

Ice Management – From the Concept to Realization

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ABSTRACT: In the present time in the Russian Arctic and freezing seas there's the growth of industrial activity. In addition to the traditional navigation in the ice-infested waters the development of the new offshore hydrocarbon deposits is planned. New production and uploading platforms and high-tonnage tankers appear in the Arctic. Widening of the sea activities in the Arctic, the implementation of comprehensive technical projects and the need to ensure their safety made it necessary to develop and introduce principally new information and logistics system - a system aimed at "managing ice conditions" or the so-called "Ice Management" (IM). The vast experience of the informational support of the ice navigation is accumulated in Russia, many components of the IM are developed and implemented in the active practice. The paper presents the summary of such experience. The concept of development the IM on the Shtokman Gas Condensate Field is discussed.

1 PURPOSE OF ICE MANAGEMENT

In order to provide active navigation, countries having access to the Arctic seas elaborated systems of hydrometeorological support (HMS). This term means set of actions aimed at systematic support of subjects carrying out activities in the Arctic with information on current and foreseeable ice and hydro-meteorological conditions along the navigational routes or in the regions of production activity.

Widening of the sea activities in the Arctic, the implementation of comprehensive technical projects and the need to ensure their safety made it necessary to develop and introduce principally new information and logistics system - a system aimed "at managing ice conditions" or the so-called "Ice Management" (IM). "Ice Management" is the system of specific actions for advance assessment and early prevention of dangerous ice phenomena, including as well active use of the technical means to effect the ice formations in order to reduce their negative impact on the offshore producing facilities

In contrast to HMS system, which is simply informational system, IM could be referred to as a group of comprehensive information and logistics systems. The main purpose of these systems is to assess risk of arising situation in advance and develop recommendations on methods of active management of the situation.

2 INFORMATIONAL SYSTEM OF RUSSIA ON SEA ICE

Arrangement of the ice management is based on ice and informational systems, which by now have been developed in the majority of national ice services. Creation and development of these services is predicated on their tasks on informational support of various activities in the freezing water areas. Any ice informational system consists of three main blocks: one of the collection of information, another of its processing and analysis and the third of distribution of information to consumers. As an example, consider the experience of Russia (Фролов и др, 2003; Smirnov et al. 2000).

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Until the mid 1980's, common hydrometeorological support for the Arctic region in Russia did not exist. During navigational period, Arctic seas have been divided into zones of responsibility between the Headquarters of Marine Operations (HMO) that included scientific and operational teams providing hydrometeorological support of navigation. The main source of information on the state of ice in the Arctic seas and in the lines the Northern Sea Route was visual aerial ice reconnaissance.

As satellite information on the ice cover state in the Arctic seas had started to be used more widely, the development of the unitary system of hydrometeorological support became a matter of time. Such a system was established in the late 1980s. It was mainly based on the "Automated Ice and Informational System for the Arctic" alternatively known as "North" (Бушуев и др., 1977; Фролов и др. 2003).

Infrastructure of the "North" system is presented by territorial hydrometeorological centers (Murmansk, Arkhangelsk, Dikson, Tiksi, Pevek), regional centers for receiving and processing satellite data (Moscow, Yakutsk, Khabarovsk). AARI is the leading center of the "North" system.

Contemporary Russian system of monitoring of the sea ice in the Arctic water areas provides collection, processing and distribution of the ice information to customers practically in the real time and has a unitary center of Ice and Hydrometeorological Information (AARI).

The main source of data on the state of the ice cover in the Arctic and the freezing seas is a satellite remote sensing (information comes from satellites NOAA, Fengyun and EOS (Terra, Aqua), RADARSAT1, Envisat). Surface-mounted receiving complex of AARI in Saint Petersburg is equipped with stations for receiving satellite information (Telonics, USA and ScanEx, UniScan-36, Russia) and provides satellite images in the real time.

Other sources of information about the environmental state in the Arctic are the network of polar hydrometeorological stations, expeditionary research vessels; automatic meteorological buoys deployed on the drifting ice in the Arctic Ocean; domestic and foreign centers of hydrometeorological and ice information;

Center of Ice and Hydrometeorological Information is in charge of:

- Composing review and detailed ice charts;
- Making long-term ice and weather forecasts;
- Making medium- and short-term ice, meteorological and hydrological forecasts;

- Elaborating recommendations on navigation at performance of the marine activities.

Transfer of the real-time information products (charts, forecasts and other information) directly to customers is carried out by means of conventional and satellite communication channels. To transmit information to large ships and icebreakers equipped with INMARSAT communications systems and electronic cartographic navigational and informational systems (ECNIS / ECDIS), special technology developed at AARI is used.

The basic principle of the system is that all information products should be prepared in the unitary center at special "automated work places" (AWP) and then transferred directly to the Captain's workplace (i.e. conning bridge) – to the "End User" AWP. This system represents a technological complex, which is called "Adaptable complex for monitoring and forecasting of the atmosphere and the hydrosphere state for support of marine activities in the Arctic and in the freezing seas of Russia" ("AKMON") (Миронов и др., 2009). "AKMON" allows us to adjust the process of monitoring of the environmental state to the specific physical and geographical characteristics of the work area and the specific needs of the customer. On the bridge, Captain of the vessel can obtain an image illustrating ice conditions combined with a navigation map.

3 PURPOSE OF IM SYSTEM

Experience of comprehensive marine operations in ice demonstrated that informational support with data on the current and foreseeable hydrometeorological and ice conditions is not enough for the efficient and safe functioning of complex technical systems (producing platforms, unloading terminals) and transport systems (transportation of oil products by tankers, the work of the tanker-platform system). Considering the enormous maintenance cost of the facilities and potential environmental consequences (e.g., an accident in the Gulf of Mexico in 2010) as well as the complexity of the environment conditions of the Arctic region, it is necessary to perform a set of mutually dependant informational and logistical activities, that must be based upon the IM system in order to come to an effective management decision.

IM system includes permanent monitoring of the ice conditions, forecasting, assessing the risk of any possible ice conditions, preparing recommendations on the most effective decisions. Final procedure in the sequence of the IM system's steps is the activates aimed at suspension of marine operations (such as full stop of production-unload operations on the platform), re-scheduling (e.g., choice of alterna-

tive route for tanker) or the use of various technical means to influence the ice cover for eliminating danger (e.g., towing bergy bit in a distance where it doesn't threaten the platform).

"Ice management" system is not an absolutely new invention. Currently, as the world practice and Russian one in particular are concerned, a certain experience has been obtained in navigation in the ice by means of ice-breakers of different class and the use of drilling platforms in the freezing seas. To reduce the risk of the activities and prevent of dangerous impact of ice and icebergs on the vessels, floating and immovable platforms and terminals, it is necessary to manage ice conditions (IM).

Different countries and organizations acting in the Arctic started to implement various IM systems, which at this stage of development were focused on specific local operations and types of activities.

Following examples illustrate the most successful cases in the IM system arrangement:

- Ice management in the region of Great Banks of Newfoundland, where drilling platforms and FPU function, with use of different methods to change the drift of icebergs (Comprehensive..., 2005).
- Ice management to support high-latitude experimental drilling in the drifting ice of the Central Arctic Basin ("ACEX-2004" project) with a mobile drilling platform (Юлин, 2007).
- Ice management to support work in the ice of special unloading equipment for loading oil tankers near the port of Varandei (south-eastern Barents Sea).
- Ice management to support work in the ice of special unloading equipment for loading oil tankers in De-Kastri ("Sakhalin-1" Project) (Herbert, Mironov, 2007).
- Ice management to support loading of oil tankers near the complex "Vityaz" ("Sakhalin-2" Project, phase 1).

4 THE CONCEPT OF THE IM SYSTEM'S STRUCTURE (IM STRUCTURE BY THE EXAMPLE OF THE SHTOKMAN GAS CONDENSATE FIELD)

All of the abovementioned examples of the IM system's arrangement had the same disadvantage as they were designed for the particular marine operation or a specific local area and consequently considered and were limited by the needs of this operation. Nevertheless, widening of activities range in the Arctic imposes the need to develop a universal IM system. In this particular case, universality means the possibility to adjust the system, based on common arrangement principles, to any operation and any region of the Arctic.

It is the main objective of the "Ice Management" system to provide safety of the vessels and offshore facilities whilst functioning in the presence of the sea ice and icebergs in difficult meteorological conditions of freezing seas.

The main common principles of the arranging ice management system are:

- The system should be structured in such a way that to provide high reliability level under any environmental conditions and any conditions of functioning;
- IM system should decrease frequency of interaction of offshore objects with ice formations
- The system should be able to reduce ice loads on the objects when it is impossible to avoid them;
- Activities connected with the ice management should ensure safety of the facility, cut down facility idle time, provide safe and effective disconnection of the facility, accelerate its removal and the safe re-connection.

According to the international standard ISO 19906 (2009), the ice management system should consist of the following subsystems:

- 1 Subsystem for monitoring and forecasting the ice cover state and distribution of icebergs;
 - 2 Subsystem for evaluation of potentially dangerous ice phenomena and ice formations;
 - 3 Subsystem, using various technical means for effecting the ice cover and icebergs;
 - 4 Subsystem for preparing the facility to a hazardous situation and ensuring its disconnection and removal.
- 5 STRUCTURAL AND FUNCTIONAL SCHEME OF IM SYSTEM (BY THE EXAMPLE OF SGCF)

The suggested IM system (Shtokman Gas Condensate Field (SGCF) region as an example) should consist of four listed sub-systems, each developed and involved to a different degree of development, taking into account the regional and functional requirements for marine operations. Structural and functional scheme consists of 4 subsystems:

- *Subsystem for monitoring* provides a regional monitoring of icebergs and the ice cover in the Barents Sea and includes modules for collecting and processing of global and regional data, modules for analysis and forecasting, for control of technological processes and transfer of information products.
- *Subsystem for the threat evaluation* provides local monitoring within a specified radius around the producing vessel (platform) and the estimate of probability of dangerous ice phenomena appear-

ance, taking into account the specified radius of risk.

- *Subsystem for influence on ice* lets to develop recommendations for active influence on the ice by means of icebreakers and vessels (tugboats) of various ice class taking into account characteristics of ice regime and helps to make the decision on which technical means to use.
- *Subsystem for preparing* helps to develop recommendations on procedures to begin disconnection and removal of the facility and then, reconnection.

6 ARRANGEMENT SCHEME OF IM SYSTEM (BY THE EXAMPLE OF SGCF)

6.1 Regional and local monitoring.

Region of SGCF is located in the margin zone of the Barents Sea, where the sea ice and icebergs aren't recorded every year. If ice enters the field area, average duration of the ice period comprises about 2 months and the maximum – 5.5 months (Haymov и др., 2003). In addition, SGCF area is situated in bergy waters, i.e. there's no sea ice but the probability of encountering icebergs exists.

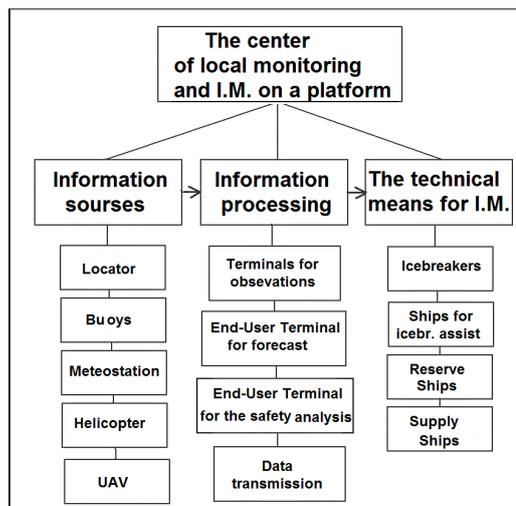


Fig. 1. Arrangement structure of the Ice Management System (fragment)

Taking into account the multiyear and seasonal characteristics of the sea ice and icebergs variability, as well as the high maintenance costs of local monitoring of the ice cover on board the vessel (platform), it seems reasonable to use dual scheme arrangement (fig 1):

- 1 Regional monitoring of the ice cover and icebergs is carried out on the base of the coastal center of the automated ice and informational system of AARI (Saint-Petersburg).
- 2 Local monitoring in the Shtokman GCF region is performed from the platform. In the case there's probability of appearance of ice and icebergs in

the field region, immediate response group is directed to the platform to carry out additional observations and analyze the potential risk for ice formations to come in the immediate vicinity of the platform.

Regional monitoring of icebergs and the ice cover in the Barents Sea should be carried out throughout the year. Data of the regional monitoring data should be used to make long-term forecast of the ice edge position, and the medium-term forecast of ice distribution and drift of icebergs which later will help to make a decision on the beginning of the group's work on the platform.

In the coastal center of the regional monitoring, module for the collection and processing of information including station receiving satellite images and telecommunication center should function in the 24-hours mode. Module for creating informational products as well as the one for managing technological processes operates in the mode agreed on with the Customer.

Local monitoring is the main source of information of the subsystem for the threat evaluation and is performed by the technical means installed immediately on the platform or near the producing platform.

To achieve objectives of the local monitoring on the platform, and near it, it is necessary to use various equipment: ice radar, helicopter, set of unmanned aerial vehicles (UAVs); camcorders, spotlights, meteorological complex; buoy-markers (for GPS-tracking); Doppler profiler and current meters.

Center of local monitoring should function all year round in the 24-hours mode. On the platform, it is necessary to receive information from the regional center, perform 24 hour ice observations, to analyze general and local information (both current and prognostic), to estimate the possibility of the ice threats. If necessary, helicopter is used to identify potentially dangerous objects.

7 ANALYSIS OF THE ICE THREATS.

Ice conditions can be divided into two groups by the way of manifestation, formation, period of existence and an impact on the technical structure:

- 1 Dangerous ice phenomena.
- 2 Dangerous ice formations.

Dangerous ice phenomena (DIP) result from the influence of the atmosphere and the drifting sea ice, usually formed by dynamic factors, appear suddenly, active in the limited area and for a limited period of time. The main way to avoid them is the short-term forecasts with an advance time from several hours to 3 days

Dangerous ice formations (DIF) are solid objects, floating on the surface of the sea area, which physically affects the technical structure of its mass. The main way to avoid their influence is early detection, long- and short-term forecasts of the ice formation's motion and, if necessary, affect them by technical means.

For the SGCF region the following DIP can be distinguished: intense ice drift, compacting, icing (aerial and spray). Dangerous ice formations for the SGCF are, in our opinion, giant, vast, and big floes (breccia) of the first-year ice, any floes and medium floes of the significantly deformed first-year ice, floebergs, icebergs, bergy bits and growlers.

Table 1. Evaluation of the level of threat of a dangerous situation and recommendations on the ice management

Threat level	Time required	Colour	IM actions
No threat	Not limited (more than 5 days)	Green Vessel/ Platform works	Regular ice monitoring
Potential threat	From 3 to 5 days	Blue Vessel/ Platform works	Regular ice monitoring
Insignificant threat			Regular ice monitoring
Distance from the facility is more than 50 km	From 2 to 3 days	Yellow Vessel/ Platform works	Preparation to the possible use of technical means
Real threat			Use of all the possible technical means to eliminate the threat
Distance from the facility is 10-50 km	From 1 to 2 days	Pink Vessel/ Platform works	Decision to use additional tech. means
High level of threat			Use of all the available and additional technical means to eliminate the threat
Distance from the facility is 4-10 km	from $T_{pred} = T_{min} + T_{crit}$ to 1 day	Red Vessel/ Platform works Readiness to disconnect vessel/platform	Decision to disconnect the vessel/platform Immediate disconnection of vessel/platform at the same time with active influence on the threat by the all technical means
Critical threat			
Distance from the facility is less than 4 km	Less than T_{pred}	Black Disconnection of the vessel/platform	

Taking into account possible threats, the time they were discovered, the time various technical means were applied to them, different detection radius and the time required for analysis, coming to decision and implementation of certain actions, table of levels and thresholds of allowable risks can be composed (Table 1). This table presents levels of

threat, time needed for necessary measures and recommendations for IM activities.

In order to illustrate the threat level easier, range of colors (from black to green), a widely used in the ice management practice, is associated with description.

8 METHODS PERFORMED BY TECHNICAL MEANS AIMED AT DESTRUCTION OF ICE FLOES AND CHANGE OF THE ICEBERGS DRIFT

Protection of the marine facilities against the pressure, piling and the stress caused by drifting ice and icebergs is rather complicated and expensive problem, but technically it can be solved. The task is to destruct large forms and monoliths of ice to the parts of smaller sizes, that freely moves around the structure without creating a critical pressure and stress.

Technological solution of the problem is to breaking down large ice formations (floes, medium floes, small floes) to the smaller part in front of the protected structure. In general, allowable sizes of the ice formations are those with sizes of less than 20 m in diameter. Gained experience in the ice management shows that there're one or several icebreakers required (depending on ice condition) in order to influence the ice on the ice if you want a few icebreakers, depending on ice conditions (Юлин, 2009).

Various methods to influence icebergs were applied to provide safe production of hydrocarbons in the Great Bank of Newfoundland and in the Labrador Sea. Under the influence of strong Labrador Current, carrying icebergs on to the producing platform, a sufficient security measure is to change the trajectory of the iceberg by a few degrees deflection from its initial courses.

The most commonly used techniques are towing with help of synthetic cable (72% of all of the operations), the deflection by propeller stream (9%), towing by net (7%) and the deflection by water cannons (6%). In the rest cases of deflection of icebergs were performed by less common means (towing by two vessels etc.). (McClintock et al., 2007). Main factors limiting the use of different means to change the iceberg drift are their weight and the wave height. Depending on the wave height, towing of icebergs can be carried out successfully in from 69% to 85% of cases; however, if the wave height is more than 5 meters, the success rate drops to 60%.

Icebergs of almost all the sizes (except for small icebergs and bergy bits) can be towed with efficiency of 76-80%. The average time of influencing the iceberg for a various methods ranges from 4 hours

(in case of use propellers) to 8.6 hours (in case of towing by two vessels) (Comprehensive ..., 2005).

From the works (Crocker et al., 1998; Comprehensive..., 2005; McClintock et al., 2007) we can conclude that as a rule for each size gradation of the iceberg, the most effective method is different. Thus, the most effective way to change the course of growlers and bergy bits is the deflection by the propeller stream. Bergy bits and small icebergs can be successfully deflected by the water cannons. Bergy bits, small icebergs and even medium-size icebergs can be towed by special nets. Method for towing medium and large icebergs, proved its reliability, is the towing by one vessel with use of synthetic rope (AARI has such an experience, described in Stepanov et al., 2005). Towing large and giant icebergs requires two vessels (icebreakers).

In the area of SGCF it is possible to detect drifting hummocked ice floes, which can be broken into smaller parts not threatening the process of hydrocarbons production by technical means if necessary. If icebergs or bergy bits enter the area, there can be a situation when it's impossible influence the trajectory of their drift effectively and there is a high probability of collision with the facility. In this case, if the criteria are specified, there is a need to implement measures to stop production, disconnect the producing vessel and remove it into a safe distance.

The ultimate measure to eliminate the ice threat, letting to avoid damage of producing vessel, is its disconnection and removal to a safe distance. At the same time, it should be admitted that this measure is highly undesirable due to interruption of the producing cycle (the decrease in the amount of raw) and the subsequent resuming of production (which may require considerable time).

9 THE PROSPECT OF CREATION OF THE UNITARY INFORMATIONAL SPACE AND SECURITY SYSTEMS FOR TRANSPORT OPERATIONS IN THE ARCTIC AND FREEZING SEAS.

Development of the marine and economic activities in the Arctic and other freezing water areas, the complex character of environmental conditions, arising technological and environmental risks strongly require new forms of information service for these comprehensive industrial and transport systems, which include exploration, production, loading and transportation of raw materials.

The most promising way in our point of view is the development and implementation of innovative information and logistics systems, "Ice Management" systems

Russia and other countries, acting in the Arctic, have accumulated wide experience in development and use of the individual elements of these systems.

By now, the concept of IM system was elaborated in Russia for regional conditions of Shtokman GCF. Individual elements of the system already have been successfully working in a number of projects. Analogous systems can be adjusted to other objects of activity in the Arctic region. Use of the IM systems for activities in the Arctic will allow to reduce risks caused by environmental conditions and to make operation of technological systems safer and more effective.

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