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ICE MANAGEMENT AND OPERATIONAL STRATEGY FOR FLOATERS IN ICE

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ABSTRACT

A new standard was published in late 2010 for the design of oil and gas production facilities in ice-covered and cold regions - ISO 19906, Arctic Offshore Structures (ISO, 2010). In the present paper, the rationale that went into the development of requirements for the design and operation of floating structures in ice environments is described. Floating production platforms need to be treated as a system that includes hull, stationkeeping, riser and subsea components when dealing with ice actions. The primary focus is on ensuring overall system reliability with respect to human safety and environmental consequences.

The design philosophy and operational approaches adopted for floating structures can vary substantially from those for fixed platforms. Floating installations can be configured to suspend operations and move off location, thereby avoiding interactions with extreme ice features. Ice management can also be used to actively modify ambient ice conditions, and thereby mitigate the potential for adverse ice actions. The standard provides the necessary guidance for developing a sound operating strategy involving ice management.

The primary issues addressed in the paper include mechanical systems, hull integrity, stationkeeping, and design and operation in the context of an ice management system.

INTRODUCTION

The key focus of this paper, is to provide guidance to the designer in developing a sound operating strategy for floaters in ice. The design and operational approaches for floating structures can vary substantially from those for fixed platforms, particularly when ice is a key consideration. Floating installations can be configured to suspend operations and move off location, thereby avoiding interactions with extreme ice features. Ice management support techniques can be used to actively modify ambient ice conditions, and thereby mitigate the potential for adverse ice actions.

The interplay between various design and operational aspects can have a strong influence on the fundamentals of the design approach that is selected for a floater. Some of the primary ice-related issues for floating installations are highlighted in the following subsections.

The ISO 19906 standard addresses such ice-related issues, in the form of additional requirements, due to the nature of the ice covered and cold weather environment. These additional requirements include:

Ice actions and hull design Establishing the requirements for the design, construction and operation of a hull with respect to the environmental actions and action combinations, for local and global considerations.

Cold weather materials and design of marine systems Establishing the requirements for the design, fabrication and operation in view of the arctic environment.

Ice management Establishing the requirements for an ice management system covering the detection, threat evaluation and implementation of active mitigation measures by means of an alert system to contend with hazardous ice situations, including both glacial ice features and sea ice.

Disconnection Establishing the requirements for disconnection in the event of hazardous ice situations, with emphasis on ensuring timely and successful disconnection, and on how these requirements are implemented during the design, construction and operational phases.

GUIDANCE FOR DEVELOPING A SOUND OPERATING STRATEGY

Objective

In the responsible conduct of its business, an operator is committed to ensuring that the health and safety of personnel are not compromised, and that any adverse effects to the environment are minimized.

To achieve these objectives, a comprehensive operating strategy needs to be in place to cover all activities associated with the design, construction, installation, commissioning, production, transportation, decommissioning and abandonment phases of any field development. The purpose of such an operating strategy is to:

- outline the policies and procedures as they relate to floating operations in ice
- clearly demonstrate that the design, construction and operation of a floater has addressed the relevant ice-related issues with respect to ice actions, cold weather, ice management and disconnectability
- define procedures to ensure safe operations in an ice environment;
- outline procedures, roles and responsibilities through an ice management plan, and establish ongoing training procedures.

Considerations

To implement such a strategy, the designer should understand the dynamics of the physical environment and its effect on the floating facility. In particular, the designer should:

— define load events and design scenarios, based on existing environmental data
— define a set of operating modes, and develop performance criteria and associated limits
— for each design scenario, define representative actions due to ice, waves, wind and current on the floating platform and on the mooring system

The elements of an operating strategy are provided in Figure 1.

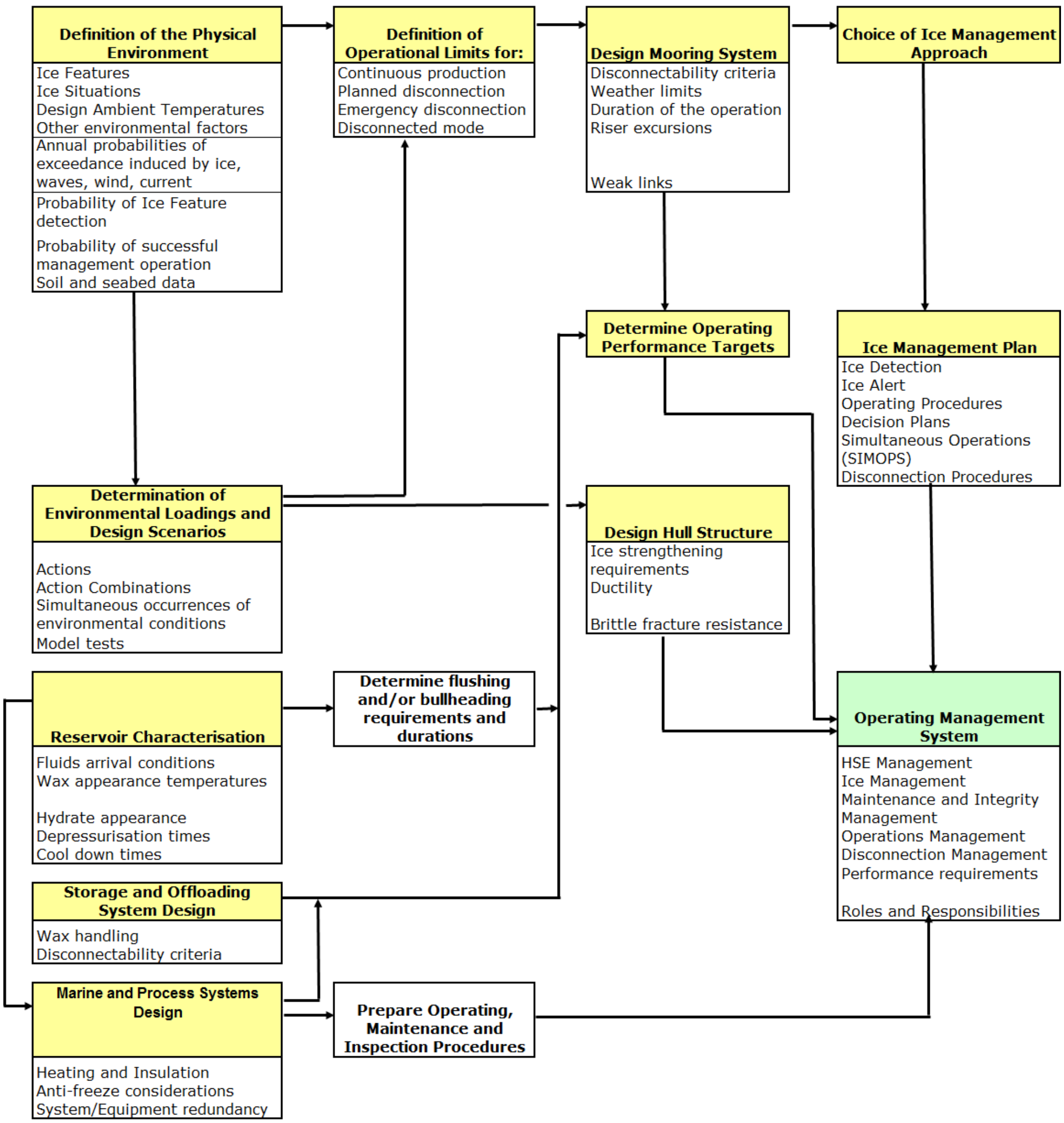

Figure 1. Operating framework for floating structures in arctic environments

Physical Environment

Identification of key dynamic environmental processes and related events, and specific responses to them, are keys to successful floater operations. While ice and metocean conditions are the same as those for fixed structures, the behaviour of a floating structure is often more complex, due to a higher sensitivity to different combinations of environmental actions and the dynamics involved. Because of this and because of the need to define operational envelopes, there can be substantially increased requirements for ice and metocean data, including detailed time series.

Because long term data are often lacking in arctic environments, operating plans and procedures need to recognize the associated uncertainties.

The ISO 19906 standard provides a definition for service temperature based on minimum hourly averages because these are most representative of actual temperatures. For floating structures where the detailed design is performed using other standards, daily average temperature values may need to be considered for machinery and material requirements. In such cases, the relationship between daily and hourly average values should be verified to ensure that the local climate is properly addressed.

Reservoir Characteristics

Field reservoir characteristics have a major influence in the drainage strategy, which in turn dictates the requirements for decreasing downtime. Fluid composition, which drives chemical injection, wax inhibition and flow assurance strategies, needs to be verified during the preparation phase of the basis of design. The potential for hydrate formation must be managed during steady state production and for shutdowns and start-ups, during normal and/or emergency disconnection scenarios. To that effect, acceptable cool down times for the flow lines, manifolds and trees have to determined, based on the expected frequency and duration of process shutdowns/disconnect scenarios. These are important issues as they relate to alert systems and secure times.

Fluid composition also drives the design requirements of the process and utility systems. Key considerations are heating and insulation requirements to prevent freezing or wax appearance under extreme low temperatures.

Performance

Performance is measured in terms of overall uptime, from the reservoir to the export facilities. Normally a production availability assessment is performed at an early stage in the design process. Considerations have to be given to the impact of downtime due to either routine or emergency disconnection for ice considerations.

The limiting conditions imposed by environmental factors on the platform and associated systems will be largely predicated upon the final design criteria adopted for the floater and equipment specification.

The criteria selected for equipment and system redundancy and availability, scheduled maintenance, and unscheduled shutdowns and breakdowns will also directly impact upon operational efficiency.

ICE MANAGEMENT

Ice management systems

Ice management includes the performance of management systems, the requirements associated with the detection, threat evaluation and operational components of such systems, as well as requirements relating to the planning and operation of a system, including training of personnel.

Operational procedures to reduce ice actions

Clause 8.2.7 emphasizes the importance of ice management, and begins with the following statements

> *"Operational procedures may be used to mitigate ice actions on fixed, floating and subsea structures provided that it can be shown that, in combination with structural resistance, the intended level of reliability is achieved. Operational procedures include ice management, disconnection and removal, clearing of snow and ice accumulations, rubble and spray ice barriers, and seasonal operation. Ice management can be used to alter the ice regime, through decreases in floe size and the destruction or removal of potentially hazardous ice features, and through local reduction in ice coverage."*

In this way, Clause 8.2.7 essentially allows the use of floaters in ice environments with ice management support and promotes safe developments in the Arctic and in other cold regions. The challenge is how to assess this quantitatively.

Methodology to assess the effect of operational procedures

This section highlights the manner in which operational procedures can be assessed. Let the probability distribution (probability density function) of ice actions on the structure be represented as $f_Z(z)$, with annual interaction frequency, n. After the ice has been managed, making the features smaller, less frequent or both, the distribution is altered to, say, $f_Z{}^*(z)$, with interaction frequency, n^*. The challenge is to determine the relationship between the two distributions $f_Z(z)$ and $f_Z{}^*(z)$, and the interaction frequencies n and n^*.

As an example, assume that the ice action, z, on a structure depends on the size, w, and the drift speed, v, of the ice feature and another parameter, u, such as sea state or ice concentration. While there may be other factors such as the strength of the ice that apply, these do not affect the approach as long as they are independent of w, v and u. Consider the joint probability distribution of size, drift speed and sea state or ice concentration for the ice features potentially reaching the structure, $f_{W,V,U}(w,v,u)$, and the functional relationship (e.g. impact or interaction model) between these parameters and the action

$$z = \mathrm{g}(w,v,u) \tag{1}$$

Equation (1) could represent an ice load (iceberg impact, unbroken ice cover, managed ice). The size parameter could be the mass for iceberg impacts or the thickness for ice sheet interactions. Regardless of the functional form of the relationship for the action, the probability distribution of the action, $f_Z(z)$, can be obtained by Monte Carlo simulation based on the joint distribution $f_{W,V,U}(w,v,u)$.

Consider now the probability of detection in sufficient time to manage the ice feature, $p_D(w,v,u)$, and the probability of a successful management operation, $p_M(w,v,u)$. The probability of an ice feature reaching the structure can be expressed as

$$p(w,v,u) = [\ 1 - p_D(w,v,u)\ ] + p_D(w,v,u)\ [\ 1 - p_M(w,v,u)\ ] \qquad (2)$$

The first term represents the failure to detect the hazardous ice feature and the second represents the failure to manage it physically, once it is detected. It is emphasized that the probabilities apply for ice features that are destined to hit the structure, so that the probability, $p(w,v,u)$, represents the proportion of ice features that still make it through to the structure, in spite of the management system in place, as a function of the parameter values w, v and u.

For floating platforms, the frequency of ice feature interactions can also be reduced through disconnection of the structure. Disconnection can be considered in the same way (McKenna et al., 2003), where the probability of an iceberg reaching the structure is

$$p(w,v,u) = [\ 1 - p_D(w,v,u)\ ] + p_D(w,v,u)\ [\ 1 - p_M(w,v,u)\ ]\ [\ 1 - p_C(w,v,u)\ ] \qquad (3)$$

in which $p_C(w,v,u)$ is the probability of successful disconnection within sufficient time to avoid impact.

The ice feature size, drift speed and sea state or ice concentration distribution after ice management is

$$f_{W,V,U}{}^*(w,v,u) = p(w,v,u)\, f_{W,V,U}(w,v,u) \,/\, \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} p(w,v,u)\,\mathrm{d}w\,\mathrm{d}v\,\mathrm{d}u \qquad (4)$$

While the lower integration limit is shown as $-\infty$, it will be 0 when the parameter has only positive values. The probability distribution of the action, $f_Z{}^*(z)$, can be obtained once again from Equation (1) by Monte Carlo simulation using the joint distribution $f_{W,V,U}{}^*(w,v,u)$.

The decreased ice interaction frequency is calculated from the probability of an ice feature reaching the structure, integrated over the joint distribution of iceberg size, w, drift speed, v, and sea state or ice concentration, u, as

$$n^* = n \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} p(w,v,u) f_{W,V,U}(w,v,u)\ \mathrm{d}w\,\mathrm{d}v\,\mathrm{d}u \qquad (5)$$

The general situation is shown where the three parameters w, v and u are dependent. If they are independent, then $f_{W,V,U}(w,v,u)$ can be replaced by $f_{W,V}(w,v)\ f_U(u)$ or $f_W(w)\ f_V(v)\ f_U(u)$, as appropriate. The same can be done for $f_{W,V,U}{}^*(w,v,u)$. If Equation (1) does not depend on sea state or ice concentration, u, i.e. $z = \mathrm{g}(w,v)$, then Equation (4) can be integrated over u to yield $f_{W,V}{}^*(w,v)$.

If, for example, detection and management do not depend on the size and speed of the ice features nor on the sea state, then the probability that an iceberg reaches the structure is the constant value, p, in which case the following apply

$$n^* = n\,p \qquad (6)$$

and

$$f_Z{}^*(z) = f_Z(z) \qquad (7)$$

This is sometimes done as a first estimate to assess the effect of ice management. If the ice management system is 75 percent effective, then $p = n^*/n = 0.25$ and the design value for the action is simply assessed based on a reduced interaction frequency.

As an ice feature approaches the structure, the probability of detection can improve, the probability of successful management might decrease because of lack of time and the probability of successful disconnection will decrease. These features can be captured in Equations (2) and (3) by considering the effect of time for the ice feature to reach the structure, t, in each of $p_D(w,v,u,t)$, $p_M(w,v,u,t)$ and $p_C(w,v,u,t)$ to thereby obtain $p(w,v,u,t)$ (McKenna et al., 2003). For detection probability, time can be estimated based on range divided by drift speed. With an optimal ice management system having access to unlimited resources, the minimum value of $p(w,v,u,t)$ with respect to t can be used to obtain $p(w,v,u)$. Empirical data or simulation can be used to assess whether the minimum value is representative of the system performance.

Interpretation of iceberg towing data

Clause 8.2.7 emphasizes the importance of incorporating past ice management experience for new developments

> *"The effectiveness of operational procedures shall be founded on documented experience, where applicable, and the approach shall reflect the uncertainty inherent in the input data and modelling techniques."*

PAL (2010) have documented 1691 iceberg management operations off Canada's east coast which include towing, water cannon and propeller wash. Because towing (and its various derivatives) is the most common technique for the size of icebergs that are most likely to contribute design loads on structures, these 1416 operations are considered in the following discussion. Tows involving grounded icebergs have been ignored since this is a site specific issue.

Although an index has been developed in PAL (2010) to measure tow success, an alternative is to consider the distance that the iceberg is deflected normal to its original track. On average over all iceberg lengths, sea states and drift speeds, the probability that a tow attempt exceeds a specified off-track deflection distance is given in Table 1. Since off-track deflection distance is independent of the above parameters, this may be all that is required to estimate the probability of successful ice management, p_M, for different sized structures and projected iceberg widths.

Table 1. Probability associated with off-track deflection distances (from PAL, 2010)

Deflection normal to track [km]	0.5	1	1.5	2	2.5	3	4	5
Probability of Exceedance	0.84	0.77	0.72	0.68	0.63	0.60	0.55	0.49

A feature of the tow data is the small number of tow operations for sea states greater than 4 m significant wave height. Operations are difficult to accomplish safely under such conditions and due consideration should be made of the characteristics of the tow vessel and the local sea conditions when assessing success rates. The data in Table 1 also assume that a sufficient number of tow vessels is available.

The same concepts can apply to sea ice management (see, for example, Wright et al. 1999).

Ice Alert System

The need for systematic and well defined ice alert procedures has been identified as a key ingredient to any ice management system in the new ISO Arctic Standard.

"Ice alert procedures can be used to initiate appropriate operational reactions to any ice hazards or adverse ice situations in a timely manner, in order to mitigate threats. Appropriate operational reactions can include shut-in of production, disconnection of the structure, moving it off location or the evacuation of personnel, depending on the nature of the offshore system that is being supported."(from clause 17.1)

The use of an ice alert procedure is a very central element to the types of floating operations and ice management systems described in this paper, since these procedures establish both clear decision making thresholds and well-thought-out response actions for pre-defined hazards. In this sense, they are fundamental. As covered in the ISO 19906 standard, these types of ice alert concepts can also be applied to fixed structures, in addition to floaters, and have been in the past (Wright and Weaver, 1982).

Ice alert procedures were first introduced to support floating drilling operations on the East Coast of Canada and in the Beaufort Sea in the 1970s, and have been utilized with a highly degree of success since that time (Wright and Browne, 1999; Wright 2000). These ice alert procedures have also been improved on as more in-ice operating experience with different floating systems has been obtained. More recently, these alert concepts have been applied to support a variety of in-ice operations in other parts of the world, such as the offshore Sakhalin Island and Caspian Sea areas.

One example of an ice alert system is given in Table 2, in this case, the procedures used to support Kulluk drilling operations in the Canadian Beaufort Sea. This example is a simple illustration of the concept, which involves the diminishing difference between the ice hazard time (HT) and well secure time (ST) for this straightforward drilling case, and the "well secure and marine response" actions that were activated. This type of ice alert procedure is further described in Wright and Browne (1999) and Wright (2000) along with those used by Canmar for their drill-ship system. This type of logic can be extended to a broader spectrum of operations. In actually fact, the basic Kulluk ice alert system was advanced to include more specific well and marine support system alerts, which in turn were incorporated into the Kulluk's overall alert procedures.

Table 2. Kulluk environmental alert status

Colour code	**Meaning**	**Hazard time, less secure time (HT-ST)**	**Drilling response**	**Marine response**
Green	Normal operation	HT - ST > 12 h	Normal operations	Normal watch
Blue	Early alert	HT - ST < 12 h	Normal operations	Alert watch and ice management
Yellow	Early warning	HT - ST < 6 h	Restrict operations to available lead time	Begin preparations for hazard and tactical ice management
Red	Drilling must stop, vessel may move off	HT - ST = 0	Secure well as appropriate	Final preparations for hazard and ice management
Black	Ice: vessel must move off Weather/wave: vessel must stream off on moorings	HT (for disconnect) < 2 h	Disconnect	Ice: move Kulluk off site Weather/wave: stream off on moorings

One extension of this type of ice alert system has been promoted in conjunction with some operations for the Sakhalin II project (Keinonen et al., 2006). The suggested approach involves another layer of "risk assessment" which, in practical terms, is best focused on communication with onshore-based management rather than the actual operational people in the field. This additional layer of "ice risk assessment" is not recognized in ISO 19906, but may be useful for more general communication purposes.

HULL INTEGRITY

In terms of hull integrity for floating production vessels, the practice to date has been to adapt requirements developed for ice-strengthened trading ships. The basis of ice strengthening of early Beaufort Sea drillships and FPSOs in the Grand Banks were the Finnish-Swedish Ice Class Rules (more commonly known as the Baltic Rules). It is reasonable to assume that this general practice will continue at least in the near future, and the ISO 19906 requirements permit the use of these rules. Of course there are fundamental differences in the philosophies of the ship ice class rules and those embodied in ISO 19906. At some point there may be interest from industry in recasting traditional ice class requirements in a manner consistent with the structural design philosophy in ISO 19906.

In terms of ice class rules there are now a modern set of rules developed specifically for Polar shipping: IACS Unified Requirements for Polar Shipping (IACS Polar Rules). The Baltic Rules are for shipping exclusively in first-year ice whereas Polar Rules are intended for all types of Arctic ice up to heavy multi-year ice. Hence, in the Baltic Rules there are no hull strengthening requirements outside the bow and the ice belt in the vicinity of the waterline, whereas the IACS Polar Rules has strengthening requirements for virtually all parts of the hull below the ice belt. This reflects the likelihood, or at least the possibility, that the hull will encounter significant ice forces outside the ice belt from features such as glacial ice, multiyear inclusions, ridges and rubble. Therefore, the IACS Polar Rules may be a better guide than the Baltic Rules for determining the extent of ice strengthening in severe ice conditions.

A different set of conditions apply if the unit in question is to be designed to perform seasonal operations. In that case the unit will, in general, need to either be towed to the site, or will transit under its own power, and the reverse will occur at the end of the season. In this operational mode, the ship rules can be used with a minimum of adjustment.

The demands due to managed ice on the hull of floating structures will clearly depend on the characteristics of ice, particularly speed, thickness and concentration (glacial ice features are a special case). In low ice concentrations, the demands are generally on the global system and the first line of defence will be the stationkeeping system, mostly likely a system of moorings or less likely some kind of dynamic positioning system. At higher concentrations, local strength may become significant although the demands on the global system can still be expected to dominate. For still more severe ice conditions demands on both local and global strength may be significant. An example of the latter is a pressured ice condition which can be threat not only to the stationkeeping system but also to the global (e.g. transverse bulkheads) and local structural integrity (e.g. plate panels).

A change in ice direction can pose a significant threat to moored ship-shaped platforms, especially in heavy and/or pressured ice. A change in direction will initially be experienced by the bow of the ship and if the ice management vessels are unable to assist the unit in realigning itself with the ice direction, then significant side loads can be experienced. Depending on the severity of such an occurrence, it can also pose a threat to the mooring system.

ISO 19906 notes the importance of considering dynamic effects. Moored structures may be dynamically responsive to ice action and global ice loads may be amplified as a result. This responsiveness will, in general, depend on the characteristics of the ice and ice management can play an important role in reducing or eliminating dynamic effects.

STATIONKEEPING

Introduction

When selecting a floating installation concept, the means by which the installation will keep its position is certainly one of the most important ones. Ideally, it would be beneficial to have an installation with a passive system that could resist all possible ice actions the installation could experience. In some areas, the level of ice actions can be large enough that it may not be cost effective or even feasible to include a completely passive system. Instead, to cope with the largest ice loads, the system may be designed as a system with move off capabilities and perhaps also a great deal of ice management.

With reference to Figure 2, there are basically three different design and operating approaches for station keeping:

- passive: no move-off capability, no ice management capability;
- semi-active: move-off capability, no ice management capability;
- active: move-off capability, ice management capability.

When designing the station keeping system, it is also important to know whether the system should operate all year round or just seasonally, when the ice load levels may be limited in some areas.

Mooring systems and disconnection modes

For floating installations, experience shows that both active and passive means can be used for stationkeeping, see Table 3.

For installations with quick disconnection capability, two potential disconnection modes can be designed for:

(a) Planned disconnection, which allows ample time for depressurizing and flushing of flowlines and for start-up of production after the floater has been reconnected; and
(b) Emergency disconnection, which allows sufficient time only to shut down wells.

If the installation is equipped with marine propulsion system and/or thrusters these should be adequate for the operating environment, both as a part of the station keeping system on location as well as transiting after a possible disconnection. Consideration should be given to both design service life and required maintenance, ref. also section 13.8.2.7 in the standard.

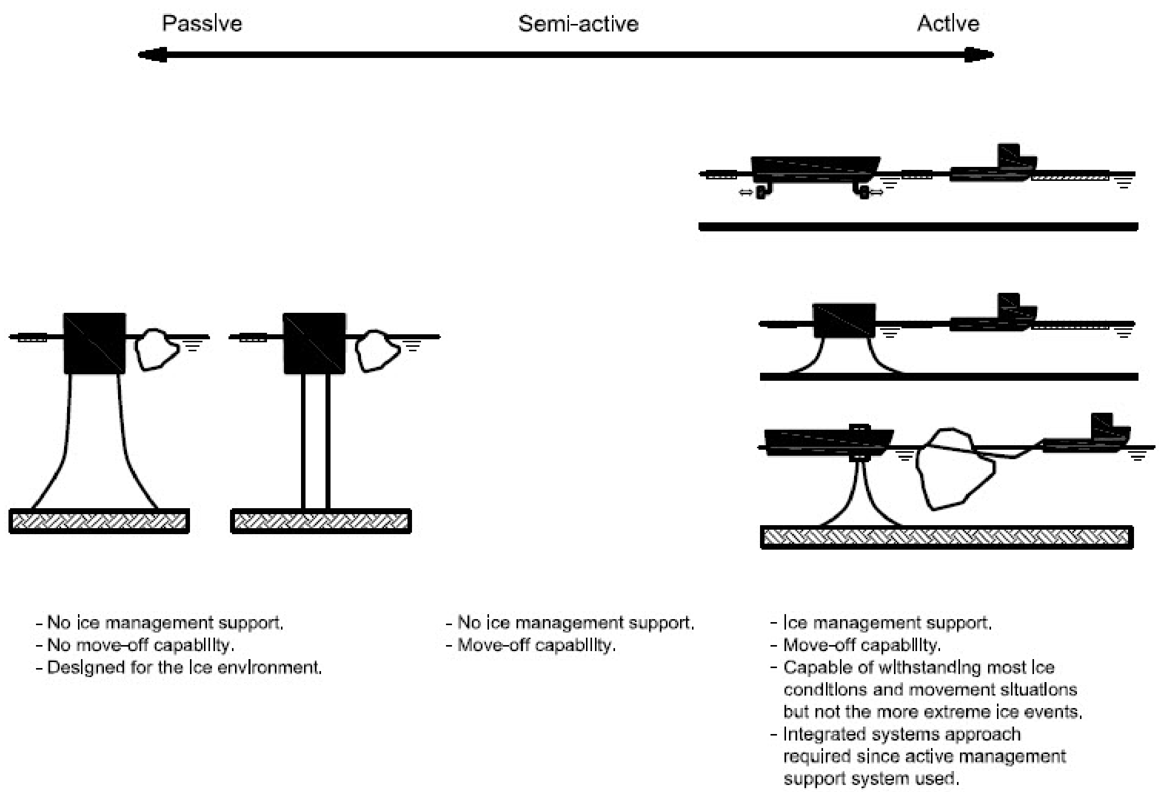

Figure 2. Range of options for stationkeeping in arctic and cold regions

Table 3. Overview of stationkeeping systems

Structure type	**Normal stationkeeping system**	**Alternatives**
Monohull (fixed direction)	Spread moored	Slack or taut lines fixed or quick disconnect
Monohull (rotatable)	Single-point moored turret	Slack or taut lines fixed or quick disconnect DP or thruster assisted
Semi-submersible	Spread moored	Slack or taut lines fixed or quick disconnect DP or thruster assisted
Spar	Spread moored	Semi-taut, taut or catenary lines
TLP	Vertically, tensioned, tethers	Fixed system, no possibility for disconnection

Local Design Issues

Attention should be paid to details when designing a position keeping systems for ice prone areas. Local ice load minimisation, easy operation, maintenance and replacement should be key factors in the design. Factors to be considered should include:

(a) Mooring lines should be routed so as to avoid direct exposure to ice actions in the splash zone and below, depending on the design ice interaction scenarios. Ice features caught by the mooring lines can result in additional ice actions on the mooring system.
(b) Anchor fairleads shall be positioned to minimize such effects or localized ice management may be adopted.
(c) All propulsion and dynamic positioning equipment shall likewise be located with careful consideration to potential ice impact. Consideration shall be made in the design for slowing and jamming of the propeller(s) by ice.

MECHANICAL SYSTEMS

General requirements for mechanical systems on floating structures are given by ISO 19904-1. Emphasis in ISO 19906 is on mechanical system that normally have a strong interface with the structural design and safe operation of a floating structure, such as

- sea inlets and cooling water systems;
- ballast systems;
- marine systems instrumentation
- lighting
- HVAC and air systems
- starting arrangements
- propulsion, thruster and steering
- offloading systems

As a main principle mechanical systems and machinery essential for the safety of the operation of the unit shall, when stored or located in exposed positions, be able to perform their functions at the unit's lowest anticipated air temperature.

Where necessary, heating and insulation systems are to be provided. Systems and equipment, which could be subject to outside ambient air temperatures upon failure of the primary heating system, should be provided with an independent source of heat or fabricated from materials that will not be susceptible to brittle fracture under the anticipated loads and temperatures.

Furthermore, systems and equipment should be designed so that personnel exposure to cold temperatures and other environmental hazards during normal operations, including routine maintenance, is minimised.

Heating and insulation should be provided in spaces where low temperatures might affect the safe working of personnel or affect the proper functioning of equipment.

CONCLUSIONS AND RECOMMENDATIONS

A key aspect for floaters is that the entire system be designed appropriately for the geographical location and environmental conditions. This could potentially involve seasonal operation, special operating procedures, ice management and/or disconnection. A floating production structure typically relies more than a fixed structure on operational considerations to operate safely in an ice environment. The monitoring of environmental conditions and hull performance, support vessel operations, and shutdown procedures all have a greater role for floating structures.

Without special provisions for the design, construction and operation of an integrated system for detecting, evaluating and altering threats from ice features, most floating structures could not operate in ice environments.

There is an interplay between ice actions and the motion of a floating structure, which introduces additional complexity to the specification of the actions. Local features of the structure such as propellers, rudders, thrusters and mooring line connections are integral to the performance of a floating structure. Ice actions may be reduced by alteration of the ice environment through management procedures.

Floating production facilities differ from fixed structures in that they must operate as ships in addition to their production functions. All of the marine systems, including thrusters and ballast control, must be designed for the arctic environment and operated with it in mind.

Understanding the dynamics of the physical environment is of great importance to the designer in developing, and implementing, a sound operating strategy for floaters in ice. This strategy will be a powerful tool to ensure that the health and safety of personnel is not compromised, the adverse effects to the environment are minimised and the production performance targets are met.

REFERENCES

ISO, 2010. ISO 19906 Standard, Petroleum and natural gas industries — arctic offshore structures.

Keinonen, A., Browne, R., Lam, E. and Jolles, W. 2006. Six Years in Sakhalin Offshore Oil – Management of Risk, Operations in Ice, Paper No. ICETECH06-105-RF in proceedings of ICETECH 2006, Banff, Canada.

McKenna, R., Ralph, F., Power, D., Jordaan, I. and Churchill, S., 2003. Modelling iceberg management strategy, in Proceedings of the 17th International Conference on Port and Ocean Engineering under Arctic Conditions, Trondheim, Norway, Vol.2, pp.645-654.

PAL, 2010. Comprehensive Iceberg Management Database Report - 2009 Update, Provincial Aerospace Environmental Services Division report to Canadian Hydraulics Centre, National Research Council of Canada, PERD/CHC Report 20-84.

Wright, B. and Weaver, J. 1982. Winter Ice Alert Monitoring at the Tarsuit Caisson Retained Island. Proceedings of the Offshore Technology Conference - 1982. Houston, Texas.

Wright, B. and Browne, R. 1999. Evaluation of Full Scale Data For Moored Vessel Station-keeping in Pack Ice (with Reference to Grand Banks Developments). PERD/CHC Report 26-200.

Wright, B. 2000. Full Scale Experience with Kulluk Station-keeping Operations in Pack Ice (With Reference to Grand Banks Developments). PERD/CHC Report 25-44.