controlling the risks associated with tandem offtakes involving shuttle tankers at F(P)SOs while the second deals with the use of towing assistance during offtake operations, (Ref. 35).

Environmental conditions

Wind and current affect tankers differently depending upon the laden condition of the tanker. A fully laden tanker, being deep in the water, is affected more by the current than by wind. Conversely a tanker in ballast and on reduced draft, is affected more by the wind than by the current.

In general, during the early stages of the cargo transfer the F(P)SO will be the laden vessel, the offtake tanker the ballast vessel. As the loading proceeds the roles will be reversed.

At times when the wind and current are from different directions, the F(P)SO and the offtake tanker will “naturally” settle on different headings each influenced by a different force. The “attitude” of the offtake tanker to the wind and current may induce a forward motion of the tanker that will result in the vessel “creeping” towards F(P)SO. Forward motion of the offtake tanker can also be induced by subsea counter currents, which will take greater effect the deeper the vessel goes.

In some conditions, the relative heading of the offtake tanker to the F(P)SO may change rapidly and often, the offtake tanker moving from one side of the F(P)SO to the other, this motion is known as “fish tailing”.

The above effects are countered and controlled by the use of a tug moored to the stern of the offtake tanker and are discussed below.

The mooring arrangement will be dependent on the weather limits, and these are to be specified based on the considerations noted below.
Collision

There is a risk of collision during the approach manoeuvre, and throughout the period the offtake tanker is on station. However, such collisions can be expected to be of lower impact energy due to the very slow speed of the offtake tanker when close to the F(P)SO.

It is important that a qualified and experienced pilot is employed to control the vessel when manoeuvring in the field. Restricted zones around the F(P)SO and over subsea appurtenances, where tankers should not enter without a pilot, should be specified and well delineated. Anchorages should be provided for any tankers awaiting loading (see section 4).

The pilot will be aware of the berthing manoeuvre and will operate with support boats familiar with the mooring operation. A “pull back” tug can be secured to the stern of the tanker during the berthing manoeuvre to provide a stern pull in the event the tanker suffers mechanical damage.

During the approach the speed will be reduced as the distance between the tanker and the F(P)SO shortens. The pilot should allow for an abort at any time during the approach. The approach should be made such that in the event of power failure the tanker would pass clear of the stern of the F(P)SO.

The “pull back” tug should be retained on the stern of the tanker throughout the period on station to prevent the tanker “creeping” up to the F(P)SO. It is appreciated that the tanker may use the main engine to provide stern power, but modern ships tend to have diesel engines that cannot be used at a slow speed for extended periods.

It is important that the relative position of the tanker to the F(P)SO is monitored throughout the operation, by personnel on board the F(P)SO and the tanker or by distance monitoring equipment.

Fire/Explosion

The risk of a fire or explosion on one vessel spreading to the other is greatly reduced due to the separation between the vessels. The system, however, should allow for a rapid release of the export tanker in the event of an emergency (see - Emergency Cargo Shutdown and Emergency Mooring Release).

Oil pollution

The risk of oil pollution is no greater than that for an SPM operation. The volume of oil lost could be the volume of the entire hose string if the hose is damaged. Breakaway couplings should used in the hose to protect the hose string from pressure surges, (see section “Emergency Cargo Shutdown and Emergency Mooring Release”).

The risk of pollution from collision damage to either the F(P)SO or the offtake tanker is considered low, although there is a possibility this could occur. To eliminate this risk, the oil storage tanks on the F(P)SO should be placed as far forward of the machinery space as possible, and inboard of the hull plate. The offtake tanker may have bunkers in a forward tank, which could be damaged. The offtake tanker should minimize the risk of oil pollution by having the minimal amount of bunkers in the forward tanks.

Breakaway

There is always the risk of the mooring hawser parting and the export tanker drifting clear of the F(P)SO. Such an event could put stress on the hose string with the subsequent risk of damage to the string and possible oil pollution, (see Emergency Cargo Hose Release).

The principal safeguards against a breakout are regular visual inspections of the mooring hawser together with a change-out routine. It will be necessary in the design stage of the mooring system to determine the limiting weather conditions and put in place procedures to abort the operation when they are reached.

A load-monitoring device can be fitted to the hawser attachment point on the F(P)SO, whether this is a hook or stopper. This will allow the strain in the hawser to be measured and will indicate the point at which the transfer operation should be suspended, and the tanker unberthed. Monitoring and recording loads can be used to indicate the residual life of the hawser and assist in determining the change-out of the rope.
Tandem mooring – weather vaning F(P)SO

Tandem Mooring to a weather vaning F(P)SO is common in many locations throughout the World in both harsh weather and more benign locations. As with the STS operation, the berthing manoeuvre will be carried out when the F(P)SO is on a steady heading. The F(P)SO should be equipped with a compass that will allow staff on the F(P)SO to provide the approaching vessel with the heading and with information of the yawing (swing) motion.

Figure 7.1 – Tandem Offtake from a turret moored F(P)SO

If the vessel is swinging onto a new heading (shift of wind or change of tide) or yawing beyond the pre-set limits, the approach should not be attempted.

The mooring approach will be made with the assistance of a tug or tugs from a point astern of the F(P)SO, and the F(P)SO will require sea room all around to permit the approach to be made with wind and current from any direction. A lack of sea room may result in limitations being placed on the berthing of offtake tankers.

Under normal weather conditions, or in an emergency, the offtake tanker should be able to depart from the F(P)SO. The vessel would release the mooring hawser and hose and move astern away from the F(P)SO. Being downwind and current the tanker would naturally tend to drift clear of the F(P)SO without the use of engines, however, the engines should be maintained in a constant state of readiness throughout the period on-station.

If the vessel had full power the unberthing could be done without the use of the tug. In the event the vessel lost power, then the tug should be used to tow the offtake tanker clear from the F(P)SO and from any other structures in the field.
Tandem mooring – spread moored F(P)SO

General
As previously described, “Spread Moored” is a system of mooring an F(P)SO with a pattern of anchors both fore and aft, which hold the F(P)SO on a fixed heading. The orientation of the F(P)SO is therefore unaffected by wind and current.

Tandem offtakes from a spread moored F(P)SO have been carried out but are not common. The principal risk with this operation is that the prevailing weather/current conditions do not necessarily provide a “natural” drift of the offtake tanker away from the F(P)SO, and may cause the offtake tanker to drift towards the F(P)SO.

The use of tugs will be essential to hold the offtake tanker clear of the F(P)SO at all times.

This system of mooring an F(P)SO can be considered in areas where the current and wind are nearly coincident and come from ahead of the F(P)SO such that the offtake tanker remains downwind and down current from the F(P)SO.

Collision
The risk of collision both in berthing and on-station is greater with this system than with a weather vaning F(P)SO as the wind and current may not always be aligned in a favourable direction for the offtake tanker to approach and remain moored at the loading point. Consequently tug support will be required for the entire duration of the operation.

As for berthing to a weather vaning F(P)SO, a “pull back” tug should be made fast to the stern of the tanker prior to the approach commencing. Additionally a second tug should be near the bow of the tanker on the opposite side to where the hoses will be made fast. This tug should be used in “push/pull” mode, to hold the bow steady whilst the mooring hawser are being connected.

When on-station a stern tug is vital for maintaining the separation between the tanker and the F(P)SO. The tug should have the power to hold the tanker in an acceptable position envelope in adverse weather and currents. As the availability of tug power is vital, consideration should be given to some redundancy, eg using two tugs or having a tug with more than one engine.

Currently, general trading tankers are not required to be fitted with a “strong” point on the stern, other than the emergency towing arrangement, which does not lend itself for general use. There have been incidents of mooring bits being pulled out of the deck by the force of tugs. Consequently, the effectiveness of the “pull back” tug should not be over estimated.

Monitoring weather conditions
Weather conditions must be monitored at all times, and any deteriorating weather conditions need to be predicted. This may utilise any or all of weather radar, agency forecasts, information from other offshore fields or nearby onshore locations.

Considerations when determining the environmental limiting conditions should include:

- Operating limits for the mooring boat
- Operating limits for the tugs
- Forces on the mooring system
- Forces on the F(P)SO anchoring system
- Specific safety criteria for the cargo operations
- Behaviour of the laden F(P)SO and Offtake Tanker

It must be stressed that the weather limitations for Spread Moored F(P)SOs will be more stringent than for “Weather-vaning” F(P)SOs, as in the latter case both vessels will be similarly affected.
**Current buoy**

In addition to monitoring the weather, it is important to have information about the subsurface currents. This is particularly important for the Offtake Tanker manoeuvres around the Spread Moored F(P)SO and consideration should be made to fitting a current buoy in the vicinity of the F(P)SO.

**Pilotage and support craft**

Approaching and mooring of the tanker to the F(P)SO is an operation for which the master of a general trading tanker may not necessarily have the required experience. An F(P)SO facility that has been designed for offtake by general trading tankers should employ dedicated, trained pilots or berthing masters.

The pilot would generally board the tanker well before approaching the mooring and control the export tanker from the bridge. Ideally, an experienced assistant should be assigned to the forecastle to advise the pilot of progress of approach and mooring, as well as to advise the tanker crew on mooring procedures.

The pilot would usually remain aboard the offtake tanker during the discharge to supervise connection of hoses and act as loading master and primary communications link with the F(P)SO. To assist in this role the pilot is often provided with portable telemetry equipment to initiate an F(P)SO Emergency Shutdown.

Support Craft will be required to assist mooring and a mooring boat should be available together with a tug or tugs. For tandem mooring operations, consideration should be given to mooring the tug to the stern of the tanker during the approach. This will provide stern power in the event of engine failure on the tanker.

For STS operations, generally two tugs will be required to assist the offtake tanker to moor alongside.

Additional tugs may be required to “hold” the bow in the approach. This will be more critical for Spread Moored F(P)SOs which are unable to weather-vane.

**Hose strings**

Dedicated Offtake Tankers tend to have bow arrangements with a hose coupling, the hoses are in general suspended from a gantry between the F(P)SO and the offtake tanker, or are a short string of floating hoses.

The hoses in this arrangement tend to be retained on the F(P)SO between offtakes, either on the deck or on stowage reels, see the OCIMF Offshore Loading Safety Guidelines (Ref. 10).

A weather-vaning F(P)SO can allow the hose to float free and it will generally remain clear of the vessel. If conditions are such that this is not the case and the hose tends to drift onto the F(P)SO, the end of the hose may be secured to a point at the forward end of the F(P)SO. This will, however, result in the hose being in a “bight”, and consideration should be made to the launching of the lifeboat which could be “trapped” in the bight, especially on F(P)SOs with an astern hose connection, and lifeboats placed aft.

It should be noted that securing the hose alongside the F(P)SO can hinder the operation of support craft, and cause chafing of the hoses.

If the F(P)SO is spread moored, the hose string can drift down onto the F(P)SO and the end will require to be secured.

A spread moored F(P)SO in shallow water can lay a mooring buoy away from the F(P)SO and secure the end of the hose to this. If the water is too deep, a mooring buoy may be attached to one of the F(P)SO mooring lines.

The condition of the hose string should be carefully monitored and explicit renewal criteria for hose sections should be set, floating hoses in seawater are also subject to deterioration and should be monitored and regularly checked.
Emergency cargo shutdown and emergency mooring release

For all methods of cargo transfer, there will need to be a means of rapidly stopping the cargo flow between the vessels and a means of rapidly releasing the export tanker from the F(P)SO. A dedicated export tanker will, in all probability, be fitted with an emergency shutdown and release system that is compatible with the shutdown and release on the F(P)SO as described in OCIMF publication Offshore Loading safety Guidelines (Ref. 0).

Emergency cargo shutdown

The F(P)SO should be fitted with an emergency trip on the cargo pumps, to shut-down flow with minimum notice. The export tanker should also have the ability to initiate pump stop as personnel on the export tanker will often notice any problems with cargo flow, eg pollution before F(P)SO crew become aware of a problem. A commonly used system is a telemetry radio link, such systems can be fixed or a hand held radio carried by the pilot. With an STS operation where there is close contact between the vessels, a lead or umbilical may be passed between the vessels with an actuator on the export tanker.

Emergency cargo hose release

There may be a need to release the hose rapidly in an emergency, in particular if the mooring lines or hawser should part and export tanker breaks free of the F(P)SO. The following are potential issues with mitigating actions options and they should be considered in design and operation:

- The hose may be connected to the manifold of the export tanker with a quick release coupling. This will require a manual release, but the disconnection can be made quickly. The end of the hose should be fitted with a valve in order to prevent oil pollution from an open-ended hose. This can be fitted to any hose regardless of the system of cargo transfer.
- After release from the manifold, but there will still be a requirement to lower the hose into the water using the tanker’s crane or derrick. This may take time, and the means should be in place to lower the hose and release it from the crane/derrick hook without the use of the boat.
- In an extreme emergency the hose end can be allowed to fall into the water but this could result in breaking a chain and damage to the shipside rails and fittings. Personnel should be well clear of the area if there is a possibility of the hose falling into the water.
- The hose string can be fitted with a breakaway coupling that will activate when the hose is stressed as a result of excessive pressure caused by a surge, or when the hose is stretched by a tanker breakout. The coupling will part and seal one or both “open” ends of the hose, thus minimising any oil loss.
- In a floating hose, the breakaway coupling is situated in the tail hoses, approximately 4 lengths from the tanker end of the hose string. As it activates, the last hoses will remain connected to the ship manifold, but these will not hinder the manoeuvrability of the export tanker.
- The F(P)SO may be equipped with a quick release coupling which will allow the hose to be released from the manifold on the F(P)SO. The release should incorporate a hose end valve to prevent any oil loss, although care should be taken to avoid the (loose) hose becoming fouled in the propeller as the export tanker manoeuvres clear of the F(P)SO.
Emergency hawser release – tandem mooring operations

The standard bow stopper fitted to a General Trading Tanker is not designed to be released under “load”, and the tanker must be in a position to manoeuvre ahead to relieve the load on the stopper in order to allow personnel to lift the Pawl or Stopper Bar.

In the event the tanker is not able to manoeuvre, it will not be possible to release the hawser from the ship end, and a hawser release should be fitted to the F(P)SO hawser connection.

Reasons for releasing the hawser could be fire or explosion on one vessel, excessive load on the hawser, close proximity between the vessels, risk of collision due to rapid movement in the relative headings and position of the two vessels.

The tension in the hawser should be monitored and a tension-monitoring device should be fitted into the F(P)SO hawser connection. There should be an alarm system advising of high and very high loads. The level of these alarms should be pre-determined, and contingencies put in place to define the action to be taken when these levels are reached.

It should be possible to release the hawser under load, regardless of whether the connection is a hook or a patent stopper.

Emergency mooring release – ship to ship operations

In the event of an emergency during an STS operation there will be a need to release the moorings rapidly to allow the vessels to part.

As previously mentioned, the F(P)SO could be equipped with mooring bits (as are common on all tankers) or with mooring hooks and combined winches. The latter are common on jetties and have the advantage of requiring less expertise in seamanship and are less labour intensive.

The hooks can also have a quick release capability, and can be released remotely or locally by one crew-member.

In the event the moorings are on bits, axes should be available to cut the ropes (for example, as recommended by OCIMF’s Ship to Ship Transfer Guide Petroleum, Ref. 13).

Communications

As the F(P)SO will be in an active producing field, there will normally be boat operations in the area and the F(P)SO should have continuous monitoring of the communications systems. The most appropriate system would be VHF radio with a telephone link to the shore.

It is common for the early communication between the tanker and F(P)SO to be by telex or electronic mail. This should be as early as possible and preferably at least 72 hours before the arrival of the tanker. The F(P)SO should send a prearrival message advising the tanker of requirements.

VHF contact will be made on the arrival of the tanker, and communications should be maintained between the F(P)SO and offtake tanker throughout the period, from arrival of the tanker to departure.

The pilot and assistant will provide the liaison between the tanker and F(P)SO whilst on board the tanker and this will be by “Walkie Talkie” radio. Specific emergency signals, for use in the event of a communications failure, are to be pre-determined by the F(P)SO and the tanker officers must be made aware of these.
8 Other operations

Scope

This section deals with a number of activities that can be expected to occur regularly on an F(P)SO, but that are not part of the normal loading and offloading activities. They nonetheless, present risks to the personnel, to the facilities, and to the environment due to unfamiliarity or lack of expertise with the activity. The activities included in this section include:

- Tank cleaning
- Tank purging & gas freeing
- Tank entry
- Line flushing
- Hose change-out
- Maintenance activities
- Repair/maintenance of ship-side valves and sea inlets
- Routine storing and personnel transfer
- Ancillary and field support vessel operations
- Diving/ROV operations
- Helicopter operations

Risks and safe operating criteria

Each of these activities presents risks to:

- Personnel – through possible personnel injury, fire and explosion or exposure to toxic gases
- The facilities – through collision or fire and explosion
- The environment – through accidental oil spill

It is important therefore to define the safe operating criteria under which these activities may be carried out. The safe operating criteria for the intended activities should consider and derive from:

- The individual tasks
- The metocean conditions
- Other operations that may be required to be carried out simultaneously.

Tank cleaning

F(P)SO tanks require periodic personnel entry during their lifetime for internal maintenance or inspection. In order to make a tank safe for entry, several steps in a “making safe” process must be carried out to ensure that the atmosphere is non-explosive and is safe. The first such process is tank cleaning.

It is expected that F(P)SO tanks will be regularly Crude Oil Washed (COWed) (see section 6 – Hydrocarbon Handling) and, in particular, a tank being prepared for entry will have been completely stripped and the bottom thoroughly COWed. Once the tank has been fully discharged with the cargo pumps it will require final stripping to get as much of the residual oil out as possible.

The tank would then be water-washed to clean residual oil from the side and bottom of the structure. To accomplish this, the slop tanks would normally be “charged” with clean seawater which would be circulated to the tank cleaning machines through the COW system. The water is then sucked from the tank and returned to slop tanks for decanting. This closed cycle assures that no oil is discharged over the side during water washing. After completion of water washing, oil is allowed to separate in the slop tanks by gravity and decanting and the decanted water is discharged over the side through an oil separator with a quality check by an oil-in-water monitor.

Tanks are normally washed in cycles, typically a top cycle, side cycle then bottom cycle. The washing period may be from 1-2 hours per tank depending on the crude oil characteristics and experience. Also depending on the crude characteristics, the water may need heating to aid the cleaning process and the oil/water
Guideline for managing marine risks associated with FPSOs

separation. During this period, the Inert Gas Generators must be run constantly to ensure that the tank atmosphere is maintained in the nonexplosive range. In past years a number of serious tanker explosions have been attributed to static discharges during high-pressure water washing.

F(P)SOs are constantly live and always subject to loading or cargo transfer, therefore care must be taken to ensure that the tank being washed is positively isolated from the cargo systems and the venting main system. Double valving, double block and bleed and line blinds are examples of acceptable isolation. Operating personnel and marine crew operating the F(P)SO should be made fully aware of the potential consequences to personnel and the facilities if the integrity of this isolation is compromised. Untrained personnel should not attempt this operation. It is expected that the responsible person on board will ensure that the personnel involved will have a minimum Class 2 Certificate of Competence (or equivalent) with the appropriate Dangerous Goods endorsement.

Cargo tank purging and gas-freeing

The next processes in preparing a tank for entry are purging and gas-freeing. Initially the cargo tank must be purged with a continuous supply of inert gas to reduce the concentration of hydrocarbon vapours in the tank to less than 2% by volume. This should be done through an auxiliary, independent inert gas main and not through the common inert gas/vent main. Cargo tank purging must be carried out before any possibility of introducing air to the tank to ensure that the contained atmosphere will at no time enter the flammable envelope. The guidelines given in ISGOTT [Ref. 9], Chapter 10.0 should be adhered to strictly during this operation.

F(P)SOs will need special consideration here due to the potential venting of hydrocarbons either near the process plant or near the flare stack. Calculations will have to be made at the design stage to ensure that carry over of hydrocarbons from the vent will not interfere with day-to-day operations. This is especially relevant in calm tropical days when heavier than air hydrocarbon gases tend to sink towards the deck and form gas pockets, often migrating to unexpected areas.

After purging, the tank must be “gas freed” in order to remove the residual inert gas from the tank and replace it with a normal breathable atmosphere containing 21% Oxygen. The venting of large quantities of inert gas into the atmosphere and its potential adverse affects on process equipment and personnel is a significant consideration in this step. Air may be introduced to the tanks using portable fans or with the inert gas blowers. If the inert gas blowers are used, care should be taken that the system is positively isolated from other tanks being loaded with crude oil. Gas freeing fans should be run until the measured oxygen content at all levels within the tank is 21% by volume and tests indicate that hydrocarbon gases are less than 1% LFL and all toxic gases are within allowable limits.

Of special note is the possible additional hazard when dealing with crude oil that contains H₂S. In a low oxygen atmosphere, the H₂S can combine chemically with iron rust in the tanks to form pyrophoric iron sulphides. These sulphides can produce local hot spots sufficient to ignite hydrocarbon vapours when air is introduced to the tanks. Reference can be made to ISGOTT [Ref. 9] for procedures if there is a potential for pyrophoric iron sulphides to form.
**Tank entry**

During tank entry there is a high degree of risk for all personnel involved in the operation due to live hydrocarbons being pumped and transferred throughout the ship during this operation. It is essential that before entry to any tank, that the steps to ensure safe access described briefly above are completed and checked, namely:

- Positive isolation of the cargo is assured
- COW is effectively completed
- Purging with inert gas systems is carried out.

All of the above steps should be executed in accordance with established confined space entry procedures. As a minimum, the guidance contained in Chapter 11 of ISGOTT [Ref. 9] should be strictly followed.

To ensure that positive isolation is achieved, suitable isolation methods should be used, these include:

- Double block and bleed
- Isolation spool pieces
- Removable sections of pipe

It should be noted that spectacle blinds or single valve isolation even if those single valves are of the double seal variety are not acceptable.

The Tank Entry Procedures card produced by OCIMF provides a list of simple rules about tank entry, but it is worth repeating the main points about tank entry:

- Do not enter any enclosed space unless it has been tested
- Always have a responsible person standing by
- Always have rescue equipment on stand-by
- Keep testing the tank during the whole tank entry period
- Test at all levels of the tank
- If there is any doubt about the tank atmosphere WAIT
- If someone collapses in a tank while you are there move to an area of safety immediately even if this means leaving the tank
- Never assume anything when entering enclosed spaces
- In addition, gas-freeing fans must be running and fresh air supply maintained continuously while personnel are inside any tank

**Hose flushing**

Line flushing with water may be performed as a routine operation, eg prior to retrieving a hose string aboard after loading, or it may be performed only occasionally to permit maintenance of a hose string or in response to an emergency. In either case, there is a risk of oil pollution and such operations should be treated with care.

Line flushing can be achieved by a variety of methods

- By using the F(P)SO systems
- By using a maintenance vessel
- By using the offtake tankers pumping system
Use of the F(P)SO systems
This method of hose flushing is more often associated with F(P)SOs and their arrangements used for tandem offloading rather than remote offloading through an SPM. Seawater for flushing can either come from the slop tanks (having been previously filled from the ballast system) or from the sea chests via the ballast system. Line flushing from the sea chest of the F(P)SO presents a risk of pollution/contamination because the flow path from the sea chest to the cargo export hose may allow crude oil to flow backwards out of the sea chest. Production water should not be used because it may have an adverse effect on the hose string and fittings, as it is often highly saline and may contain chemicals associated with the production.

In the case of line flushing for operational reasons it would normally be sufficient to simply displace the oil in the hose string. If however the hose string needs to be flushed for maintenance then it is recommended that at least 10 volumes of the hose be passed through the hose at sufficient velocity to clean the residual oil from the lining of the hose.

In order to flush the hose completely the hose string has to be either returned to the F(P)SO or connected to reception facilities such as a maintenance vessel, or pumped to the offtake tanker. Appropriate equipment should be provided for connecting and disconnecting these hoses as the contents make the hoses both heavy and unwieldy. A typical hose string will weigh about three tonnes per section lifted and, if there is any sort of seaway running, snatch loads may be experienced. In addition, once the hose string has been flushed with seawater the string will be heavier by approximately half a tonne.

Use of a maintenance vessel
It is becoming more common to have dedicated field support vessels (FSVs) which will have, as one of their functions, the ability to perform routine maintenance. In the case of hose maintenance, the FSV may have a flushing connection on the main deck for use in flushing the hose back to the F(P)SO using pumps on the FSV. This flushing connection may be a camlock coupling or a simple flange. In either case, the operator must ensure that the hose is securely fastened to the connection. When disconnecting the blank flange from the end of the hose string there may be some residual crude oil between the flange and the valve. This may be a flammable mixture and the operators should take the appropriate precautions. The operation should be conducted in low swell conditions and ideally in as benign weather conditions as possible since the FSV may have to stay in the same position for some time if the connection is a simple flange. Once connected the FSV should not rely entirely on the hose strength to maintain position since this may put excessive strain on either the hose string itself or the marine breakaway coupling if fitted.

Once flushing operations have started it is essential to leave adequate time for the water to completely clean the inside of the hose.

Once flushed the hose can then be disconnected if required and work begun on the hose string. However, at this point it is useful to remember that there may be residual pressure in the line and the bolts or camlock should be released in a controlled manner to relieve the residual pressure.

Offtake tankers pumping system
Modern non-dedicated tankers do not normally have the facility to pump seawater through the manifolds without changing piping configurations. In changing over the systems, the operator must be aware that there are increased chances of allowing a pollution incident to occur. It is highly recommended that any attempt to pump ballast water through the ship’s manifold is avoided for similar reasons and that there may be doubts about the contents of the ships ballast tanks.
Hose change-out

It will be necessary occasionally to remove a hose string for testing and possible replacement or to replace individual sections due to wear or damage, although with the arrival of double carcass hoses, change out of an entire hose string is becoming less frequent. Modern double carcass mainline hoses should be capable of lasting several years. End hoses, however, are changed out more frequently as they are more prone to wear and tear during connection and disconnection.

When disconnecting an entire hose string or removing a single section, the hose should have been thoroughly flushed to remove any oil as described in the earlier sections. However, small amounts of oil may still be present and the workboat should have a dispersant spraying capability to deal with minor spills as a minimum.

The installation of a new hose string is normally achieved in two phases.

- Construction phase to assemble the hose string; which is normally done near or onshore
- Installation phase; where the completed hose string is towed out and attached to the F(P)SO off-loading connection

During the construction phase, the operator frequently has little input into designing for operation except to ensure that the hose string configuration and construction is the same as the previous string. If this is not what the operating team require, they should endeavour to increase their influence with the design and procurement team.

Hose strings come in different lengths even when supplied by the same manufacturer, therefore, care must be taken to ensure that the lengths are the same (rather than maintaining the same number of sections) to ensure that the hose string will extend the required distance or, following retrieval, that it can be accommodated with the retrieval equipment.

Most hose manufacturers do not recommend mixing hoses from different manufacturers in the same string due to the nature of the flexing of the individual hoses.

Maintenance activities

Maintenance activities on an F(P)SO, particularly those involving work on deck or in tanks, need to be carefully planned, taking into account weather and sea conditions as well as the fact that the facility is continually loading crude oil and may be offloading crude oil simultaneously with planned maintenance activities. The work permit system should be well established and maintained so that all personnel are aware that work is ongoing and that necessary precautions need to be observed.

Where subsea related maintenance is to undertaken, eg hull, DP systems, riser repairs etc., water survey requirements should be planned and undertaken when judged appropriate. The condition of the equipment to be repaired will be instrumental in assigning correct resources and time to complete the job satisfactorily.

Where it is necessary to isolate equipment of tanks for maintenance, the appropriate positive isolation provisions should be maintained and procedures should be in place to ensure that the equipment or tanks are returned to their normal operating condition after the work is completed. This is particularly important for tank entry where the tank(s) involved must be isolated from the crude loading and venting systems to prevent personnel being exposed to dangerous gases, however, the tanks must be re-connected to the venting system before commencing loading to avoid structural damage to the tank.

In some geographic locations, maintenance activities are generally restricted when weather conditions have been forecast to deteriorate and access to areas would become difficult due to the F(P)SO motion. This particularly applies to access to the upper deck where there might be a risk of “Green Water”. All lifting or manual handling activities under these conditions carries increased risk of injury.

As for all offshore installations, the requirement for the identification of Safety Critical Elements and developing their associated Performance Standards remains important. The maintenance regime to ensure their
continued performance should be an identifiable and key part of the planned maintenance regime for the installation. Of particular importance to F(P)SOs is that some aspects of marine equipment have traditionally been designed to be maintained on a regular basis in harbour or dry dock. The alternative maintenance strategy for these items (based on remaining on station) must be included sensibly within the design parameters such that the performance standard is achievable over the lifetime of the installation, with an awareness that there may be some lifetime extension as oil recovery techniques continue to improve.

The maintenance regime must therefore be developed to show clearly the Safety Critical Elements and to indicate clearly their significance and continued performance.

**Repair/maintenance of ship-side valves and sea inlets**

Due to the nature of F(P)SOs having to remain on station throughout their lifetime, marine work with a potential to impact water-tightness will have to be undertaken on location.

The planning of the tasks is critical and a considered judgement should be made of other activities that the OIM may wish to stop or reduce whilst the marine repairs are undertaken.

Care should also be taken to plan having the appropriate equipment in place in good condition and suitable for the tasks to be undertaken. Other supporting equipment to maintain safety should be in place and ready to use when the work commences.

The tasks should be fully assessed for duration and a clear window of acceptable weather conditions should be forecast before initiating the work.

**Routine storing and personnel transfer**

**Routine storing**

The F(P)SO will be loaded with stores on a regular basis and frequent accidents occur during storing operations primarily due to complacency and poor communications. Consequently, the storing operation should be planned like any other work task with the hazards clearly identified. In particular, plans and procedures should take into account that both vessels may be in motion and the ability to carry out storing operations safely will depend to a great extent on the supply vessel’s ability to hold position when conditions become marginal.

A further governing factor will be the limits on the F(P)SO cranes, in particular when vessel motion causes the load to swing. This has the greatest risk of major accident hazard where the lay-down area is adjacent to the process plant.

**Personnel transfer**

Personnel transfer may be part of the offloading process where pilots are sent to the offtake tanker to control mooring and monitor the loading. In other cases, it may be intra-field transfers of personnel. In either case, there is a high risk of people being injured. Transfer can normally be effected in a number of ways and the most appropriate will depend on several factors, including location of the facility with respect to the shore and other facilities and prevailing sea and weather conditions. Common approaches include:

- Helicopters are expensive and not always available dependent on the area of operations, the sea and weather conditions and availability of helidecks or safe approach to helidecks. They are also manpower intensive and put the crew and a number of personnel at risk at one time.
- Basket transfers; considered to be dangerous by many operators and regulators and banned from many operations.
Basket transfers are governed by safety practices and regulation in different areas of operation. The guidance for use is given in the International Maritime Organisation (IMO) OSV Code, the UK LOLER and HSE, IADC and IMCA guidance and UK MCA regulations.

Boarding towers; convenient in mild climates, but offering easy access for unwanted visitors

Efforts during the design stage are vital to produce a system that is fit for purpose taking into account the experience of the people, weather and sea conditions to be encountered, the frequency of the operation and the equipment to be used. Experienced mariners should have early input into this process to ensure that risk mitigation measures are optimised.

**Diving/ROV operations**

This section describes the marine risks affecting the F(P)SO from diving and Remotely Operated Vehicle (ROV) operations and does not aim to address the risks presented to diving operations, ROV operations and associated support vessels by the F(P)SO. Hence, the many hazards found onboard, overboard and/or emitted from an F(P)SO that present a risk to underwater operations are not discussed.

The intent of the F(P)SO design should be for all underwater activities to be conducted without manned intervention and for all underwater inspections to be carried out by a ROV. In spite of these best of intentions, the possibility remains that manned diving intervention working from the F(P)SO or from a Diving Support Vessel (DSV) may on occasions still be necessary.

To manage essential underwater work, every offshore site, including F(P)SOs, should prepare a Site Information Dossier that will provide all the information necessary to a Diving or ROV contractor about the site. This document should be developed in two parts:

- Impacts on and from ROV operations
- Impacts on and from divers and diving operations

The dossier should be compiled using experienced staff of both the F(P)SO operator and the Diving/ROV Contractor. The risk assessment process should be used as a basis for the dossier.

A marking system can be implemented on the F(P)SO to identify sea inlets/outlets and bulkhead positions, this system should be referenced within the Site Information Dossier and the marks themselves should be readable by ROV CCTV.

For all underwater work in the vicinity of an operational F(P)SO an interface document should be developed between the HSE Management Systems of the F(P)SO and the underwater services contractor. The interface document should identify the activities, the tasks and the accountable person(s) who will manage the controls in a seamless fashion.

When underwater work is being performed on location, the work is best co-ordinated by the F(P)SO facility manager/OIM using a Permit to Work (PTW) system, complemented by a permit to dive system or diving interface permit. It is absolutely essential that good communications are established between divers/DSV/ROV control and the DP (or marine control) desk on the F(P)SO.

In summary, the more significant potential subsurface related activities generating risks to the F(P)SO have been found to include:

- Collision between the F(P)SO and the DSV or ROVSV due to failure(s) in the mooring system or Dynamic Positioning (DP) station keeping of the DSV, ROVSV or F(P)SO
- Collision between the F(P)SO and the DSV or ROVSV should the underwater support vessel’s mooring system become snagged on a subsea structure or the position reference system fail causing the DP system to manoeuvre the vessel erratically
- Collision between the F(P)SO and DSV or ROVSV due to rapid and/or uncontrolled heading change of the F(P)SO (while the underwater support vessel is working within the F(P)SO’s footprint)
- Loss of buoyancy of the F(P)SO due to a release of gas from beneath the vessel due to integrity breach in the subsea facilities
- Fire risk and/or an explosive atmosphere building up around the F(P)SO or DSV/ROVSV due to a release of hydrocarbons near the vessel due to the subsea production control lines rupturing/being severed
- Fire/explosion risk due to equipment on the diving/ROV/support vessel not having correct electrical classification
- Accidental blocking of a water intake (cooling or firewater etc.) on the F(P)SO due to loss of control of an ROV or other material.

**Helicopter handling**

Helicopter Operations are critical to provide a safe and efficient method of crew changing, delivery of urgent freight and one of the primary means of emergency evacuation. A reputable offshore helicopter operator should be consulted early in the design of helicopter facilities.

Guidelines on equipment, operating envelopes and procedures are provided within the UK Civil Aviation Publication, CAP 437, “Offshore Helicopter Landing Areas – Guidance on Standards”. CAP 437 gives guidance on the criteria required by the UK CAA in the assessment of the standard of helicopter landing areas for world-wide use by helicopters registered in the United Kingdom. These standards are generally considered to be an example of best practice and have become an accepted worldwide reference.

Consultation with helicopter operators and the national aviation authorities is essential if a safe helicopter-operating environment is to be achieved. It is usual for offshore helidecks to receive some form of approval from the national aviation authority. In the UK the CAA has delegated this responsibility to the helicopter operators via the British Helicopter Advisory Board (BHAB).

The International Chamber of Shipping, ICS, has published a “Guide to Helicopter/Ship Operations” which comprehensively describes physical criteria and procedures for ships. Some further guidance is available in UKOOA’s “Guidelines for the management of offshore helideck operations” and OGP’s “Aircraft management guidelines” chapters 8, 9, 19 and 20.

The location of the helideck is crucial to a safe operation, in particular its siting relative to adjacent structures and generator exhausts. It will normally be located on top of the living quarters at one end of the F(P)SO in order to facilitate both routine and emergency personnel transfer, but this is also the point of maximum acceleration due to vessel heave and pitch motion. The information related to vessel heave, roll and pitch motion must be communicated to the helicopter pilot together with other information that the pilot may require such as heading, yaw, wind speed (both from an unrestricted airflow anemometer and from the helideck), barometric pressure, visibility, cloud base and cover and sea state. Measuring instruments used to provide the data should be periodically calibrated in accordance with the manufacturer’s recommendations.

It is prudent in the design phase to carry out wind tunnel tests or computerised airflow modelling to evaluate the effects of air movement and temperatures across the helideck. One influencing factor can be the generator exhaust positioning, which may cause hot emissions to pass near to the helideck or the helicopter approach/take-off paths. These emissions may cause serious problems to the helicopter’s aerodynamic performance and must be studied carefully and comprehensively if operational limitations and potential accidents are to be avoided.

There are a number of helideck designs on the market but one of the better designs is the “Safe Deck.” It has two main features, a built in non-slip surface and most importantly, the ability to return the deck to service following a helicopter accident. It rapidly drains away spilled fuel, which reduces the risk of fire and thereby reduces the potential level of injury to people and damage to the helideck and surrounding structure.
9 Emergency response arrangements

Scope

This section describes the considerations for developing the emergency response measures that are necessary on an F(P)SO in order to:

- Maintain the safety of all personnel
- Minimise impact on the environment
- Minimise impact on assets and operations

Framework for emergency response

One output from the risk assessment process described in section 3 is an evaluation of potential failures and mitigation measures. The results of the evaluation process and the decisions taken with respect to any measures required for emergency response should be recorded and kept available to support those who operate the F(P)SO and for those involved in any subsequent changes to the F(P)SO.

The arrangements for emergency response should form an integral part of the F(P)SO facilities and its management, both onshore and offshore. They should also include others who may be expected to provide services or support in the event of an emergency, but who are not themselves necessarily directly involved in the F(P)SO management e.g. coastguards and other organisations who may be able to provide search and rescue operations.

Recovery from emergencies also needs to be in place, including arrangements to rescue and evacuate people from the F(P)SO or from the sea and transport them to a place of safety and further care. The management should therefore put in place a strategy that focuses on the ultimate goal of securing the safety of all persons. Emergency response to deal with acute oil pollution should also be integrated into the overall emergency plans. The company responsible for an F(P)SO should liaise with relevant onshore authorities to develop plans to deal with any oil spills that may affect the shoreline and onshore communities.

Emergency Response Strategy (ERS)

The emergency response arrangements should, as a minimum, conform to the requirements and recommendations of the regulator of the host country and the IMO and be supplemented by considering:

- Area evacuation, e.g. precautionary evacuation in areas of tropical revolving storms
- Combined operations wherein an integrated command and emergency response system should be developed
- Arctic operations
- Uncontrolled flow from a well

For new F(P)SOs, the development of an ERS and the measures required should be an integral part of the design process. All credible emergency scenarios that may need emergency response should be identified and the planned strategies to deal with them should be contained within the ERS, the strategy should be “live” and continue to develop and learn from experience on the F(P)SO and in that geographic location.

The ERS should contain a hierarchy for implementing measures and steps:

- Elimination, avoidance and prevention of events that may require emergency response
- Integration of emergency response into design through e.g increasing the capacity of the structure to withstand accidental loads, separating hazards from accommodation and from non-hazardous areas, providing passive fire protection, providing a secure refuge and evacuation routes that continue to be available under emergency conditions
- Provision of automatic or remotely operated safety and supporting systems to mitigate the effects of an accident, for example fire protection systems, alarm systems and anchor release systems
- Implementing measures and providing facilities to support the emergency services, e.g in connection with escape and rescue, manual fire fighting and fighting of acute oil spills
The ERS should describe the role and functional requirements for each of the systems required for emergency response. The identified system elements should form the basis of the Performance Standard and the supporting specification for each of the systems to be provided and they should be verified. Periodically through the life of the F(P)SO, all ERS related procedures and systems should be reviewed and re-verified to ensure that the strategies remain valid and any remedial actions should be identified and implemented.

Similarly, existing F(P)SOs which already have an ERS in place should be reviewed periodically to ensure that the measures and systems are sufficiently well documented to facilitate the analyses to which they will be subjected as part of the re-assessment and improvement processes.

To develop an appropriate ERS it is essential that it is based on a comprehensive range of identified hazards, that the assessments have been undertaken in a proper manner and that their potential scale of escalation (giving rise to the need for ER arrangements) has been assessed and understood. Appendix 2 contains a comprehensive checklist for hazard identification.

The ERS should contain guidelines to determine the emergency response appropriate for each event. The response may be capable of being dealt with totally on the F(P)SO with the resources, equipment and persons on-board or it may require outside assistance. In a major accident scenario there may be the need to remove some or all persons from the F(P)SO.

The resources that may be involved in emergency response comprise three categories:

- **Unit resources**: Resources which are directly under the control of the person in overall charge of the F(P)SO (the OIM) and which are immediately available. They include personnel and equipment, standby vessels, and helicopters that have been assigned emergency response duties.

- **Area resources**: Resources which are not directly under the control of the OIM, but which are located in the same area. The resources are made available by a mutual aid or co-operation agreements, and may include installations in the vicinity, supply vessels, standby vessels and helicopters.

- **External resources**: Resources which are not directly under the control of the person in overall charge of the F(P)SO, and which are not located in the area. Such resources may be the organisation and resources of the national and international rescue service, as well as other resources which professional bodies or others may place at the disposal of the field or F(P)SO manager. This may include aircraft, helicopters, coast guard and vessels, shore-based personnel resources, regional or national oil pollution resources, the public health service and resources governed by international agreements and other agreements between the operators.

Assurance that the appropriate Emergency Response arrangements have been identified, are in place and are effective involves a process of verification and a system of audits to ensure that the emergency response objectives identified in the ERS are being met.

The evaluation of either existing or proposed measures comprises an assessment of their performance followed by a judgement as to their adequacy. If the measures are judged inadequate, they must be modified or the hazard must be removed or reduced. Following such modifications, it is then necessary to repeat the evaluation to determine if they have been successful in correcting the inadequacies.

The Emergency Response arrangements are “live” and changes on or around the F(P)SO that may affect the ERS should be continually considered and re-assessed. Examples of such changes include identification of other emergency scenarios that may arise, updates to the data and assumptions used in the emergency response analyses or revisions to the availability or nature of area and external resources.
Guidelines on emergency response plans

After an ERS has been developed, effective emergency response requires an Emergency Response Plan (ERP) to set out the operational and procedural requirements to be followed under the emergency scenarios relevant to the F(P)SO.

The emergency planning, the management competences and the communications arrangements should be sufficiently adaptable and robust to allow effective assessment of the emergency as it develops and to ensure that all personnel are informed as to the action that must be taken.

Although the topics required to be considered in the ERP are wide-ranging, the plan itself should have a thread of simplicity running through it. It should be user-friendly to assist understanding and enable confidence to be built up in the plan itself.

Formulation of the plan

The Emergency Response Plan (ERP) is part of the emergency response arrangements. It should set out the operational and procedural part of the arrangements by stipulating:

- who does what
- where
- when
- how, and
- to what effect

The ERP is a working tool that will be used regularly for training and practices, and will be the basis upon which a real emergency will be handled. It needs to be clear with the emphasis on ease-of-use and the practical information that would be required in an emergency.

The parameters of the plan should cover all stages of an emergency response from detection of the emergency until the emergency is over and persons are considered to be in a place of safety. For example, the stages in an ignited hydrocarbon release may involve detection, alarm, fire fighting, muster, evacuation, recovery from the sea and transport to shore (possibly even via another vessel). Other emergencies will have a very different sequence of events and equally should be accommodated by the plan.

Where onshore, regional or inter-regional facilities are required as part of the plan, the interface between the F(P)SO’s arrangements and the onshore arrangements should be fully integrated. The plan should also consider what external notifications to government and other bodies may be required by local regulations or by pre-arranged working agreements.

Weather conditions have a major impact on the options available during offshore emergencies. The ERP should be developed to consider the implications of all expected weather conditions upon the full range of emergency scenarios envisaged.

Organisation

Ensuring effective emergency response requires a management structure, both offshore and onshore. The ERP should be developed with this structure in mind, and contain sufficient information and authority to enable decisions and command actions to be taken.

In the event of an emergency, the prime role of management is to implement the ERP to achieve the objectives laid out in the ER strategy. A command structure must be established which can remain effective in an emergency.

The organisation should take account of the existing or proposed command structure for non-emergency operations.

Where contractors’ employees form part of the organisation there must be an arrangement with the contractors’ employer, that these personnel will be available, recognise the emergency commanders and that they are capable of carrying out their assigned roles.
The development of an appropriate organisation for managing emergencies should take account of the following considerations:

- **Command and Control** - The decisions and control on-board the F(P)SO including communications with other agencies off the F(P)SO should always lie with one clearly defined individual (usually the person in overall charge) with a designated deputy in the event of an unplanned transfer of command (e.g. if the person in overall charge is injured). Consideration also needs to be given to the planned transfer of command at a selected point in the ERP; e.g. after all the personnel have left the F(P)SO. Indeed, some emergency services will expect to take control of an incident at a particular step in the rescue and recovery mission.

- **Communications** - All emergencies will require communication with corporate management, emergency services, government authorities and other interested parties (e.g. family members, the press, etc.). Procedures and facilities for this communication should be incorporated into the plan and implemented early in any emergency to ensure that the command and control structure is not overwhelmed by external demands for information.

- **Flexibility** - It may not be possible to predict accurately the actual conditions that will arise during an incident. Therefore, the plan should not be overly prescriptive, and, where appropriate, should allow sufficient flexibility to ensure the most effective response.

- **Familiarity** - The organisation developed including the chain of command should follow, as closely as possible, the day-to-day organisation for normal operations on the F(P)SO; in an emergency, personnel may not respond confidently or naturally to an unfamiliar approach. Maintaining a similar structure also has the advantage that skills and experience can be directly transferred from the “normal” to “emergency” duties. Effective emergency response relies on quick decisions and actions, it is important that personnel are aware of the command structure and how their role and actions affect others.

- **Simplicity** - In an emergency, the situation can change rapidly and it is essential that the transmission of information and decisions are effective. An overly complex organisation may not be able to respond quickly and may need to rely on the continued operation of numerous interlinked facilities, any one of which may become unavailable.

- **Redundancy** - No area of the organisation should rely totally on the availability of any single element. This means that backup systems are required for essential facilities and that personnel should have designated deputies who can take over their role. Such deputies should have the same level of training.

- **Availability** - There should be no conflict during an incident with personnel being assigned to two or more key roles. This also means that sufficient personnel with the required experience and skills should be available on the F(P)SO to carry out the roles identified within the organisation.

### Human factors

In formulating the ERP and in carrying out the assessment, realistic assumptions need to be made regarding the likely pattern of human behaviour in an emergency. For example, increased stress, reduced visibility and extreme temperatures can severely reduce human performance levels. Personnel should not be assumed to be both intrinsically capable and reliable in carrying out all duties required of them. In particular:

- Where a person is required to perform a key task as part of the ERP, it is essential that factors relevant to its success (information flows, physical requirements etc.) are assessed to ensure that the probability of a successful outcome is acceptably high and that the possibility of the situation being made worse by incorrect actions being taken is considered.

- The time allowed to complete actions, e.g. mustering, should adequately reflect the possibilities of delays being introduced by stress, physical conditions etc. and not just be based on times obtained in practices where such performance modifying factors may not be present.

- The nature of the emergency may limit the time available for the decision making process. The degree and complexity of the decisions that are required to be made should take these constraints into account.

- All personnel who have a significant role to play in the emergency plan should be identified by role and function. Contingency arrangements should be put in place to accommodate injury or unavailability of personnel.
key personnel or information sources. The way in which the emergency command and control structure will respond to changed circumstances should be considered, eg loss of part of the evacuation system.

**Combined operations**

Where F(P)SOs are involved in combined operations, for example during work-over, or discharging to off-take vessels, the ER for all involved craft and installations should be reviewed and, if necessary, revised. The presence of another craft/installation alongside may impair certain options for evacuation or escape, but equally may provide other options. A combined ER strategy should be agreed prior to combined operations commencing and the arrangements of all craft/installations modified accordingly.

A command structure for the combined operations must be established to define the respective emergency command responsibilities.

For more detailed guidelines on escape, refuge, evacuation and rescue, refer to Appendix 1.

**Training and competence**

The objective of training is to ensure that individuals are familiar with their role, any equipment that they may have to operate, emergency procedures and other relevant aspects of the ERP. It is also necessary that they will retain this awareness in demanding circumstances.

Training should be accomplished through regularly scheduled drills that emphasise familiarity with equipment and procedures, such as fire drills, evacuation drills, etc. In addition, periodic scenario-based exercises should be planned that exercise the entire emergency response organisation, including external organisations. Those people with key roles in the emergency response should have an appropriate understanding of duties, context, scenarios and roles. As part of an effective emergency response team they should be able to act in a manner that is suitable to the purpose, logical, and systematic.

There are specialist courses available to train OIMs and assess their abilities to cope in stressful emergency situations and these should be included in their training programmes.

Where “on the job” training is used to supplement more formal training, the importance of the trainee having the opportunity to observe experienced professionals at work should not be underestimated. Great care should be taken to allocate trainees to appropriate teams (in skills and experience) where they can shadow experienced operators during the operational phases where the most valuable experience can be accumulated.

All personnel on an F(P)SO should have at least basic training in emergency response, first aid, handling life saving appliances and fire fighting. In addition, as part of the F(P)SO induction process all new personnel should be introduced to F(P)SO specific issues, such as:

- Evacuation routes
- Designated muster areas
- Emergency response equipment
- The main hazards and incidents that may arise
- The emergency response procedures and the action plan (the station bill)
- The emergency response organisation

People with key roles in emergency response should be given more advanced instruction in emergency response to make sure that they are able to deal with their emergency response duties in a rational and professional manner.

**Monitoring of the plan**

The ERP should be subject to a monitoring programme to test that it continues to meet the needs of the F(P)SO and its context. Monitoring practices and drills are an important part of this process and the times required to execute certain elements of the plan may well form part of the functional requirements as well as monitoring.
The ERP will need to be reviewed and revised as appropriate in line with the findings from practices and drills and following changes to operations, plant and equipment or personnel.

**Guidelines on detection**

The hazard identification and assessment process for an F(P)SO should have identified all those major accidents that require an emergency response. In addition, there are lesser incidents that have no potential to escalate to a point at which partial or complete evacuation would be necessary, but which nevertheless require an emergency response. Suitable arrangements should be made for the detection of all these identified incidents to ensure, so far as is reasonable, that those responsible for the management of emergencies are made aware that a response is required.

**Internal communications**

Emergency Response relies upon effective and reliable communication between all personnel involved in the response. The ERP should describe the communications required and/or available for any incident (both on and off the F(P)SO) including detection and alarms, the information that is required, and when it is to be transmitted.

As well as specific communications concerning the control or handling of the incident between locations on and off the F(P)SO, attention should also be paid to personnel on the F(P)SO not directly involved in the control aspects of the incident; eg those personnel who are only required to muster will need regular information on the progress of the incident.

The system should remain available during an incident, long enough to ensure that all personnel are warned of the emergency and informed of the appropriate action they should take. The locations from which the system can be initiated should be identified and will include both manual and automatic initiation. Manual initiation should be possible from the control points and at appropriate locations around the F(P)SO.

Personnel should be provided with adequate information to allow them to:

- Initiate alarms where necessary;
- Distinguish between alarms;
- Respond to alarms.

In an emergency the telecommunication systems provided for normal operation should remain active, provided that its continued operation does not create additional hazards. This will reduce the information load on critical communications systems and should conform to an information/communications hierarchy set out in the ERP.

**Guidelines on environmental emergency response**

ISO 14001 describes the principles for an environmental management system and ISO 14004 provides general guidelines on how to implement such a system. An important part of environmental management is the planning for emergency response.

Typical oil spill emergency response measures will depend on a large number of factors including:

- The environmental sensitivity of the area of operation
- The infrastructure in place to deal with oil spills
- The speed of response of shore based assistance
- The size of credible spills
- The physical properties of the spill
In developing the arrangements for environmental emergency response the following should be considered:

- Acquiring pre-approval by government authorities of any oil spill response measures (such as dispersant spraying) to avoid lengthy approvals during an emergency
- Identifying near-by areas of heightened environmental sensitivity, such as wildlife preserves
- Identifying the proportion of oil pollution control equipment that should be operative within given time intervals from the start of the emergency
- Allocating the proportion of the oil pollution control equipment that should be located on the F(P)SO
- Providing facilities to monitor the environmental conditions, such as prevailing currents or ice cover, that may be present when the equipment is deployed
- Confirming the capacity of the oil recovery system
- Confirming the characteristics of the oil/emulsion that is to be recovered
- Providing the means to identify the extent of the spill
- Providing the facilities to handle any recovered oil

The emergency response relating to acute oil pollution from the F(P)SO should be designed to be capable of serving in an effective front-line contingency function in the event of major oil spills from the sub-surface wellhead.

Designing the emergency response to acute oil pollution should be based on an evaluation of environmental hazards in the event of discharge. The criteria should be based on available scientific data. These may include information concerning interests connected with birds, fish and outdoor life in the area. These data may vary with the seasons and should be included in the basis for establishing the emergency response relating to acute oil pollution.

International conventions have introduced the requirement to develop national plans for oil spill response and operators should ensure that their emergency response plans for their F(P)SOs are aligned with the national requirements of the waters where they are operating.

**Guidelines on medical emergencies**

The Emergency Response arrangements should address how medical treatment will be provided for those injured in an emergency. The person on the F(P)SO with the role of providing emergency medical treatment should be considered an integral part of the emergency response organisation. The emergency response procedures should ensure that the person providing medical treatment does not have other duties that conflict with the treatment of injured people.

The operator of an F(P)SO may also have an important role in providing emergency medical treatment for vessels working in the vicinity of the F(P)SO.

Where an injured person has to be moved to another location to receive further medical treatment, the method of transportation should be planned to take into account the condition of the patient. The place where such medical treatment is available may be another F(P)SO or installation where there is a qualified doctor or onshore.
Decommissioning is the final phase of an F(P)SO’s life cycle (notwithstanding re-use) but is generally subject to requirements for legal compliance that must be identified and managed at the front-end design phase.

The most common marine aspect where legal compliance in decommissioning is needed concerns the anchor-base; therefore, the issues of the national and international conventions during decommissioning are given specific attention in this section.

In terms of individual occupational health and safety, decommissioning of an F(P)SO currently introduces few additional demands beyond the earlier lifecycles or activities familiar and well practiced within the E&P industry in general, for example, handling marine hoses; handling mooring lines; handling anchors; open sea/inter state towage.

Environmental requirements during decommissioning

In satisfying the spirit and word of international conventions eg OSPAR, London Convention and IMO, it should be the operator’s goal to ensure that the anchor-base will, once the F(P)SO vessel has been permanently removed from the operating area, not interfere with ‘any other legitimate use of the sea’. In this context it is best to consider fishing as being the most common and pervasive ‘other legitimate use of the sea’. To meet this goal, regardless of water depth, removal of the anchor-base is demonstrably the preferred method. To accomplish this, when the front-end design for the F(P)SO is being developed, consideration shall be given to the anchor-base design and the most cost-effective means by which it can and will eventually be recovered.

As a “worst case scenario’, should a design be such that the operator will be unable to recover the anchor base on the basis that it is impracticable to do so; prior approval to decommission it by “dumping” at sea, ie clearing in place, will be required from the appropriate authority. This very lengthy process of approval is called derogation, ie seeking formal agreement to be exempt from compliance with the article of law/code/convention. Dumping in this context includes for example the simple abandonment of the anchor-base or perhaps, sinking it below the then current level of the seabed. A pre-condition for derogation normally requires an assessment to be conducted that will demonstrate that the alternatives to in-situ disposal (such as reuse, recycling or disposal on land) are impracticable on the grounds of undue risks to human health or the environment, or disproportionate costs.

To postpone acting upon the requirements to comply with the national and international laws, codes and conventions until the point at which the decommissioning phase has to be executed, and a position of force-majeure has to be presented to the authorities, is not acceptable practice.

An F(P)SO that makes use of Dynamic Positioning (DP) systems and has no connections to a seabed fixture for the purpose of mooring is excluded from the considerations given above.

Health and safety requirements during decommissioning

The additional or exceptional health and safety issues arising during decommissioning are all related to the particular marine tasks associated with decommissioning. A discussion of these specific tasks can be found in the next section and the application of risk evaluation and management should follow the guidelines contained in section 3 of this document.
Marine tasks associated with decommissioning

A significant number of marine and process tasks have to be addressed during decommissioning which have special constraints. These constraints are that the facilities may be:

- Inoperable within a short time afterwards and not available for any repeat, recovery or remedial actions
- Dismantled, for example, any purging and cleaning will need to be double-checked as immediate restitution to allow a 2nd opportunity to “make safe” may not be an option
- Supported by temporary equipment of limited capacity as the F(P)SO’s own equipment may have already been decommissioned
- Operated by a reduced crew, as normal production will have generally ceased and de-manning may have started
- Decommissioned because key equipment has broken down triggering the start of the decommissioning phase, therefore some supporting equipment may not be available to the decommissioning team

A checklist of the main tasks that will normally need to be considered during the hazard assessment, together with some further issues for management may be found in Appendix 3.

In addition, the procedures and practices of abandoning and clearing the seabed of subsea wellheads and appurtenances will involve marine health and safety risks for which diving and sub-surface hazard identification and assessment will be required.
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References

A selection of references is available from the OGP FPSO website – http://info.ogp.org.uk/fpso
Guideline for managing marine risks associated with FPSOs

Appendix 1

Guidelines on escape, refuge, evacuation and rescue

Escape

Essential to successful emergency response is the safe and rapid movement of persons on the F(P)SO from wherever they may be to muster areas and from muster areas to evacuation and escape points. Thus escape concerns immediate escape from the hazard and subsequent escape from the F(P)SO.

The escape routes on the F(P)SO should remain passable, so far as is reasonably practicable, for as long as they are needed during the emergency despite the effects of the incident. By preference, this should be achieved by layout considerations or direct protection of the route, rather than by the use of personal protective equipment. The external escape routes should wherever practicable be physically separated from explosion vent panels, sacrificial walls and open hazardous modules. Where this is not possible, alternative routes should be provided which are unlikely to be affected in the same incident.

Personal survival equipment (for example, breathing apparatus, smoke hoods, etc) may be deemed necessary to facilitate egress from certain locations on the F(P)SO.

Where the means of access or egress may be impaired, alternative means should be provided which are unlikely to be affected by the same incident. Emergency doors should open in an appropriate direction or be sliding doors. They should not be fastened in such a way that they cannot be readily opened in an emergency.

Access and egress routes should be readily identifiable by the use of suitable signs and markings; all personnel arriving on the F(P)SO should be made aware of the signs and marking as part of the induction process. Adequate emergency lighting should be provided which will illuminate the routes for sufficient time for personnel to make use of them during the emergency.

Signs should be provided as necessary to allow personnel to identify escape routes, including indication of the direction to muster areas, embarkation areas and means of escape to the sea. The type and location of signs should be selected to be suitable for the conditions, such as smoke, which may be present when the signs are needed.

The access and egress routes, the protection required for them and the time for which they should remain available, will generally be identified as critical to the success of emergency response and as such should have appropriate functional requirements. The routes are Safety Critical Elements. They should take account of the number of personnel who may need to use the route, the distribution of personnel on the F(P)SO and the way in which various incidents could affect the route.

Care should be taken specifically to ensure that access and egress routes are not impaired by simultaneous operations, eg major scaffolding erected for repairs whilst other hazardous work is undertaken. In such cases, alternatives should be assessed and clearly identified to the crew involved.

Casualty recovery may extend the time for which routes need to remain available and account should be taken of the possible requirement to use stretchers particularly where corners and doorways have to be negotiated. A route suitable for stretcher cases should be identified between the sick bay and a preferred evacuation point.

On large or complex F(P)SOs, plans showing local access and egress routes should be placed in prominent positions around the F(P)SO where necessary to assist personnel.

The dimension of escape routes should be adequate for the numbers of people who may need to use them. In general, escape routes should be greater than 1 metre wide. For routes which are unlikely to be used frequently (and then only by a small number of people) a reduction in this width may be acceptable but the decision should be justified. External escape routes and those used by personnel escaping from more than one area may need to be wider. All escape routes should have adequate vertical clearance.

Lifts, where provided, should not be used as parts of escape routes.
Refuge and muster areas

A refuge is a place where people can muster whilst immediate diagnosis of the event, emergency response, evacuation preparations and (possibly) preliminary recovery are undertaken. The refuge should have sufficient capacity to protect the maximum complement of the F(P)SO including space for transient visitors who may reasonably be expected to be on board.

The refuge may be an enclosure, more than one enclosure, or a designated area of open deck. The refuge is required to maintain the safety of personnel during the period required for the evacuation process to be completed. This includes allowing adequate time for the following activities:

- Completion of the full muster at the refuge
- Accounting for personnel not reporting to their assigned muster stations
- Evaluation of the situation and making decisions
- Initiation of responses to minimise the consequences and control the emergency, if possible
- Completion of the evacuation (if required). This may be done in a phased manner, initially evacuating non-essential personnel
- Allowing a contingency time for the unforeseen complications or delays

These times are not always additive but the F(P)SO should be designed so that the conditions which could impair the refuge do not arise whilst people are still arriving at, within or in the immediate vicinity of the refuge. These failure conditions may include:

- Loss of life support (eg due to smoke/gas, excessive heat stress, oxygen deficiency, toxic gas accumulation)
- Loss of structure (eg collapse of supporting structure, impairment of exterior fabric of an enclosed refuge)
- Loss of essential command support (eg loss of essential communications within an enclosed refuge and with third parties, ESD and F&G monitoring, emergency power/ lighting). It will be absolutely essential to provide effective communications between multiple refuges and have in place a clear command hierarchy. The level of ESD and F&G monitoring facilities required at a refuge should be considered in developing the escape, evacuation, rescue and recovery arrangements.

Dependent upon the approach taken to hazard management, it may not be necessary or appropriate to integrate the refuge within the living quarters or to enclose it. The purpose of the refuge may be to serve as a temporary muster point for only a short period, until the installation can be safely evacuated, the location and distance to onshore support is a key issue in this decision.

Short duration protection can be provided by partially enclosing the refuge or by locating the refuge away from the source of possible hazards. Whilst all F(P)SOs should have a place where people can muster, there may be some incidents where the muster location will not be a safe location.

Where it is not possible for all personnel to reach the refuge under certain emergency conditions there may be a need for parallel alternative arrangements to allow safe evacuation of those personnel who cannot reach the refuge.

Where a Control Station is occupied in an emergency and is not situated at a refuge, it should be possible for the personnel at the Control Station to subsequently reach a refuge if the situation makes it necessary. An auxiliary refuge may be needed to ensure this. The muster areas should be clearly identified by suitable signs. Adequate emergency lighting should be provided, giving illumination throughout the period for which personnel may have to use the area. Appropriate facilities should be provided in muster areas for communication. The areas should remain unobstructed and be able to accommodate all personnel who may need to use them.
All personnel should be assigned a muster area on arrival at the F(P)SO and be given adequate information about its location and all relevant procedures. A list of the assigned personnel should be displayed at the muster area. Procedures should be specified in the ERP for mustering at these areas, for accounting for personnel, and reporting back to the central control room. There should be contingencies within the planning that accommodate the possibility of key personnel responsible for conducting the muster being unavailable (ie having been incapacitated by the incident).

**Evacuation**

The evacuation and the escape process is only complete when all personnel reach a place that offers a level of safety no less than that existing before the event (necessitating evacuation and escape) and additionally providing facilities for rescue and suitable medical care.

Recovery and rescue arrangements will be required for all personnel using secondary or tertiary methods to abandon the F(P)SO. These arrangements may be provided by the F(P)SO operator (eg support vessel) or by other operators and national resources (eg search and rescue helicopters, passing vessels). The availability and suitability of such resources must be considered when developing the EER strategy.

It is necessary to take account of the needs of any special categories of personnel (eg divers in saturation) and additional facilities and arrangements may be needed to ensure they reach a suitable destination in safety.

All systems for evacuation and escape to the sea should be supported by training and familiarisation, based on the system requirements.

The normal means of getting to and from the F(P)SOs will generally be the preferred primary means for evacuation. However, in many circumstances it is recognised that the primary means of evacuation will not be available and there will be a need to provide a secondary evacuation method to allow a fully controlled escape to the sea from an F(P)SO that is independent of external assistance.

In some locations, the primary and secondary means of evacuation may be the same, providing it is always available and has sufficient capacity. It must be capable of dealing with the full personnel complement of the F(P)SO in a controlled manner, without undue delay (for example, when awaiting the arrival of external assistance).

In many locations, the optimum approach to provide secondary means of evacuation will be by survival craft in accordance with IMO and other acceptable standards.

The survival craft provided as a means of evacuation by sea should be easy to deploy, reliable in launch, give protection against hazards such as fire and smoke, be able to move away quickly from the F(P)SO and, where it is reasonable, should be oriented away from the F(P)SO on completion of launch. In some benign circumstances, the use of survival craft which are not totally enclosed may be acceptable.

Where provided, the survival craft should be readily accessible from the main TR and have a minimum capacity for the maximum numbers of personnel on board the F(P)SO.

The EER analysis may identify the need for additional survival craft in the event that some hazardous scenarios impair the launch or access to some survival craft. Further consideration should be given to severe weather conditions where the positions of certain survival craft may be particularly vulnerable or unusable and further redundancy may be required.

There will also be the requirement to assess needs for additional survival craft and qualified coxswains when POB numbers are swollen at various lifecycle phases, eg during commissioning and any campaign maintenance undertaken.

Tertiary methods (for escape to the sea) are intended for use only in circumstances where evacuation by primary or secondary methods (for evacuation) has not been possible.

The use of a tertiary method (for escape to the sea) is likely to introduce additional problems due to immersion of personnel in the sea and the requirement for subsequent rescue. Notwithstanding these problems, tertiary methods (for escape to sea) should be considered for all F(P)SOs to allow “last resort” access to the sea. To maximise the chances of survival of personnel entering the sea, life-jackets and, where relevant due to sea temperature, survival suits, should be provided at suitable locations on the F(P)SO.
In selecting the types, numbers and locations of tertiary methods (for escape to the sea), the likely demands from scenarios and the maximum personnel distribution should be considered. It is important that adequate diversity and choice of tertiary escape means are provided to cope with the potential variety of hazardous situations impacting the F(P)SO.

All personnel onboard should be provided with the safety equipment identified from the EER arrangements with supplementary equipment, life-jackets etc. available for personnel at places which may be used for access to the sea such as survival craft embarkation areas and at locations used for tertiary escape.

The EER arrangements should give clear instructions on the actions to be taken after the launch of the survival craft. For instance, it is considered preferable to head away from the F(P)SO on a course that takes the survival craft out of the path of any smoke or gas clouds. However, heading directly upwind should be avoided as this presents the hazard of drifting back towards the F(P)SO in the event of engine failure on the survival craft.

**Recovery and rescue**

The objectives of recovery and rescue are to make arrangements for the safety of people who need to escape from an F(P)SO in such time and in such a manner to ensure a good prospect of their survival. It should be demonstrable that these arrangements, necessary to effect satisfactory recovery and rescue, can reasonably be expected to be available when required.

Arrangements should be made for recovery and rescue of people who have:

- Had to leave the F(P)SO because of an incident
- Entered the sea as a result of a helicopter ditch close to the F(P)SO
- Fallen victim to a lesser incident such as man overboard

Although the F(P)SO personnel may not be directly involved in performing recovery and rescue operations during the latter stages of emergency response, it should be demonstrable that adequate arrangements have been made for these operations with those who do provide these services.

Some means of evacuation; for example, helicopters, bridge link, marine transfer to a vessel etc, involve personnel being taken directly from the F(P)SO to a place of safety. However, there are means of evacuation, for example survival craft, that are not in themselves a place of safety and are not normally capable of taking persons directly to a place of safety without some additional recovery activity. In such cases, arrangements will have to be made to recover these persons from the means of evacuation to a place of safety when it is safe to do so.

Rapid rescue from immersion is crucial as survival time in the sea may be very limited due to the effects of hypothermia, exhaustion and drowning, even for persons wearing survival equipment. Although rapid recovery (eg from a survival craft) is desirable, an assessment of the need to recover personnel in a safe manner must be made. For example, in severe weather it may be prudent to delay transfer of personnel from a survival craft until conditions improve, or until the survival craft reaches sheltered water.

**Location devices**

The ability to rescue and recover survival craft and life rafts is enhanced by the use of radar location devices such as EPIRB in line with SOLAS requirements. Some operators have found that use of personal locator beacons significantly improve the ability of helicopters and vessels to locate of people in the water and thus reduce the time taken to recover them.
Appendix 2

Checklist for hazard identification

Leaks of Gas and/or Oil

Blowouts
- Blowout in drilling
- Blowout in completion
- Blowout in production (including wirelining etc)
- Blowout during workover
- Blowout during abandonment
- Underground blowout

Also covered under blowouts are:
- Well control incidents (less severe than blowouts)
- Fires in drilling system (e.g. mud pits, shale shaker etc)

Riser/pipeline leaks
- Import flow-lines
- Export risers
- Subsea pipelines
- Subsea wellhead manifolds

Process leaks
- Wellhead equipment
- Separators and other process equipment
- Compressors and other gas treatment equipment
- Process pipes, flanges, valves, pumps etc
- Topsides flowlines
- Pig launchers/receivers
- Flare/vent system
- Storage tanks
- Loading/unloading system
- Turret swivel system

Non-process incidents

Fires
- Fuel gas fires
- Electrical fires
- Accommodation fires
- Methanol/diesel/aviation fuel fires
- Generator/turbine fires
- Heating system fires
- Machinery fires
- Workshop fires

Spills & leaks
- Chemical spills
- Methanol/diesel/aviation fuel spills
- Bottled gas leaks
- Radioactive material releases
- Accidental explosive detonation

Marine events

Collisions
- Supply vessels
- Stand-by vessels
- Other support vessels (diving vessels, barges etc)
- Passing merchant vessels
- Fishing vessels
- Naval vessels (including submarines)
- Flotel
- Drilling support vessel (jack-up or barge)
- Offshore loading tankers
- Drifting offshore vessels (semi-sub, barges, storage vessels)
- Icebergs

For each vessel category, different scenarios such as speed of event, impact energy, impacted by powered or drifting vessel may be separated.

Failures & loss
- Anchor loss/dragging (including winch failure)
- Capsize (due to ballast error or extreme weather)
- Incorrect weight distribution (due to ballast or cargo shift)
- Icing
- Collision in transit
- Grounding in transit
- Lost tow in transit

Structural events

Extreme loadings
- Extreme wind
- Extreme waves (loads and periods)
- Extreme currents
- Earthquakes

Failures
- Structural failure due to fatigue, design error, subsidence etc
- Foundation failure (including punch-through)
- Bridge collapse
- Derrick collapse
Crane collapse
Mast collapse
Disintegration of rotating equipment
Mooring/riser failure

Dropped objects

Objects dropped – predominant activities

- Construction
- Crane operations
- Cargo transfer
- Drilling
- Rigging-up derricks

Object types

- Storage containers
- Rubbish containers
- Tools
- Spare equipment (valves, pipes, vessels, machines etc)
- Temporary equipment (air compressors, scaffolding, welding kit etc)
- Disassembled equipment (during repair/maintenance)
- Hoses
- Tote tanks
- Gas cylinders/quads
- Drill strings
- BOPs

Transport accidents – crew-changes or in-field transfers

- Helicopter crash into sea/platform/ashore
- Fire during helicopter refuelling
- Aircraft crash on platform (inc military)
- Capsize of crew boats during transfer
- Personal accident during transfer to boat
- Crash of fixed-wing aircraft during staged transfer offshore
- Road traffic accident during mobilisation

Personal (or occupational) accidents

- Slips
- Trips
- Falls
- Lifting strains
- Scalding
- Burns
- Toxic exposure
- Asphyxiation
- Poisoning
- Pipe laying
- Disease
- Bacterial (eg legionella)
- Electrocution
- Radiation ionising and non-ionising (eg microwaves)
- Respiratory (eg dust, fibres etc)
- Heat exhaustion
- Extreme cold, frostbite
- Vibration white finger

Diving accidents

- Trapped (moorings, hoses, lines, umbilicals, air lines, structure etc)
- Communications (with F(P)SO and/or DSV, other divers)
- Interfaces with ROV
- Interfaces with bell
- Interfaces with other vessels
- Faulty air/mixture supply, quality, pressure, temperature etc
Appendix 3

Checklist for marine tasks during decommissioning

In establishing the boundary for this checklist, all procedures and practices needed to abandon and clear the seabed of the subsea wellhead have been excluded.

It has also been assumed that the subsea well head has not been abandoned prior to decommissioning the F(P)SO. From a risk assessment point of view, abandonment of the subsea well head before decommissioning the F(P)SO and decommissioning all components as an integrated process is preferred.

Riser – disconnection & recovery
- Flushing
- Disconnection
- Recovery

Well control hoses – disconnection & recovery
- Flushing
- Disconnection
- Recovery

Loading hose – recovery
- Flushing
- Disconnection
- Recovery

Mooring chains/lines – recovery
- Disconnection from F(P)SO (What if? Lines break)
- Buoying-off for recovery
- Recovery (What if? Anchor-block/Foundation stuck/held up in seabed)
- Concurrent diving and mooring operations

Anchor – recovery
- Recovery (What if? anchor drags over subsea wellhead)
- Concurrent diving and mooring operations

Towage
- Line connection (What if? loss of tow line)
- Tug communications (What if? control of tug(s) ambiguous, lost)
- Tug performance/capability (What if? tug failure, loss of steerage)

Quality of ballast water
- Pumping ballast water (What if? wrong quantity, quality)

Seabed clearance of mooring foundations/anchor bases/anchor piles/riser guide structures/flowline termination points – recovery
- Raising from seabed (What if? anchor-block/Foundation stuck/held up in seabed; winch line(s) break; blasting/cutting anchor piles)
- Recovery to surface (What if? anchor-block/Foundation releases during lift; anchor-block/Foundation; drags over subsea wellhead)
- Concurrent diving and mooring operations
Emergency response
- Additional personnel during decommissioning (What if? POB impacts on availability, competencies or roles in the ER framework)
- Phasing of decommissioning of ER related equipment
- Reliance on external emergency services during decommissioning (What if? availability of external resources within ER changes when under tow, crossing boundaries/areas of responsibility)

Tanks & tank cleaning
- Disposal of vessels & equipment (What if? residues are deemed to be waste and exceed the limits of the country of next destination)

Vessel to reuse
- Identification and transfer of legacies

Vessel to salvage
- Identification and management of legacies
- Waste management of residues in process equipment and storage tanks
- Breaking & scrapping
  - Location selection
  - Health, safety and environmental practices
  - Waste disposal
What is OGP?

The International Association of Oil & Gas Producers encompasses the world’s leading private and state-owned oil & gas companies, their national and regional associations, and major upstream contractors and suppliers.

Vision

- To work on behalf of the world’s oil and gas producing companies to promote responsible and profitable operations

Mission

- To represent the interests of oil and gas producing companies to international regulators and legislative bodies
- To liaise with other industry associations globally and provide a forum for sharing experiences, debating emerging issues and establishing common ground to promote cooperation, consistency and effectiveness
- To facilitate continuous improvement in HSE, CSR, engineering and operations

Objectives

- To improve understanding of our industry by being visible, accessible and a reliable source of information
- To represent and advocate industry views by developing effective proposals
- To improve the collection, analysis and dissemination of data on HSE performance
- To develop and disseminate best practice in HSE, engineering and operations
- To promote CSR awareness and best practice