Noble Denton Canada Ltd.
Marine and Engineering
Consultants and Surveyors

PACK ICE MANAGEMENT

on the

SOUTHERN GRAND BANKS OFFSHORE NEWFOUNDLAND, CANADA

(SCOPING STUDY)

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1.0 INTRODUCTION

Pack ice management is a matter of considerable importance, particularly for floating development systems working on the Grand Banks, which lies several hundred kilometers southeast of Newfoundland on Canada's East Coast. Although pack ice is not experienced annually across the more southerly parts of this area, where the Terra Nova and Hibernia oil fields are located, it is of real concern when it does occur and is therefore a significant operational issue. Additionally, the likelihood of more frequent and persistent pack ice occurrences that can constrain floating system operations will increase as activities on the Grand Banks move further towards the north and east, for example, at the Whiterose location. Future exploration and development activities that are now being considered for more distant areas like the Orphan Basin and Flemish Cap will be even more susceptible to pack ice.

In this regard, the feasibility of any future development projects undertaken in the Grand Banks area may, in part, be reliant on the success of pack ice management support. From a technical perspective, related in-ice considerations range from the design of lower cost fixed structures, through downtime levels for FPSO and tanker loading operations, to questions involving evacuation and oil spill response. In terms of project economics, the potential for significant downtime during pack ice intrusions can be an influential factor, depending on the particulars of the development system.

Past experience with the operation of floating units in other Arctic and sub-Arctic regions has shown that floating exploration and development systems can be successfully kept on location in pack ice, with good ice management support. However, even when a floating platform is suitably ice strengthened, it can encounter difficulties and downtime while station-keeping in pack ice, if the associated ice management system is ineffective.

The question of pack ice management is a complex subject, due to factors such as:

- The particular type of platform being supported, either floating or fixed.
- The function of the platform (e.g.: drilling, production, storage, loading).
- The level of ice strengthening of the platform.
- The method of station-keeping for the platform (e.g.: bottom-founded, anchored, or dynamically positioned).
- The ice environment in which the platform is operating.

With the exception of heavily ice-reinforced GBS platforms, most development systems working in the Grand Banks region will require some level of pack ice management from independent vessels, at certain times. In this regard, there has long been a misconception that ice-strengthened support vessels classed for transits through certain types of pack ice will also be capable of performing ice management duties in similar conditions. There is a major task distinction between ice transits and ice management that must be recognized. The key to successful in-ice vessel transit or *ice navigation* is simply to avoid heavy pack ice and, where necessary, to operate at slow advance speeds appropriate to the ambient ice conditions. *Ice management*, on the other hand, requires that all pack ice moving towards a platform is either broken up or deflected, to effectively defend it against the adverse effects of the approaching ice, and allow the platform to safely operate within its station-keeping limits.

Pack ice management, by its very nature, includes aggressive icebreaking, often at high speeds, especially if the ice drift is fast and the encroaching pack ice features are severe. Also, the pushing of large ice floes at high power is often required. This non-traditional use of ice-strengthened support vessels, particularly those classified as Type ships (not icebreakers), presents an increase in the potential for ice damage to them. Should any ice damage occur and one or more support vessels be disabled, it could have a major impact on the success of the entire operation being supported. In this regard, it is important to recognize that any support vessels used for pack ice management within either current or future Grand Banks development projects should be appropriate for the intended task.

This report presents the results of a brief scoping study regarding pack ice management considerations on the Grand Banks, and on suitable ice management vessels in particular. The work was carried out as a PERD study for the National Research Council of Canada, by Noble Denton Canada Ltd., with input from B. Wright & Associates Ltd.

2.0 OBJECTIVES AND APPROACH

The primary objective of this report is to highlight some of the key pack ice management considerations for various development systems intended for use in Grand Banks pack ice conditions. Although a number of relevant topic areas are addressed in this report, the main emphasis has been placed on the ice strengthening and performance capabilities of support vessels that may be needed to provide effective pack ice management services in the region.

Practical information about the range of ice management activities that would be required to support station-keeping operations with different platforms and vessels in Grand Banks pack ice conditions is provided, along with some guidance notes about vessel “suitability criteria” for pack ice management in this area. However, as a scoping study, the report is not intended to specifically identify the most appropriate support vessels for use within various Grand Banks development projects, nor critique any of the pack ice management plans and systems that are now in place.

The report has been sub-divided into a number of topic areas and sections, to reflect the scope of work and the study tasks undertaken. They include:

Past Pack Ice Management Experience

A review of past experiences with pack ice management operations in support of offshore exploration and production systems in other Arctic and sub-Arctic regions

Expected Grand Banks Pack Ice Conditions

A description of the typical pack ice regimes and conditions likely to be encountered by platforms and vessels operating in the Grand Banks region, with particular reference to the southern parts of the area

Platform Characteristics & Ice Management Needs

A brief review of the types of platforms typically used for exploration and development operations on the Grand Banks, both floating and fixed, their design features and their needs for pack ice management support

Pack Ice Management Techniques

A discussion of basic pack ice management techniques for various platforms and vessels, supplemented with some details about operational difficulties, restrictions and hazards

Suitable Pack Ice Management Support Vessels

An identification of the key issue areas surrounding the use of different support vessels for effective pack ice management activities on the Grand Banks, and a conceptual check list of "suitability criteria" for these vessels in relation to their level of ice strengthening and performance limits

3.0 BACKGROUND

3.1 Some Basics

Ice management is a general term that is often used to describe the support activities a stationary vessel or platform may requite to allow it to maintain position and continue operations in moving ice. In this global context, ice management includes the following range of tasks, all of which are intended to increase the safety and efficiency of station-keeping operations in ice.

- ice monitoring and forecasting
- ice hazard detection and tracking
- ice alert system implementation

- icebreaking and/or clearing (including iceberg towing), as required, as a means of physically reducing the threat of potentially hazardous or operationally restrictive ice interactions with the vessel or platform

Weather and ocean observations on both regional and local scales are another important input, as are forecasts of certain weather and sea parameters, and reports from support vessels about ice conditions in the local area and their performance in these conditions.

The range of ice-related support activities that are outlined above must be operated as an integrated system, in order to be effective. Since the focus of this report is on pack ice management, the manner in which this type of system is actually employed is illustrated in Figure 3.1, in the context of a moored vessel station-keeping operation in moving pack ice. The logic flow is clear, with physical ice management by support vessels being used to fragment and/or clear potentially hazardous ice features as required, to keep mooring line tensions and offsets of the floater within acceptable tolerances. In this report, the term "ice management" is used less generally, and only to specifically describe support vessel operations that involve physical icebreaking and ice clearance.

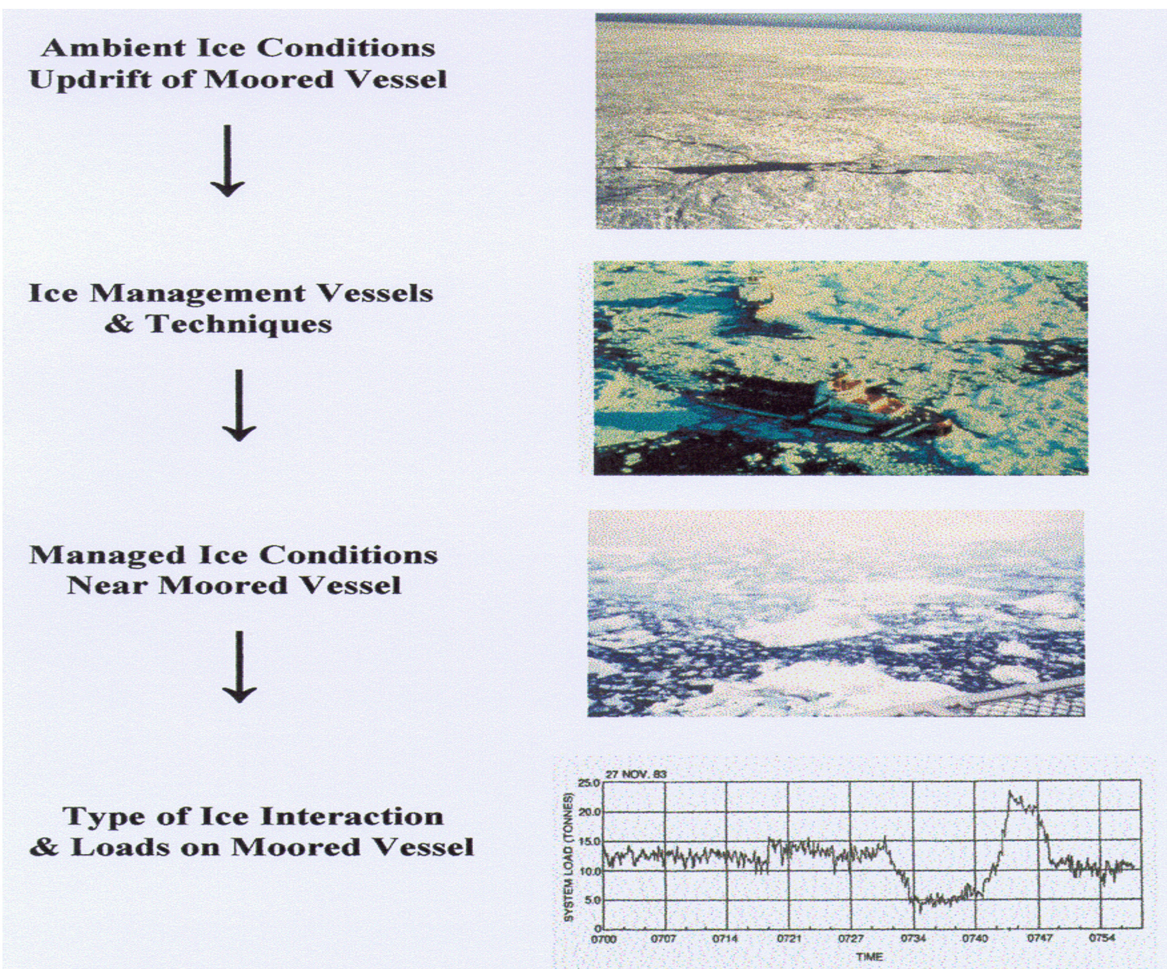


Figure 3.1:

This case, which involves drilling operations from the Kulluk in Beaufort Sea pack ice, is an obvious example of ice management support. However, in concept, it is analogous to what would be required to allow FPSO station-keeping or tanker loading operations at an offshore loading station during pack ice intrusions onto the Grand Banks.

The level of ice management that may be required varies with the type and function of the vessel or platform being supported, and the pack ice conditions on hand. Application areas for ice management by support vessels are broad, ranging from operations to reduce the loads that may be exerted by pack ice on floating vessels (e.g.: an FPSO or a tanker loading oil), through facilitating necessary re-supply, to enabling safety standby services at gravity based platforms. Although it is unlikely that any fixed structures designed for use on the Grand Banks will require any pack ice management to reduce ice load levels on them, it may be needed to "permit" iceberg towing, should icebergs and pack ice be present concurrently.

The difference in the use of a support vessel for in-ice transits and ice management duties has already been mentioned. In the first case, the vessel tends to avoid heavy ice features and navigate at slow speeds, appropriate to its level of hull strengthening and power. In the second case, however, the vessel is tasked to break and/or deflect all of the heavy ice features moving towards a station-keeping platform. This often requires the use of high power and high speed for icebreaking, loosening of close pack ice, and pushing of large floes. Ramming and rapid turning is also involved. Practical experience has shown that it is extremely important for ice management support vessels to be appropriate in terms of design, hull strength and powering for these intended tasks.

3.2 Past Experience with Drill-ships

Ice management to support moored vessel station-keeping operations in pack ice has been used since 1976, when Canmar (a subsidiary of Dome Petroleum) first brought drill-ships into the Canadian Beaufort Sea for exploratory drilling. These drilling vessels, 4 in total, were primarily intended for open water use and normally operated during the Beaufort Sea's summer and early fall seasons. However, with ice management support, they soon developed the capability to station-keep in a variety of ice conditions. This extended their open water operating season, although they did not work extensively in heavy ice.

Two of Canmar's drill-ships were ice strengthened to the Baltic Class 1A Super level for seasonal operations in the Arctic and the other two to Baltic Classes B levels. Otherwise, they were relatively conventional with displacements of about 15,000 tonnes and overall dimensions of roughly 100m x 20m x 9m. Each vessel was deployed with an eight point mooring system comprised of 2 3/4 " wire lines (four bow and four aft) that came off the deck and through the waterline (except for the Explorer 4 which had underwater fairleads). These mooring lines were equipped with remote anchor releases (RARs) that allowed the drill-ships to quickly disconnect from their anchors and move off location, should difficult ice or storm conditions occur. The drill-ship mooring systems were not designed to be particularly capable in ice, but could resist global ice forces of about 100 tonnes (0.981MN) - an order of magnitude less than a typical FPSO - with acceptable vessel offsets and tensions in the individual lines. However, once moored, they were aligned in a fixed direction and could not reposition themselves in response to changing pack ice drift directions without moving. Dynamic positioning was attempted by one of these drill-ships but was found operationally impractical, due to the shallow water depths in which wells were often drilled (20m to 50m).

Ice management support for Canmar's drill-ships was originally provided by four 7,200 BHP anchor handling tug supply (AHTS) icebreakers fitted with twin propellers. Each of these icebreakers had an ASPPR Arctic Class II classification, approximately equivalent to a CAC 4 vessel in the new Canadian Arctic Class system. They were relatively small icebreaking vessels with multi- purpose roles, and were expected to carry out re-supply, anchor handling and safety standby duties, as well as providing ice management support.

Since these vessels offered the only real means of ice protection for drill-ship operations, they were often assigned to assist with urgent ice management needs at a particular site, leaving less capable "type" vessels for safety standby and other support duties at other drilling locations. When ice conditions became problematic at more than one drilling site, it was sometimes necessary for the drill-ships working at these "ice threatened sites" to suspend operations and leave (or be forced off) location, due to the lack of ice-capable support vessels. This factor resulted in significant amounts of downtime.

At this stage, it is important to note that some of these Class II support vessels suffered significant ice damage to their hulls and steering equipment at times over the first few years of Canmar's drilling operations in the Beaufort Sea. This was not only due to the inappropriate design features and levels of ice strengthening of the support vessels for the range of ice conditions encountered, but also to the inexperience of many of the vessel operators in recognizing hazardous ice conditions and the lack of well coordinated pack ice management strategies.

Based on these experiences, it quickly became apparent that the number, design and ice strengthening of Canmar's support vessels was not suitable for maintaining the level of ice management needed for all of the drill-ships, particularly in the harsher ice conditions that could be experienced in the Beaufort during the summer and fall drilling season. It was also determined that the operating season of one or more of the drill-ships could be significantly extended with the use of stronger and more powerful icebreakers. This was most apparent during the early summer period, when the drilling operations attempted were usually exposed to high concentrations of large thick and heavily ridged first year ice floes. Later on in summer and early fall, drilling operations could also be interrupted by the presence of partial concentrations of drifting first year ice, and by large isolated old ice floes moving southwards from the southern boundary of the polar pack.

These circumstances led to the development of coordinated ice management strategies, new techniques, and new icebreaking vessels to support Canmar's drill-ship fleet. They also gave rise to the formulation of ice alert systems that provided practical guidance to rig and icebreaker operators in relation to the prudence of their operations. These ice alert systems were configured to identify when certain decisions and actions should be taken, to proactively prevent hazardous ice situations from developing, to minimize unnecessary drilling downtime within reasoned boundaries, and to reduce the potential for damage to ice management vessels due to overly aggressive icebreaking operations (ones that may actually be unwarranted).

In 1979, a larger and more capable icebreaker, the Kigoriak, was added to Canmar's Beaufort exploration fleet, with an immediate improvement in its overall ice management capability, in operational "up-time", and in drill-ship protection. This ship was classed as an ASPPR Arctic Ice Class IV icebreaker (approximately equivalent to a CAC 2 vessel in the new system), was equipped with 16,800 BHP, and incorporated a special spoon bow design with side reamers to increase icebreaking efficiency and turning characteristics in high ice concentrations. The task of the Kigoriak was to break large thick floes (including multi-year ice), before they became hazardous to drill-ship operations. This initial long range management of large floes allowed the smaller Class II icebreakers to break any remnant ice approaching the drill-ships into smaller pieces, and to clear any unwanted accumulations of broken ice from around the drill-ships, and away from their exposed anchor wires.

The addition of this "heavy" Class IV icebreaker contributed to late season extensions for Canmar's drill-ships, and also allowed for earlier spring breakouts of the entire fleet from its over-wintering harbor. Another Class III icebreaker (approximately a high CAC 4 vessel equivalent); the Robert Lemeur, was added to Canmar's drilling fleet in 1982. This vessel traveled between rigs, allowing more flexibility for ice management support and resulting in less ice-related drilling downtime during Canmar's Beaufort exploration operations.

Views of drill-ship station-keeping operations in managed pack ice conditions in the Beaufort are shown in Figure 3.2, for illustrative purposes. It is important to recognize that without ice management support, in-ice operations like this would simply not be feasible, due to unacceptably high ice load levels on the moored drilling vessel.

Figure 3.2

Figure 3.2

Figure 3.2

Information about the drill-ships, their ice management support vessels and rough operating limits is provided in Table 3.1 A and B.

Summary of Beaufort Sea Ice Management Operations			
Vessel Type	**Vessel Name**	**Ice Class**	**Notes**
Drill-Ship Characteristics	Canmar Explorer 1 & 2	Type A	8 anchor mooring system
	Canmar Explorer 3	Type B	8 anchor mooring system
	Canmar Explorer 4	Type B	Only drill-ship with a totally submerged 8 anchor mooring system and a side hull air bubbling system feature
Support Vessel Characteristics	Canmar Supplier(s)	Arctic Class 2 (CAC 4)	Length of 62m and power of 7200 bhp
	Canmar Kigoriak	Arctic Class 4 (CAC 2)	Length of 91m and power of 16800 bhp
	Robert Lemeur	Arctic Class 3 (CAC 3)	Length of 83m and power of 9600 bhp

Table 3.1 (A)

Typical Operating Conditions & Levels of Ice Management		
Season	**Ice Type & Concentration**	**Level of Ice Management**
Summer	Thick Ice (1m+) – low	2 x CAC 4 Icebreakers (I/B)
	Thick Ice - moderate	2 x CAC 4 + 1 CAC 3 (I/B)
	TFY – high (and/or old ice)	3 x CAC 4 + 1 CAC 2 (I/B)
Winter	Thin First Year Ice (THFYI)	2 x CAC 4 (I/B)
	THFY 2 + Deformation/Ice Pressure	3 x CAC 4 + 1 x CAC 2 (I/B)

Table 3.1 (B)

3.3 Past Experience with the Kulluk

Learning from Canmar's earlier experiences with their drill-ship operations, Gulf Canada Resources Ltd. designed and built a second generation floating drilling unit named the Kulluk. This moored vessel was expressly intended to conduct extended season drilling operations in Beaufort Sea ice conditions.

The Kulluk's design recognized some of the shortcomings of drill-ship operations in ice, and incorporated a variety of features to improve its performance capabilities over a more demanding range of pack ice conditions. For example, the following ice-issue areas were considered and accommodated by the Kulluk's design.

- minimizing the icebreaking and clearance forces that the vessel could experience from any direction, by providing an omni-directional capability to resist ice action

- providing a strong mooring system to resist the higher ice loads levels associated with the heavy ice conditions expected during extended season operations, within acceptable line tensions and vessel offset limits

- developing a submerged mooring system to eliminate the problems that drill-ships experienced with ice entanglement in their anchor wires at the waterline

- developing a hull form to enhance ice clearance, and reduce the possibility of ice moving down the hull and then under the vessel, where it could interfere with the mooring and riser systems, and the moon pool area

- configuring an ice management system that was capable of dealing with the more difficult pack ice conditions expected in the Beaufort's extended drilling season, to reduce "heavy ice" load levels on the Kulluk's mooring system

The Kulluk was built with a very strong hull, which was constructed to Arctic Class IV (CAC 2) standards. It has deck and waterline diameters of 100m and 70m respectively, an operating draft of 11.5m, and a displacement of 28,000 tonnes. It has a downward sloping circular hull form that is intended to fail any oncoming ice in flexure at relatively low force levels, and an outward flare near its bottom to ensure that broken ice pieces clear around it, and do not enter its moon pool or become entangled in its mooring lines.

The vessel has a radially symmetric mooring that, in combination with its circular shape, provides an omni-directional capability to resist pack ice and storm forces. The mooring system is comprised of twelve 3 ½ inch wire lines and is capable of resisting relatively high ice loads, up to 750 tonnes, while drilling operations are underway. An important feature of the Kulluk's design is the through-hull path of its mooring lines and their underwater fairleads which, combined with the unit's hull form, reduces the threat of ice fouling the lines.

The Kulluk's hull form provided it with good icebreaking and ice clearance capabilities, which reduced the ice force levels and minimized the tensions that were experienced by its mooring lines, along with the vessel's response motions in ice. Its moorings were also equipped with RAR's, to permit quick disconnects when required.

Since the Kulluk was not designed with any propulsion, it is basically a conical barge that was towed from one location to another. As with Canmar's drill-ships, ice management support was a key factor in enhancing the vessel's station-keeping performance in ice, as well as in towing the Kulluk through any ice present during moves from site to site.

Typically, the Kulluk was supported by between two and four highly powered icebreakers to provide ice management during operations in heavy Beaufort Sea ice conditions. They were heavy and powerful AHTS vessels that included the Ikaluk and Miscaroo, equipped with 15,000 BHP, and the Kalvik and Terry Fox with 23,200 BHP. This level of ice management offered by these vessels resulted in a major advancement to the efficiency of in-ice operations with a floating drilling unit, and produced a significant decrease in downtime and major extension to the Beaufort Sea drilling season. Because these vessels were properly designed for their intended tasks, they did not incur any real damage during their ice management operations and performed well, often in very severe ice. The lessons learned from Kulluk drilling operations in Beaufort pack ice are fully described in two recent PERD reports (Wright et al, 1999 & 2000). Three views of Kulluk station-keeping operations in managed pack ice conditions are given in Figure 3.3, again for illustrative purposes. Table 3.2 (A & B) provides related information in tabular form.

Figure 3.3

Figure 3.3

Figure 3.3

Summary of Beaufort Sea Ice Management Operations			
Vessel Type	**Vessel Name**	**Ice Class**	**Notes**
Drill-Ship Characteristics	Kulluk	Arctic Class 4 (CAC 2)	Conical shape; uses 12 anchor totally submerged mooring system; features an ice friction reducing coating
Support Vessel Characteristics	Miscaroo & Ikaluk	Arctic Class 4 (CAC 3)	Length of 76m and power of 15000bhp
	Terry Fox & Kalvik	Arctic Class 4 (CAC 2)	Length of 88m and power of 23200 bhp

Table 3.2 (A)

Typical Operating Conditions & Levels of Ice Management		
Season	**Ice Type & Concentration**	**Level of Ice Management**
Summer	Thick (1m+) - low	1 x CAC 3 icebreaker (I/B)
	Thick – moderate	2 x CAC 2 (I/B)
	TFY – high (and/or old ice)	2 x CAC 2 + 1 CAC 3 (I/B)
Winter	Thin First Year (THFYI)	None – (1 x CAC 3 sby I/B)
	THFY 2 + Deformation/Ice Pressure	1 x CAC 2 (I/B)
	Medium First Year (MFY)	2 x CAC 2 (I/B)
	MFY with deformation/Ice Pressure	2 x CAC 2 + 1 (CAC 3) (I/B)

Table 3.2 (B)

It should be recognized that this specially designed platform was capable of operation in heavy ice long before the Canmar drill-ships were able to leave port in the spring and long after the drill-ships returned to port in the winter. In addition, the 'downtime' for the Kulluk was very low in comparison to the anchored drill-ships. This was primarily due to the high level of ice management support available to the platform, as well as the Kulluk's special 'in ice' design features.

3.4 Other Beaufort Sea Structures

During the 1980's, several heavily ice strengthened gravity based (GBS) platforms were also constructed and used for drilling operations in the offshore Beaufort. They included Canmar's Single Steel Drilling Caisson (the SSDC), Global Marine's Concrete Island Drilling System (the CIDS) and Gulf Canada's mobile Arctic caisson (the Molikpaq). All of these bottom-found gravity based structures (GBS) - that were capable of being moved to various drilling locations - were designed to withstand high ice load levels, without the need for any ice management support. In addition, shallow Caisson Retained Island (CRI) island structures such as 'Tarsuit' used concrete caissons placed on a 1:5 sand berm for year round operations. Although no ice management was necessary for these structures to maintain position, considerable experience was gained with ship operations around them in pack ice, for example, during re-supply activities and various emergency evacuation and oil spill response drills.

Exploration and proposed development projects in the Canadian and U.S. Beaufort Sea were suspended in the early 1990s, largely due to a major downturn in oil prices, and most of the drilling equipment laid-up. Since that time, it has all been sold by its original owners. In this regard, it is interesting to note that the GBS platforms and the supporting Beaufort Sea icebreakers are still operational. The Molikpaq and CIDS (now called the Orlan) are being used as production platforms off Sakhalin Island, where heavy first year pack ice cover is present for about half of each year. The SSDC has also been reactivated, drilling off Alaska in the winter of 2002/03, and planned for use at a drilling site in the Canadian Beaufort Sea during the winter of 2005/06.

The Beaufort icebreakers, Ikaluk and Miscaroo (re-named the Smit Sakhalin and Sibu), have been operating in the Sakhalin region since 1999, where they provide re-supply and ice management services for the Sak II offshore development project. The Kalvik and Kigoriak are now working in northern Russia, while the Terry Fox was sold to the CCG in 1994, and is being use as part of their icebreaker fleet within Canadian waters.

3.5 Recent Experience off Sakhalin Island

The Molikpaq was sold to the Sakhalin II project group in 1996, and then modified for use as a production platform in the first phase of their offshore Sakhalin development. In 1998, this structure was deployed at a site in the Piltun-Astokhskoye field, which lies off the northeast Sakhalin shelf in about 30m of water. The following spring, after a number of production wells were drilled, a sub-sea pipeline was installed to move produced oil from the Molikpaq to a SALM buoy, which was to be located about 2 km away. This pipeline installation was planned for the May time frame, when only late break-up ice conditions and open water were expected on-site. However, ice clearance in 1999 was late and the construction operation was confronted by heavy pack ice. Rather than accepting a delay, ice management was used to allow the pipeline installation to proceed, despite the heavy ice conditions encountered. For the first time, a dynamically positioned, ice strengthened diving & construction vessel carried out the completion operation on the SALM buoy and pipeline. Two, and sometimes three, support vessels were employed to provide the necessary level of ice management, two former Beaufort icebreakers, the Smit Sakhalin and Smit Sibu, and a Russian icebreaker, the Magadan. The ice management aspects of this operation are described in a POAC paper (Keinonen et al, 2001), with views of the in-ice operation shown in Figure 3.4. Here, the main point to note is that the pipeline installation was accomplished largely in ice, with good ice management support.

Figure 3.4

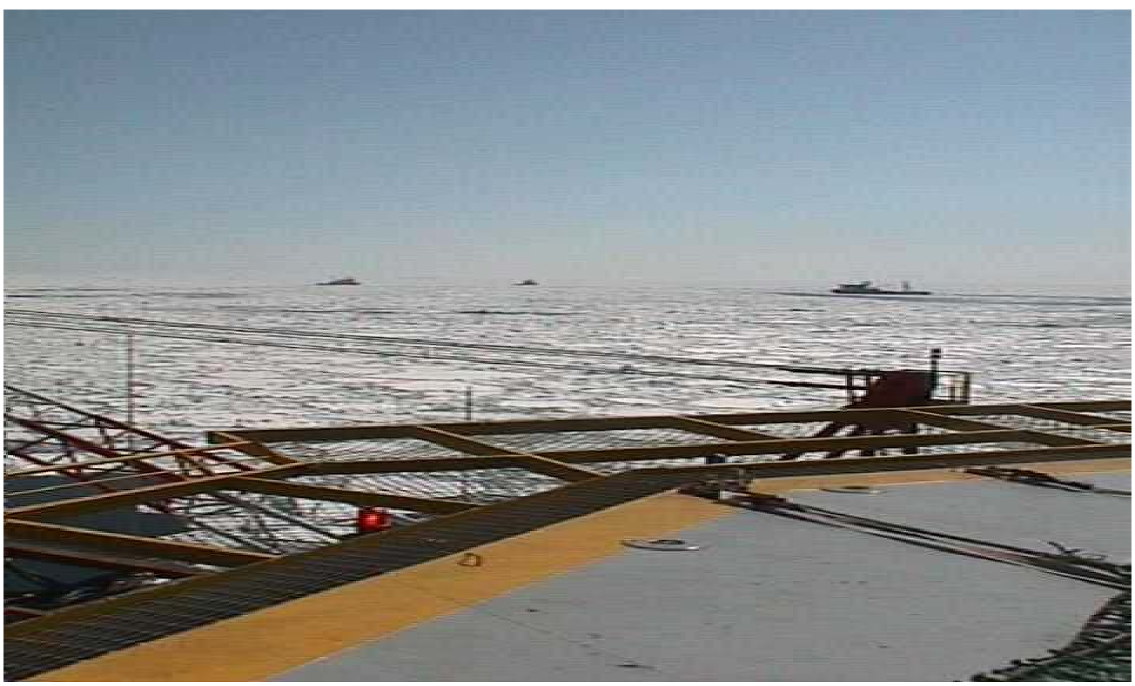


Figure 3.4

Figure 3.4

Once in place, the pipeline was connected to a SALM buoy, with produced oil from the Molikpaq moved through the system to an FSO tanker, during the subsequent open water period in 1999. In this first year, the SALM buoy was lowered prior to the onset of ice freeze-up in late fall.

Since that time, an FSO tanker (named 'Okha') has been escorted to the SALM location through various (including high) concentrations of degrading thick first year ice each spring (in May), and bow moored to the SALM buoy. Ice management, typically provided by two support icebreakers, has been used during SALM buoy raising operations and to safely keep the FSO on location loading oil, until the ice break-up process is completed and all ice has cleared from the site. Once in open water, shuttle tankers then make cargo lifts from the FSO while moored (bow to stern) in tandem to it.

The FSO also remains on location at the SALM into the freeze-up period, when the ice is thin, with the aid of two ice management vessels. The extended season production and oil export operation at the Molikpaq is generally terminated in late December, as the new ice thickness increases. The FSO is then escorted through the growing ice cover and south, and the SALM buoy is lowered into a dredged "glory hole" on the seafloor for the winter.

A view of this FSO loading operation, which has been carried out in moving pack ice over the last 5 years, is shown in Figures 3.5 for the freeze-up period. Related information is presented in tabular form in Table 3.3 (A & B). It is noteworthy that the FSO Okha is about 150,000 DWT, not dissimilar in size to the floating vessels that are being used or planned for use on the Grand Banks.

Figure 3.5

Figure 3.5

Summary of FSO Sakhalin Ice Management Operation			
Vessel Type	**Name of Vessel**	**Ice Class**	**Notes**
FSO Characteristics		Canadian equivalent Type D	158,000 DWT
Support Vessel Characteristics	Smit Sakhalin & Smit Sibu	Arctic Class 4 (CAC 3)	LOA 76m and power of 15,000 bhp
	Magadan	CAC 4	Beam 21m; disp.6200t; power of 10,000 bhp
	Krasin	CAC 2	Beam 26m; disp. 20214t; power of 36,000 bhp

Table 3.3 (A)

Typical Operating Conditions & Levels of Ice Management		
Season	**Ice Type & Concentration**	**Level of Ice Management**
Summer	Thick (1m+) - low	1 x CAC 3 + 1 CAC 4 icebreaker (I/B)
	Thick – moderate	2 x CAC 3 (I/B)
	TFY – high (and/or old ice)	1 x CAC 2 x 2 x CAC 3 (I/B)
Winter	Thin First Year (THFYI)	1 x CAC 3 + 1 x CAC 4

Table 3.3 (B)

It should be noted that ice management is typically carried out using a combination of only two of the above mentioned vessels depending on ice conditions. One IM vessel stays in for close IM (one of the Smit ships) and the other will carry out long distance breaking or ice reconnaissance.

Based on past and ongoing experiences with various operations in other ice-covered areas of the world, it is our view that most floating vessel station-keeping operations in Grand Banks pack ice should be feasible, with appropriate ice management support. Although no such operations have yet taken place on the Grand Banks, pack ice did encroach to within several tens of kilometers of the Terra Nova FPSO during the winter of 2003. At the time, pack ice management was being contemplated as an alternative to a move-off of the FPSO, as a means of enhancing its ability to safely maintain location.

At this stage, it should be noted that pack ice conditions on the Grand Banks, when an ice intrusion does occur, are generally quite mild in comparison to those seen in the Beaufort or offshore Sakhalin Island areas, where most of the pack ice management experience has been gained to date. In the next section, expected pack ice conditions on the Grand Banks are briefly reviewed, before discussing various pack ice management issues further.

4.0 PACK ICE CONDITIONS ON THE GRAND BANKS

4.1 General

The Grand Banks lies close to the extreme southern limit of the pack ice cover that forms off the East Coast of Canada each winter. As mentioned earlier, pack ice is not an annual occurrence on the Grand Banks, but it can move into the region from more northerly waters. Source areas for the pack ice cover that is sometimes found on the Banks include Baffin Bay, Davis Strait, the Labrador Sea, and the waters off northeast Newfoundland. As pack ice drifts southwards from these areas towards the Grand Banks, warmer air and water temperatures, in combination with more open ocean conditions, tend to dissipate the pack ice. A branching that is seen in the southward flowing Labrador current at the north end of the Grand Banks also tends to keep any encroaching pack ice to the east and west of its central crest, as the ice moves southwards.

4.2 Occurrence and Coverage

Regionally, the annual ice cycle on the East Coast of Canada begins in September, with the formation of new ice in northwest Baffin Bay following the near complete clearance of ice from all the areas between Canada and Greenland south of 78˚N each summer. A combination of local pack ice growth and predominantly southerly ice drift, driven by the prevailing northerly winds and the strong cold Baffin Current, advances ice southwards beginning in October. At this time, coverage increases most rapidly in western parts of Baffin Bay and Davis Strait. By December, on average, the leading edge of the advancing pack lies off the northern coastline of Labrador. In typical years, the ice edge reaches the northern tip of Newfoundland in early January, and the northern portions of the Grand Banks by mid-February.

The pack ice that is found off Newfoundland usually reaches its maximum coverage in March, but can sometimes remain in fairly high concentrations well into May. To give some feel for the extent of this pack ice cover, median and maximum ice edge advances off Newfoundland and onto the Grand Banks are shown in Figure 4.1, for the mid March period. This figure was taken from the 1997 Terra Nova Development Application and is based on an analysis of 33 years of ice charts for the Grand Banks region (1963-1995).

In their application, the Terra Nova proponents noted that higher pack ice intrusion probabilities were seen from 1983 to 1995, as opposed to the previous 20 years (1963 to 1982). Here, it is interesting to note that there have been few pack ice intrusions onto the southern parts of the Grand Banks since 1995, with the exception of 2002.

In this case, high concentrations of pack ice moved southwards and in late March, were in very close proximity (10 to 15 km) to both the Hibernia and Terra Nova sites, where production operations were underway. At the time, the pack ice cover did move across the Whiterose location, remaining over the site for about 5 days.

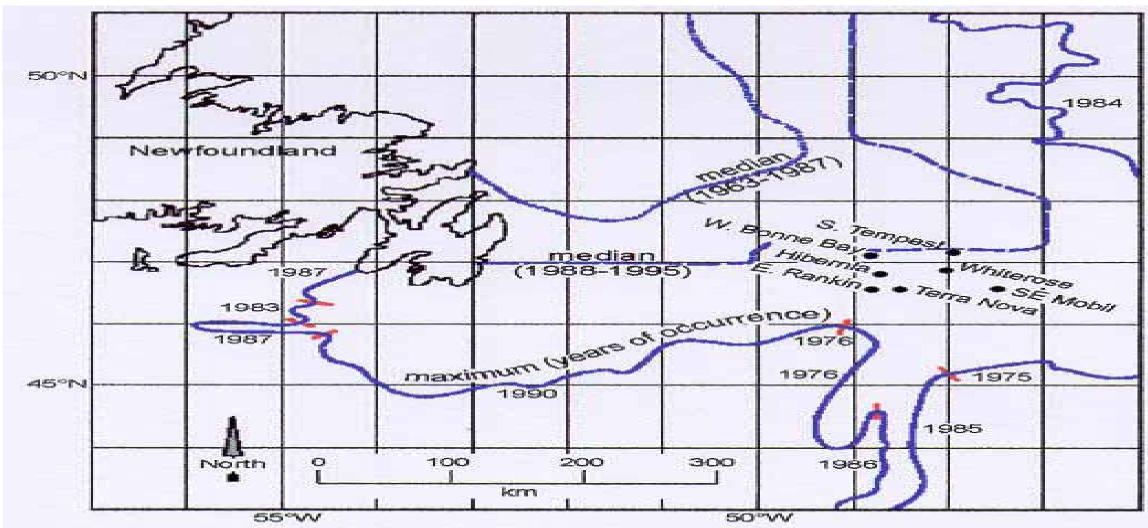


Figure 4.1

In an earlier PERD study (Wright et al, 1998), statistics were developed to describe pack ice coverage at seven representative locations on the Grand Banks. These statistics were based on an analysis 10 years of CIS ice chart data (1985 to 1994), for the sites shown in Figure 4.1. Although the absence of pack ice on the Grand Banks in recent years would tend to modify these statistics and reflect a somewhat "lesser degrees of severity", they are still instructive. A few summary points are given as follows.

- Pack ice intrusions onto the Grand Banks are not an annual occurrence but they do occur once ever several years on average, based upon an analysis of historical ice coverage data from the past 40 years.

- More southerly areas like the Terra Nova location are less susceptible to pack ice intrusions than sites like the Whiterose field, where pack ice occurrences are more common. New exploration areas such as the Orphan Bank and Flemish Cap are more likely to experience pack ice intrusions on a near annual basis.

- The ice concentrations that are seen on the Grand Banks, when pack ice intrusions do occur, are quite variable, and range from low to high ice coverage situations. Although loose pack ice conditions (1 to 6/10ths) are expected much of the time, ice concentrations in the close (7 to 9/10ths) to very close (9+/10ths) categories should be expected about 30% of the time, when ice intrusions are experienced.

- These pack ice intrusions events may occur anytime from late January to mid May, but are more likely to be seen in the March and April time frame. The durations of these pack ice intrusions can be anywhere from a few days to a few weeks, depending upon the particular location.

4.3 Ice Characteristics

There is a limited amount of "hard information" about the characteristics of the pack ice cover that is found on the Grand Banks. This comment applies to a variety of pack ice characteristics, ranging from ice floe sizes, through the presence of ridges and rafted ice areas, to the occurrence of old ice floe fragments and glacial ice features within the pack ice. However, several on-ice field investigations have been carried out to assess pack ice conditions on the Grand Banks. This data, together with CIS ice charts, and observations obtained from aerial over-flights and ships working in the area provide a reasonable view of the range of ice conditions that should be expected. Some key points are briefly summarized as follows.

- The ice floe sizes that are seen when pack ice intrudes onto the Grand Banks are typically small, in the range of 20m to 100m in diameter. However, during some of the more extreme pack ice intrusion events, ice floe sizes can be in the range of 100m to 500m (or larger).

- The level ice thicknesses that are most common are in the 30 cm to 70 cm range, with ice types in the < 30 cm and 0.7m to 1.2m being seen about 10%`of the time.

- Significant pressure ridges, rubble fields and rafted ice areas are uncommon in the pack ice that is seen on the Grand Banks. Any ridge and rubble sails are generally limited to heights of less than a meter, while keels depths are typically no more than several meters in depth.

- However, when substantial pack ice intrusions do occur and ice conditions can be more onerous, with larger ridges and more substantial areas of ice rubble and rafting. Remnants of old ice floes and small glacial ice masses can also be incorporated into the pack ice cover.

4.4 Ice Movements

- When pack ice is present on the Grand Banks, typical ice drift speeds are in the range of 0.5 knots, with extreme ice drift speeds of up to several knots over short time scales (a few hours).

- The general ice movement directions that should be expected are towards the south or southeast, but can be any direction over short time scales (a few hours).

- Tidal influences on the Grand Banks are not sufficiently strong to create cyclic reversals (two fold) in pack ice movement directions over time scales of 12 to 24 hours.

Several representative views of pack ice conditions on the Grand Banks are provided in Figure 4.2. These photos are intended to provide the reader with some feel for the type of pack ice that should be expected during typical ice intrusions.

Typical Pack Ice conditions located near Whiterose (compliments of P. Rudkin)

Typical Pack Ice conditions located near Whiterose (compliments of P. Rudkin)

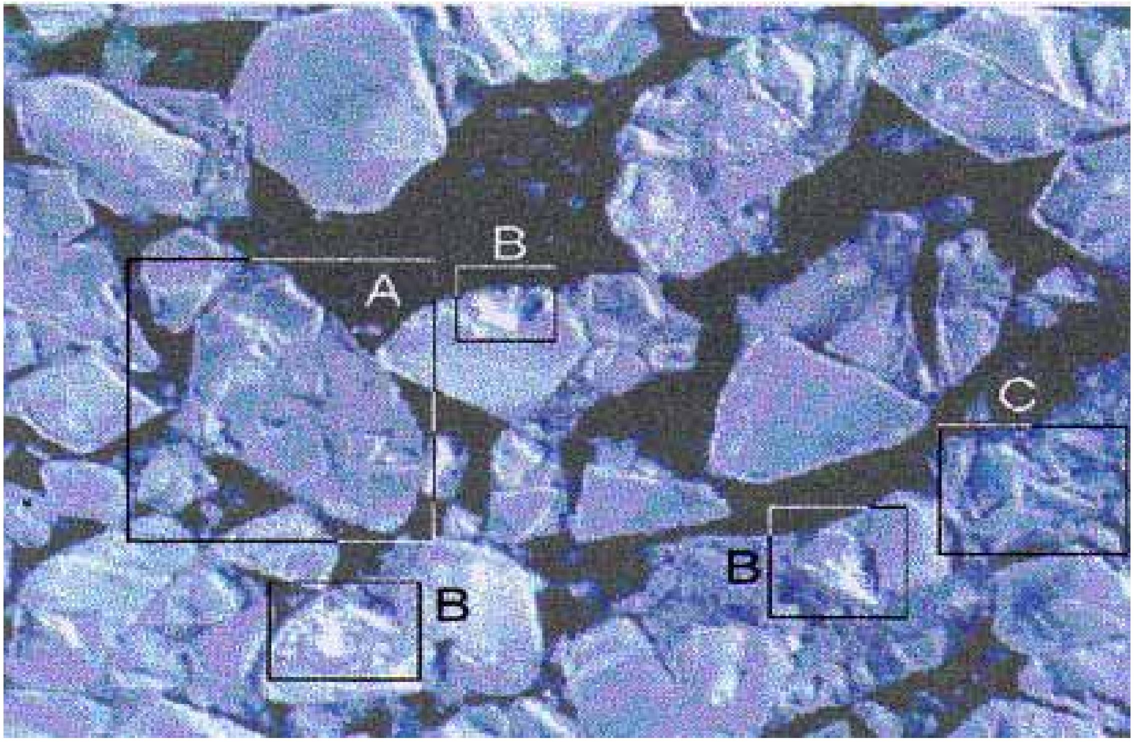


Figure 4.2

Sea ice near the pack ice edge on March 25th, 1989 (compliments of G. Crocker);A=conglomerate floe; B=rubble generated at floe boundaries; C=ridging around perimeters of conglomerate floes. Typical floe sizes in this photo are in the range of 50m.

Historical information about the range of pack ice conditions that can be experienced at various locations on the Grand Banks is very important. This type of information can be used as a basis for assessing the need for pack ice management support, for input into strategic ice management planning, and in the identification of suitable support vessels to carry out any pack ice management functions that may be required.

5.0 PLATFORM CHARACTERISTICS & ICE MANAGEMENT NEEDS

5.1 General

There are a wide range of platforms and vessels that could be used within the scope of development projects on the Grand Banks. However, environmental factors such as water depth, high storm waves, low temperatures, and the presence of icebergs and pack ice dictate which ones are most sensible. The systems now being employed in the area are indicative of the most applicable type of technologies to expect, and can be viewed as representative systems for the purposes of this report.

5.2 Type of Platform and Station-keeping Considerations

Gravity based platforms, like the Hibernia GBS, are typically designed with the ability to withstand the loads from large iceberg impacts and hence, have an inherent capacity to withstand pack ice interactions. As a result, ice management is not required to support them, from the standpoint of keeping ice load levels within acceptable levels. However, ice management will, at times, be required to support some of the operations that may be carried out around a GBS platform. For example, ice management would be needed for the safe operation of the Hibernia platform's tanker loading system, should an extended occurrence of pack ice be experienced on site. Additionally, consideration must also be given to the capability of support vessels to provide effective safety standby duty and re-supply, should pack ice conditions be encountered at the GBS location.

Turret moored FPSO's, DP vessels and tankers that are moored at single point loading facilities have a distinct advantage over floating systems anchored with fixed alignments, since they can vane into moving pack ice, thereby presenting a much reduced profile to any ice interactions. The Terra Nova FPSO and shuttle tankers that offload oil from the Hibernia GBS through an OLS system are examples of these types of vessels.

Their ability to withstand ice forces and continue station-keeping operations will depend on the capacity of their mooring and/or propulsion systems, which are often considerable. In most cases, however, ice management support will be needed to keep load levels and any other adverse ice effects on these vessels within acceptable levels, at least in heavy pack ice conditions.

While station keeping, vessels fitted with multiple thrusters can use strategically directed propulsion wash to help reduce ice accumulations and some ice impacts, and enhance the smooth flow of ice and its clearance around them. These types of capabilities and maneuvers would help to reduce the amount of pack ice that needs to be managed up-drift by support vessels. Also, turret moored and dynamically positioned vessels can move-off a location on very short notice, once their production or loading operations have been suspended. However, a turret moored FPSO may require considerable time to reconnect to a released mooring system, should it be forced off location. Ice capable support vessels can also play a role in escorting such vessels through ice and in helping them reconnect, should any ice persist.

Semi-submersible rigs and drill-ships are typically anchored with either 8 or 12 anchor lines. They are generally used to drill exploration and production wells on the Grand Banks and as such, are not "permanent" platforms like a GBS or an FPSO. Accordingly, drilling operations from them are normally carried out when no pack ice is present, and they move off location when ice becomes threatening.

Should drilling operations with these types of vessels be contemplated in any pack ice, conditions, consideration would have to be given to the effectiveness of ice management support in reducing the potential for high mooring tensions caused by pack ice action on them. Ice management would also be required to prevent local ice loads on their hulls, which are often only nominally ice-strengthened. Another consideration of particular importance for the operation of a semi-submersible in pack ice is the effect of any ice interaction with its marine riser which, on most rigs, is not within a leg but is exposed.

If pack ice conditions become threatening and a decision made for a semi or drill-ship to vacate location, consideration must be given to the possibility that anchor systems will need to be retrieved in the existing pack ice conditions. In some circumstances, ice management may be required by each of the anchor handling vessels during the recovery and return of anchor systems to the rig.

As a contingency, all moorings used by anchored vessels operating in ice are fitted with some type of emergency quick release system. Various methods are used to disconnect mooring chains from the rig such as a chain “shear link” or an acoustic release mechanism between the mooring wire and anchor. Issues associated with a “quick rig release” include careful positioning of the mooring where the ends to be dropped stay clear of any sub-sea assets, and the considerable amount of time and work necessary to retrieve and restore anchor systems back onto the rig.

Once a rig moves-off location and is underway, additional consideration must be given to towage. In this regard, ice escort may be necessary to move the rig from the location to open water, should pack ice be present along the route. Some semi-submersible rigs have a different ice classification for their transit and operating drafts. Often, the strengthening at the transit draft is less than that for operating, so good (but cautious) ice escort may be required through any pack ice encountered.

5.3 Some Operational Considerations in Ice

Every offshore operation that is carried out from a platform, either floating or fixed, in a pack ice environment is unique. As a result, ice management requirements are specific to the particulars of the system being supported, its in-ice limits, and the ice conditions that are at hand. The following points highlight some of the important inputs requiring careful consideration, in order to determine if the equipment being used and exposed to pack ice is fit for purpose.

- the type, design, level of ice strengthening and method of station-keeping of the platform used
- the number, ice capability and availability of ice management support vessels
- the formulation of, and adherence to, an effective set of ice alert procedures
- the experience of field operators in the ice environment
- the concentrations and types of pack ice anticipated, its drift speeds and directions and the degree of variability in these ice factors
- the weather conditions, including wind, visibility and the potential for waves and swell in combination with pack ice
- the frequency and reliability of ice and weather reports and forecasts

A few comments about some of these factors are given as follows:

5.3.1 Number, ice capability and availability of ice management support vessels

The pack ice conditions and type of offshore operation will determine the number and capability of ice management support vessels needed. For example, in low concentrations of slowly moving small ice floes, only one ice management vessel may be necessary. As the ice drift speed, floe sizes and/or ice concentrations increase, more support vessels will be required. Also, the type of pack ice present in the operating area, in terms of its thickness, roughness and strength, will determine the level of hull strengthening and powering that is appropriate for the ice management support vessels. The possible presence of growlers, bergy bits and/or multi-year ice floe fragments, which are often difficult to see in high concentrations of pack ice, is another factor to recognize when considering support vessel hull strengths. Although capable icebreakers like those used in the Beaufort Sea would be comforting to have on hand should a heavy and persistent pack ice intrusion occur, these types of capable and highly strengthened icebreakers are not readily available in the East Coast area.

5.3.2 Effective ice alert procedures

Ice alert procedures provide an indication of the severity of ice conditions affecting an offshore operation, identify hazardous ice features or situations to it, and outline a series of pre-defined response actions, including ice management, should adverse conditions arise. An effective ice alert procedure is critical to operations and is designed to ensure that personnel on the platform, its support vessels and the management ashore understand the ice situation, so they can immediately recognize and address changing circumstances. Similar to the existing Iceberg Alert system, a typical pack ice alert system uses a color (or number) code to indicate the level of threat to the offshore operation posed by pack ice. To ensure that appropriate actions are taken by the platform and its ice management support vessels in various ice conditions, alert levels can be defined by the proximity of potentially hazardous ice conditions to the operations area, and/or the observed mooring loads and displacements being experienced by the platform.

5.3.3 Experience of field operators in the ice environment

For efficient and effective ice management, and to reduce the potential for any ice-related damage to the support vessels, ship operators should be experienced in ice management operations. This experience includes areas such as ice alert procedures, the recognition of operationally hazardous ice features and situations, the use of appropriate ice management techniques for different ice conditions, and the limitations of the supporting vessels when operating in ice.

5.3.4 Weather conditions including wind, visibility and waves

Local weather and sea state conditions are an important consideration when assessing ice management support. Wind is the prime mover of pack ice and wind speed, direction and variability will affect the distribution, concentration and movement of pack ice.

Waves play a significant role in relation to ice floe sizes and deterioration. In addition, the motion of ice in waves, especially when in opposition to the motion of a vessel, can increase impact forces and, in some high sea situations, give rise to high ice impact loads on lesser strengthened hull plating, particularly above or below an ice belt.

To be effective the vessel maneuvering speeds used for most pack ice management techniques are generally high, and may need to increase as ice drift speed increases. This means there is a potential collision hazard, especially in poor visibility conditions, when more than one support vessel is used for ice management. In this regard, support vessel tactics must be coordinated so that operators remain in designated zones.

6.0 PACK ICE MANAGEMENT TECHNIQUES

6.1 General

The desired result of carefully planned and properly executed ice management by one or more support vessels is to modify the ice environment around a station-keeping platform. The intent is to ensure that no hazardous or restrictive pack ice interactions are experienced which would affect its ability to maintain location with safely and efficiency.

Ice management tasks include keeping any ice loads applied on a platform to levels that are within the limitations of its station-keeping system, ensuring that pack ice properly clears around it and does not become entangled in its moorings, enter its moon pools or turrets, and so forth.

The type of pack ice management that support vessels provide can be divided into two basic procedures:

- **Icebreaking**, whereby large floes or high concentrations of mobile pack ice that can exert global ice loads of thousands of tonnes on a station-keeping platform are broken into small pieces by support vessels, so they can flow around the platform at low global load levels. This also tends to reduce the range of local ice loads that may be applied on the platform’s hull and in turn, the potential for any related hull damage.

- **Ice dispersal**, whereby large floes are pushed clear of a platform so that ice forces on its station-keeping system are minimized, or high concentrations of small ice pieces spread out by the support vessel using high speed maneuvers or propeller wash, to minimize any adverse ice accumulations or loadings on the platform.

As noted earlier, pack ice management, in itself, is a complex subject due to factors like the particulars, function and in-ice capabilities of the platform or vessel being supported, the type and number of support vessels being used, and the various ice conditions that can be encountered. A special complication for pack ice management on the Grand Banks of Newfoundland is the fact that there may be a threat from both pack ice and glacial ice, concurrently. Should this situation arise, it could necessitate the towage of an iceberg that is surrounded by pack ice. This raises questions of the capability of a support vessel to actually deploy an iceberg towing system and tow a berg in pack ice, with success, while at the same time avoiding structural damage.

Although there are no documented cases of iceberg towing in high concentrations of pack ice, based on the combined experience of iceberg towing and of pushing very large multi-year floes, a number of difficulties can be anticipated. These difficulties are related to initial “capturing” (or “lassoing”) of the iceberg, and then maintaining a steady and effective towing tension and direction. The problems anticipated are due primarily to glacial and pack ice moving in different directions, due to the different environmental forces that provide the greatest influence on the drift of these ice forms. For example, the free drift of an iceberg is mostly influenced by surface and sub-surface currents depending on its keel depth, whereas pack ice movement is primarily influenced by the wind speed and direction. It is likely, especially in a high ice concentration or a moderate concentration of large pack ice floes, the support vessel tasked to perform the iceberg tow would require some ice management from another vessel, to assist with the deployment and connection of berg towing equipment. Once the tow is connected then additional ice management assistance may also be necessary, to break or disperse any pack ice that interferes with the towing vessel’s progress.

Small glacial pieces calved from the main berg, such as growlers and bergy bits, may also be in the surrounding area. In some circumstances, these small ice pieces can be difficult to identify in pack ice, particularly in poor visibility conditions. Any contact made by a vessel with low ice class, particularly one attempting to provide ice management services to either an iceberg towing vessel or the platform itself, could result in serious damage.

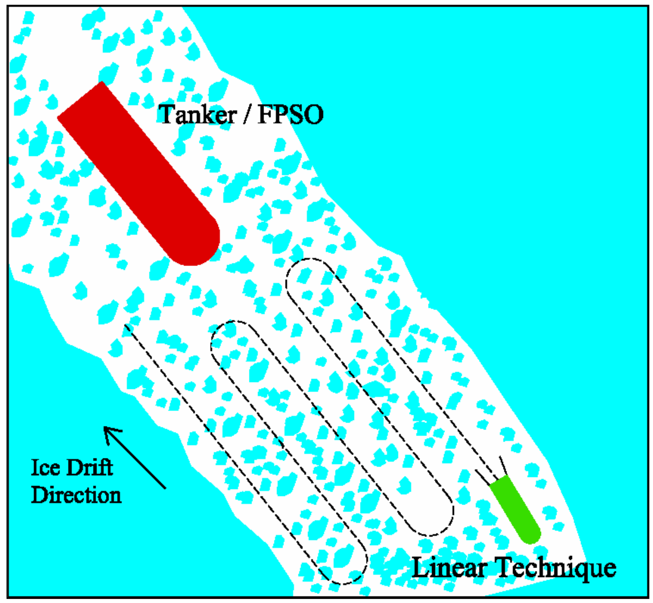
6.2 Specific Ice Management Methods

Here, a brief description of the five basic pack ice management techniques used to reduce ice load levels and defend floating platforms that are station-keeping on a mooring or by dynamic positioning is provided. In addition to these techniques, there are a number of variations and combinations that are effective in certain ice situations. When more than one ice management vessel is operating up-drift of a platform, each can use a different technique that is most suitable for its operating capability.

Three of the five basic techniques involve particular icebreaking patterns, including the linear, sector and circular techniques. The remaining two are ice clearing procedures that include pushing heavy ice floes and the use of high power propeller wash to break thin ice and clear brash ice and small floes from around the station-keeping unit.

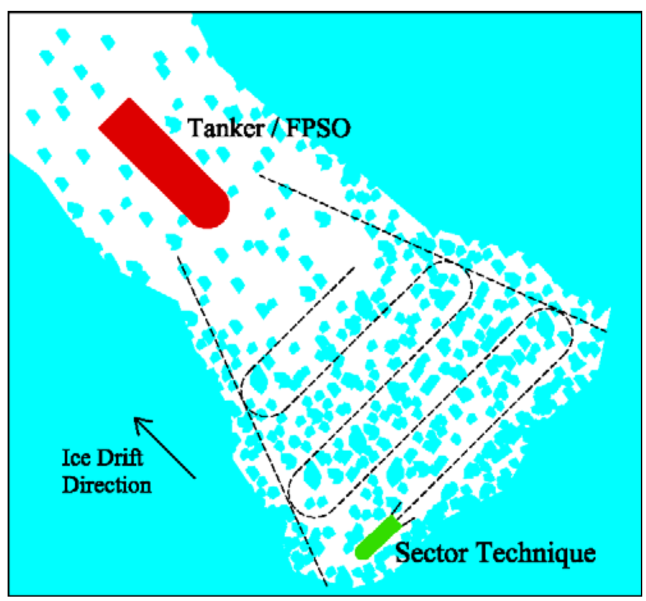
6.2.1 Linear

The linear technique is an icebreaking pattern used by a support vessel to break pack ice up-drift of a floating platform in straight lines, parallel to the direction of ice drift. This icebreaking pattern is typically used when the ice drift speed is fast and the ice drift direction remains reasonably constant.



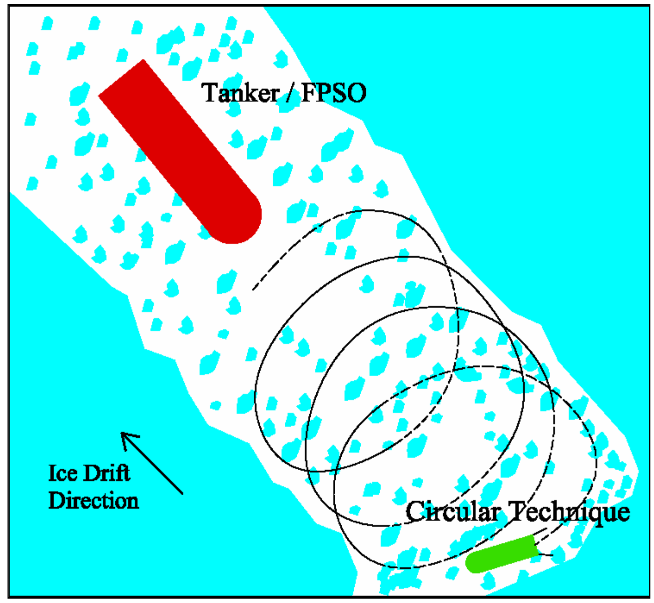
6.2.2 Sector

The sector technique is an icebreaking pattern that provides wide managed pack ice coverage around the approaching ice drift direction. This technique requires the support vessel to steam back and forth across the drift-line between 2 designated bearings that create the sector. This pattern is typically used when ice drift speed is slow and/or when the drift direction is variable or changing rapidly.



6.2.3 Circular

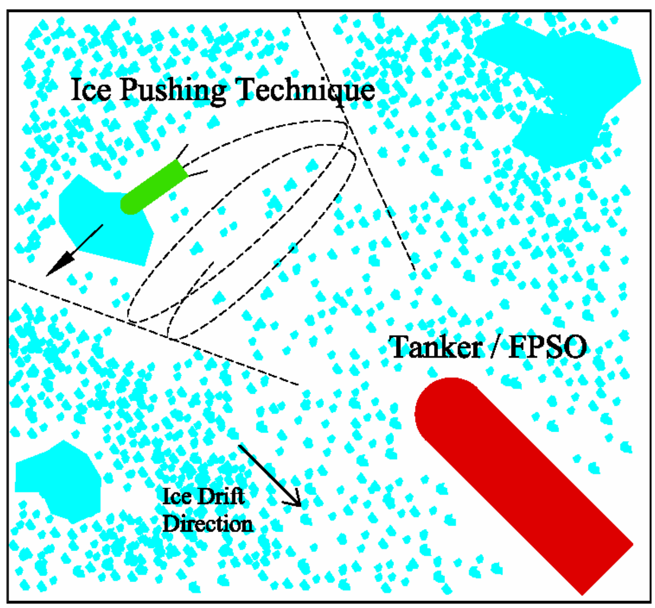
The circular icebreaking technique is a procedure that requires the support vessel to steam in a circular pattern up-drift of the platform location. The diameter of the circles will vary with the speed of the ice drift, and the maneuverability and speed of the support vessel. This pattern is typically used in high concentrations of thin ice or small diameter thick ice floes and when the ice drift direction is variable.



A circular pattern is also made completely around a platform as an effective method to relieve ice pressure.

6.2.4 Pushing ice

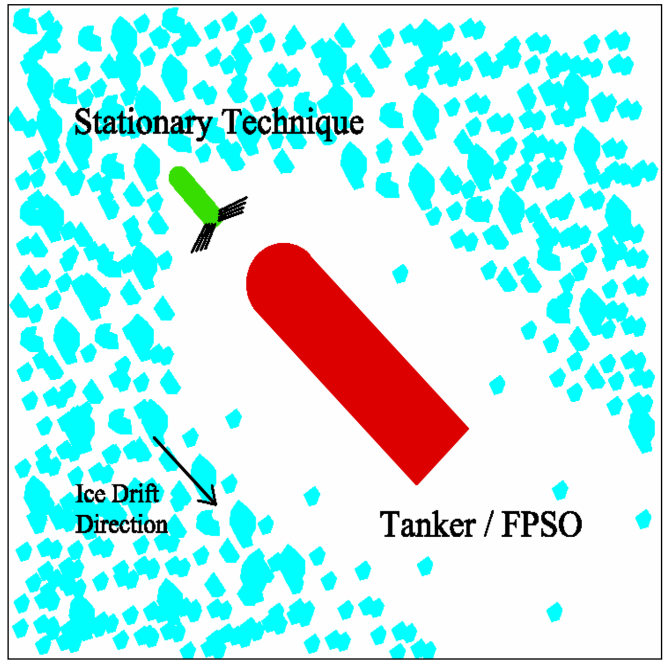
Pushing ice is an effective way of removing medium and large ice floes from the drift line. The pushing direction is usually at right angles to the approaching ice.



The benefit of pushing a large floe instead of breaking it is that the threat to the platform is removed from the drift-line whereas if the ice is broken up-drift, the broken remnants may still pose a threat. Care must be taken to properly forecast any change to the ice drift to ensure that the ice will not become a threat at a later time. To allow full power pushing, the bow strength of the vessel(s) used must be appropriate. At least two vessels are often used to prevent floe rotations.

6.2.5 Propeller Wash

Propeller washing of small pieces of thick ice, even if present in high concentrations, can be very effective to reduce or prevent ice accumulation against the platform. This technique is particularly effective when used by vessels fitted with azimuthing main propulsion. Such a system allows the support vessel to remain almost stationary up-drift of the platform on the drift line, with the propellers angled outwards and using high power to wash ice to each side of the platform.



There are sometimes restrictions to the use of this approach, for example, if there is only one vessel and poor visibility which prevents knowing what ice may be coming from further up drift.

6.3 Other Factors

Model ice test results, confirmed by practical experiences with moored and dynamically positioned platforms operating in pack ice, show that the level of ice management support required for a floating platform depends heavily on:

- the capability of the station-keeping platform to vane into the approaching ice drift
- the capacity of the platform's mooring or propulsion system to withstand global ice loads
- the design characteristics of the platform to enhance ice clearance and avoid any ice accumulation around it

The number of ice management support vessels that are required to support a particular platform and operation will vary with ice concentration, type, floe size, and drift speed. The number needed is also highly dependent on the capabilities of the support vessels in terms of the speed at which they can manage ice (including icebreaking or floe pushing with safe bounds).

Experience has shown that one appropriately powered and ice strengthened vessel can usually manage small scattered thick first year ice floes (up to 3/10ths), and moderate amounts (up to 7/10ths) of fairly thin ice when ice drift speeds are not excessive. More vessels are generally necessary when ice concentrations and/or ice drift speeds are high.

For example, off Sakhalin Island, an icebreaking support vessel that was observed to be capable of managing 3/10ths of small (40m) heavily ridged ice floes moving at 1 knot could only effectively manage 2/10ths of similar ice when the drift increased to 1.8 knots. In the same ice conditions, two vessels with similar capabilities were observed to manage 9/10ths of this type of ice at a 1 knot drift speed, and 7/10ths at 1.8 knots.

However, the capabilities of ice management support vessels at one location do not all need to be the same. In this regard, when there is more than one ice support vessel for a platform:

- The largest and most capable ice strengthened vessel is typically deployed farthest from the platform. This vessel should have very experienced personnel onboard, to provide the first assessment of the "manageability" of the approaching pack ice and coordinate the other ice management ships. This lead vessel is responsible for the "first response" to approaching ice, for example, breaking large heavy floes.

- The smallest and most maneuverable vessel(s) is normally assigned to work in a zone closer to the platform. This vessel may have less ice capability than the "outside vessel" in terms of overall powering and strength. However, it must have sufficient hull strength and powering to prevent any ice damage to it during high speed maneuvering, and perform its duties in a satisfactory manner.

The coordination of a number of ice management support vessels, including the operating techniques to use strategically and tactically, and the zone of ice management, is usually dictated by the most experienced support vessel Captain, in close communication with the Marine Lead/OIM onboard the platform. Any decision to increase levels of ice management support to ensure operational and environmental safety is primarily based on:

- the operational circumstances
- the performance of existing ice management vessel(s)
- the current versus anticipated ice conditions

Decision making like this is normally made within the framework of the ice alert system that has been defined for the operation, and specified by appropriate pre-defined response actions.

6.4 Hazards When Providing High Speed Ice Management

Ice management techniques that involve icebreaking are most effective when carried out at high speed. However, it is important for operators to consider:

- Hull damage when determining maximum icebreaking speeds. For example, high speed must be limited to that which is safe for the vessel's ice class specification. In addition, icebreaking at high speed can increase the amount of ice/propeller milling experienced, especially on support vessels operating at shallow or light draft.

- Sharp high speed turns carried out in heavy ice will increase ice interaction (and potential damage) on steering equipment.

- In thin pack ice or low ice concentrations, combined with high sea swells, low temperatures and strong winds, there is a high probability of heavy vessel icing. Icing accumulations due to freezing spray is significantly increased with high operating speeds. A reduction of speed or limitation of courses that can be steered to avoid heavy icing (and stability problems) can result in a decrease in overall pack ice management effectiveness.

- In well managed ice, care should be taken to monitor engine room cooling water temperatures, since slush and small pieces of ice drawn into the engine cooling intakes can cause rapid overheating, resulting in sudden propulsion shut down and machinery damage. Should propulsion shut-down be experienced on a support vessel that is operating up-drift of a platform, it could become a serious collision hazard. Vessels with a low ice classification may not be appropriately designed for this situation.

6.5 Hazards When Providing Close Range Ice Management

In most cases, ice management maneuvers carried out in support of a station-keeping platform in high ice concentrations should not be carried out at very close range. In this regard:

- Ice that is trapped between the hull of the support vessel and the floating platform can be displaced, significantly increasing the ice forces on the platform’s hull.

- The sideways displacement of ice broken at high speed by a support vessel can create problems if deflected toward the station keeping vessel, for example:

    - rapid movement of the bow of a moored unit (and increase of mooring line tensions)
    - high ice impact force on the hull of the station-keeping platform
    - ice pushed into the propulsion/steering equipment of the station-keeping platform, particularly if it is operating at light draft at the time

6.6 Hazards When Pushing Large Ice Floes

The ice force placed on the bow of a vessel pushing a large floe can be significant, depending upon the size and thickness of the floe, the age of the ice (in terms of its hardness), and the power used by the ship to achieve the desired deflection away from the platform being protected. The amount of pushing force applied to a large ice mass must be appropriate to the level of ice strengthening (stiffening) in the bow region of the support vessel. In this regard, amount of "in-built" stiffening to resist ice damage varies with the construction (ice classification) of the vessel. Similar to icebreaking, the less the amount of ice strengthening a vessel has in its bow area, the less power that it can safely apply. When the amount of power is restricted to avoid ice damage, the effectiveness of the resultant ice management is reduced. An important point is that vessels engaged in ice management, especially TYPE ships, should have the ability to monitor ice loads on their hulls, using strategically mounted strain gauges.

6.7 More General Aspects

Many vessels with ice classification are constructed with an "ice belt" located slightly below the light waterline to a position a little above the load waterline. This typically means that the ship has some thicker plate and additional stiffeners in this area for resistance to high local ice pressures and the potential for impact damage at certain elevations around its waterline. This is appropriate for general navigation in ice, however, there are instances where such vessels have been used for ice management and have suffered significant ice damage to areas of the hull that were not ice strengthened.

When a vessel is managing pack ice at high speeds, there are obvious reasons why under-hull damage can occur. A couple of related comments are given as follows.

- When a vessel makes contact with thick ice, instead of breaking the ice with the bow, the ship rides up on top of the ice, crushing and breaking the ice with the ship's bottom as it rides-up. Most icebreakers have an ice-skeg at the joint of the stem to the keel to prevent the ship from riding up too far on heavy ice features. This ice-skeg is not a requirement for vessels with a low ice classification, and could be a problem during aggressive ice management with such a vessel. Additionally, any bottom damage that may occur can be a pollution problem, if the oil fuel tanks are located in forward wing tanks or double bottoms.

- When small, hard ice pieces are struck and forced downward, the inherent buoyancy of the ice can bring it back to impact the ship's bottom aft of the collision bulkhead. In addition, the flat bottom and transom stern shape of a typical supply vessel hull is such that once the ice has made contact with the lower hull, it is guided into the forward side of the kort nozzle/propellers. This can result in damage to support vessels that do not have either suitable propeller material or shrouding for ice interactions.

A view of ice-related damage to a vessel is shown in Figure 6.1 below.

Figure 6.1

7.0 PACK ICE MANAGEMENT WITH VESSELS ON THE GRAND BANKS

7.1 General

The previous sections of this report have provided information about past experiences with ice management in ice covered areas, pack ice conditions on the Grand Banks, the types of systems operating on the Grand Banks and their ice management needs, and various aspects of ice management support. Here, some of the more direct considerations that are associated with the use of different support vessels for pack ice management activities on the Grand Banks are briefly reviewed. A conceptual check list of "suitability criteria" for ice management vessels is also outlined in relation to their levels of ice strengthening and performance limits.

7.2 Support Vessel Capability

Here, it should be stated that different classification societies and regulatory authorities have different requirements for ice class, making it difficult to show a direct equivalency comparison. To address this problem, various class societies and governmental authorities are currently engaged in the process of harmonizing ice class requirements. It should also be noted that the regulatory requirements for various ice classifications have become more demanding over the years. This can result in an old vessel having the same "ice class notation" as a new vessel that meets a higher standard.

It has already been stated that ice management requirements for each in-ice operation are unique, and should be considered on a case by case basis. However, a difference in the necessary ice capability for support vessel tasks can be readily identified using the tables 7.1 and 7.2 below.

Table 7.1 shows the approximate equivalencies for vessels classed for ice navigation.

Approximate Equivalencies for Vessels Classed For Ice Navigation

Canada CASPPR	GL	Russian	ABS	BV	DNV	LR	Typical WMO Ice Type and Thickness Capability
E	E	(L4) LU	D0	1D	Ice C	1D	Grey (0.0 – 0.15m)
D	E1	(L3) LU2	1C	1C	1C	1C (Ice 3)	Grey White (0.15 – 0.3m)
C	E2	(L2) LU3	1B	1B	1B	1B (Ice 2)	Thin First Year (1st Stage) (0.3 – 0.5m)
B	E3	(L1) LU4	1A	1A	1A	1A (Ice 1)	Thin First year (2nd Stage) (0.5 – 0.7m)
A	E4	(UL/ULA) LU5	1AA	1A Super	1A*	1A Super	Medium First Year (0.7 – 1.2m)

Table 7.1

Table 7.2 shows the approximate examples of equivalencies of vessels classed as icebreakers.

Approximate Equivalencies for Vessels Classed as Icebreakers

Russian	Lloyds Reg.	Canadian Arctic Class CASPRR	DNV.	Operating Criteria	
Class	Class	Class	Class	Typical WMO Ice Type and Thickness Capability	Ice Thickness
(LL4) LU6	AC1	CAC4	Ice 05	Winter ice with pressure ridges	0.5m
			Ice 10	Thick first year ice with old ice inclusions	1.0m
(LL3) LU7	AC1.5	CAC3	Ice 15		1.5m
			Polar 10	Multi-year ice floes and glacial ice inclusions	2.0m
(LL2) LU8	AC2	CAC2	Polar 20		
(LL1) LU9	AC3	CAC1	Polar 30		3.0m

Table 7.2:

From these tables, it is clear that the ice class identified for 'ice navigation' is different from those recognized for 'icebreaking'. As discussed earlier, the ice management tasks required by a vessel to support platform operations in pack ice often involve ice braking

The following table, Table 7.3, makes use of the information provided in tables 7.1 and 7.2. Representative ice types and ice thickness ranges are listed in relation to various support vessel tasks for offshore operations.

ICE CONDITION	***TASK***	***ICE CLASS***
Thin First Year (0.5m - 0.7m)	Transit to the rig (navigation)	DNV 1A
Thin First Year (0.5m – 0.7m)	Standby at the rig (navigation)	DNV 1A
Thin First Year (0.5m – 0.7m)	Ice Management (icebreaking)	DNV Ice 05
Thin First Year with old ice inclusions	Ice Management (icebreaking)	DNV Ice 10

Table 7.3:

To identify support vessels that are suitable for providing effective pack ice management services to projects on the Grand Banks of Newfoundland, it is critically important to recognize that the general operating criteria described in Table 7.1 for different vessel classes assumes ice navigation, but not ice management.

7.3 Current Grand Banks Support Vessels

The vessels that are now being used to support various offshore activities on the Grand Banks are varied in size, power and ice capability. Recently, there were two Anchor Handling Tug Supply vessels (AHTS) based in St. John's - one having equivalence to a Canadian TYPE A and one TYPE B ice classification. In this regard, they had the capability to provide reasonably good ice management support in typical Grand Banks pack ice conditions. However, the majority of AHTS vessels used on the Grand Banks have an equivalency to the Canadian TYPE D (ABS and DNV 1C) ice classification which may be appropriate for ice navigation but not for providing aggressive ice management support to a platform.

Other commercial vessels appropriate for ice management are not easily available. For example, there are only two medium powered AHTS with high ice class operating out of Nova Scotia. Most of the strong, high powered icebreakers designed and built for Beaufort Sea IM are now operating in Russia. A few new icebreaking supply vessels are now working in the North Sea.

7.4 Conceptual Check List to Determine Vessel Suitability

The key questions that should be asked when considering pack ice management needs for any given operation on the Grand Banks, and when selecting appropriate support vessels to satisfy this function, are highlighted below. These provide a conceptual check list of the main items to consider.

Pack Ice and Environmental considerations expected, including:

- Ice Concentrations
- Ice Types
- Level Thickness
- Average and Maximum ice Floe Diameter
- Amount of Ice Deformation
- Amount of Ice Ablation (strength loss or melt)
- Maximum anticipated ice drift speed
- Amount of glacial ice present (ice bergs and small ice masses)
- Wave heights in low ice concentrations
- Lowest temperature
- Snow cover on the ice
- Visibility Considerations

Platform Capabilities and Operational considerations, including:

- The type and function of the platform and its level of ice strengthening and global resistance
- The station-keeping (and transit) method used by the platform
- The platform's ability to freely vane

Support Vessel Suitability and Performance, including:

- Level of ice strengthening required to manage expected ice types
    1. as the primary IM vessel
    2. as a secondary IM vessel
- Power is provided/required to maintain continuous ice management
- Level of maneuverability is necessary/provided
- Suitability of ship's stability for the conditions (including icing)
- Practicality of ship's operating draft
- Type of propellers (in nozzles or open)
- Any friction reducing coating on the vessel
- Any ice management enhancements on the vessel (i.e. air bubbling, friction reducing coating)

These points, which identify key areas of consideration, can be built upon to develop guidelines for appropriate ice management vessels in the future.

8.0 CLOSURE AND RECOMMENDATIONS

The use of ice strengthened support vessels for pack ice management on the Grand Banks is not a new concept. In this regard, the use of ice management vessels to support station-keeping platforms and enable operations in pack ice environments has been successfully employed in Arctic and sub-Arctic regions in the past. These ice management operations have provided valuable lessons in identifying platform operability and ice management limitations.

Although pack ice intrusions are not an annual occurrence at current development project locations on the Grand Banks, they do occur and can persist for days. As activities move further to the north and east, pack ice occurrences will be much more prevalent and can persist for much longer periods.

One of the most important considerations for the uninterrupted operation of a platform that is station-keeping in pack ice, or a tanker that is loading oil in pack ice on the Grand Banks, is the utilization of appropriately ice strengthened vessels for support. This is also a relevant consideration for operations such as platform re-supply, safety standby and EER, as well as oil spill response.

Since high speed maneuvering and icebreaking are key elements of pack ice management procedures with support vessels, it is imperative that vessel limitations in various pack ice conditions, both operational and structural, are well recognized. Clearly, there is a distinct difference between vessel transits where heavy pack ice is avoided and transit speeds generally kept low, and aggressive ice management. This task difference *in the same ice condition* makes it necessary for an ice management vessel to be more capable than one that is simply intended for navigation through pack ice.

Based on this scoping study, it is felt that further investigation into the ice-capability of support vessels that may be tasked with ice management duties on the Grand Banks is warranted. An obvious step to extend this scoping study is to talk with various Grand Banks operators, ship owners and ship captains, about some of the issues raised in this report. This type of interaction and dialogue should lead to a better understanding of what can and cannot be accomplished in terms of pack ice management to support activities on the Grand Banks, should a pack ice intrusion occur.

It is also recommended that a set of generic guidelines be created to indicate a minimum structural (class) requirement for vessels intended for pack ice management functions, assuming typical ice management speeds for the range of pack ice conditions encountered in the Grand Banks region. Such guidelines would be useful to planners of future Grand Banks development projects as an input for necessary determinations of vessel requirements. They would also be of use to current project and ship operators, to assess the systems that are now in place, and how they should be strategically and tactically employed in pack ice situations.

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