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Ship-to-ship Operations in Cold Climate Environments

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ABSTRACT: Within the Norwegian maritime cluster there is a growing interest in studies of harsh weather marine operations. For the oil industry offshore loading is a preferred operation for production at minor oilfields far from existing infrastructure. Safe and cost-effective production from recent oil and gas discoveries close to the coastline of Northern Norway introduces new challenges due to cold climate environments. At the same time increased transit of oil from northwest Russia will require increased ship-to-ship transfer in an optimized cargo chain from the oilfields to customers in Europe and the USA.

1 BACKGROUND

Ship-to-ship cargo transfer is a critical element in many transport chains, especially for oil and gas products. A large part of oil export from northwest Russia is transported by smaller tankers or rail to Murmansk where floating storage tankers are at anchor. Conventional oil tankers are used to carry the oil to European or American customers. Since 2005 condensate has been transferred in sheltered waters close to Kirkenes in northern Norway (close to the Russian border). A number of ship owners and agents have proposed different areas for ship-to-ship crude oil transfer operations in sheltered waters in fjords along the Finnmark coast.

This paper will review previous, present and proposed applications of ship-to-ship transfer of oil and gas in the cold climate environments of northern Norway. The main focus will be on regulations for and experience from operations done in sheltered waters in this part of Norway. The Norwegian way will be compared to traditional lightering operations done in US waters. Other items that will be discussed are the development of guidelines for doing conventional lightering operations within Norwegian territorial waters in the northern part of the Norwegian Sea as well as the Barents Sea. At present the Norwegian authorities only accept ship-to-ship oil transfer in sheltered waters. Finally, the presentation will look into the work done by Ship Manoeuvring Simulator to develop realistic training scenarios for emergency lightering operation under harsh environmental conditions at sea.

2 APPLICATION OF SHIP-TO-SHIP OPERATIONS IN THE EUROPEAN ARCTIC

2.1 *Ship-to-ship oil transfer in northwest Russia*

At present the only oil production in the European Arctic takes place in northwest Russia. Due to the seasonal ice cover in harbours east of the Kola Peninsula small ice-strengthened tankers are used to transfer crude oil and condensate to floating storage and offloading vessels in Murmansk or for direct ship-to-ship transfer operations in Norwegian waters. Figure 1 shows the locations with existing or planned transhipment of Russian oil for export.

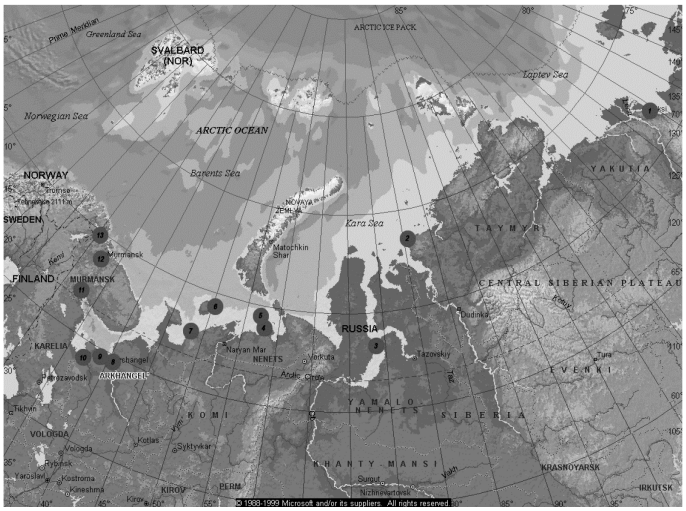

Fig. 1. Locations with existing or planned transhipment of Russian oil for export, Bambulyak & Frantzen (2005a)

In 2003 a Russian shipping company started an oil transport chain where smaller river tankers of the *Nefterudovoz* class used the White Sea – Baltic canal and transferred their cargo to larger ocean-going tankers in the White Sea. Transhipment was done offshore, close to the Osinki Islands. The ocean-going tankers were used to transfer the oil to floating storage and offloading ships in the Murmansk area. The plan was to transfer some 800 000 tonnes of oil products in the summer season in 2003 and to increase the shipment to 1500 000 tonnes in 2004, Bambulyak & Frantzen (2005b). The first transfer was made on June 24th 2003. On September 1st an accident took place during the approach and mooring phase of the lightering operation. The small river tanker had steel-to-steel contact with the ocean-going tanker resulting in a hull plating crack on the river tanker. It is estimated that a spill of some 20 tonnes of M-100 fuel oil took place. The transfer operations were temporarily stopped by the government while the consequences of the incident were studied. On September 23rd the shipping company was allowed to restart the operation on the condition that the shipping company prepared and presented a "List of measurements for the improvement of the interaction in respect of prevention and management of emergency situations in the area of the Onega transhipping complex". However, the shipping company decided to end this operation and to deliver oil for export through other harbours.

Since that time the Russian authorities have forbidden offshore ship-to-ship transfer of oil products. Instead floating storage and offloading ships have been integrated as elements in the export chain for Russian oil from the Barents Region. The first transhipment terminal RPK-1 in the Kola Bay (location C, Figure 2) was constructed by Murmansk Shipping Company in 2002. In August 2004 a 127 000 dwt tanker was anchored at this offshore transhipment terminal (location D, Figure 2) and started to operate as a Floating Storage and Offloading (FSO) vessel. The capacity of this terminal is 5.4 million tonnes a year. The second offshore terminal RPK-2 was built by the White Sea Service Company and started operation in December 2003. It only worked as a ship-to-ship transfer facility for 3 months. The third terminal RPK-3 started operation in March 2004 (location E, Figure 2). The FSO is Belokamenka, a converted old VLCC. The capacity of this export facility is approximately 3 million tonnes crude oil annually. The present operational capability of the vessel is 5 million tonnes of oil a year. This capability can be increased to 10 million tonnes when needed. This vessel is an important element of the export chain for crude oil to Europe and also plays an increasing part in oil export to US west coast. A fourth terminal is located in the Severomorsk District, planned capacity is 2.5 million tonnes oil annually (location F, Figure 2).

Fig. 2. Existing and planned oil terminals in Murmansk and the Kola Bay, Bambulyak & Frantzen, 2005a

The production from Prirazlomnoye has been delayed some years, but the latest prognosis is that it will start in 2008. Two ice-strengthened shuttle

tankers of 70 000 dwt have been ordered. They have been designed by Aker Arctic and are under construction at Admirality Yard in St. Petersburg. These vessels will transfer the oil to Murmansk for delivery to the Belokamenka FSO.

2.2 *Ship-to-ship transfer in northern Norway*

During the last few years a number of companies have evaluated possible ship-to-ship transfer operations in northern part of Norway. To reduce the sailing distance for ice-strengthened vessels, sheltered sites along the Finnmark coast have been in focus. Bøkfjorden close to Kirkenes has been proposed by different companies. In 2002 a test ship-to-ship transfer was done, three Lukoil tankers of approximately 15 000 dwt transferred crude oil to a 45 000 dwt tanker.

A major Norwegian ship owner worked for some years to establish a permanent FSO unit in Bøkfjorden. The varying governmental requirements introduced during their preliminary investigation together with protests from environmental protection non governmental organizations (NGOs) made the shipping company freeze further work. Towards the end of 2005, another company, Kirkenes Transit, obtained permission to perform up to 25 gas condensate transfers in Bøkfjorden. Figure 3 shows MT Perserverance performing a STS operation during the winter season where there is thin ice in the operational area. The permission has later been withdrawn and the company has moved this operation to the west and is now doing it close to North Cape in Sarnesfjorden.

Fig. 3. Ship-to-ship transfer of gas condensate in Bøkfjorden

3 NORWEGIAN AUTHORITIES AND STS OPERATIONS

3.1 *The Norwegian view on ship-to-ship transfers in northern waters*

The Norwegian authorities have introduced a strict view towards applications for planned STS operations. At present their policy is that such operations have to be done in sheltered coastal waters. Different regulations are applied for short-term and permanent operations. Different governmental institutions and non-governmental environmental protection organizations have had hard discussions on safety aspects and the risk of oil pollution in the vulnerable coastal regions in northern waters resulting from errors made during STS operations. In late 2006, the Norwegian Pollution Control Authority withdrew their permission to perform STS gas condensate transfer in Bøkfjorden. The reason for this decision was the status of the fjord as a national salmon fjord, lacking knowledge of the salmon and its vulnerability for oil pollution and uncertainty about how the operations would influence the sea bird population.

3.2 *Norwegian Coastal Administration – guidelines for STS operations in sheltered waters*

In discussions with representatives of the Norwegian Coastal Administration it has been stated that at present they will only allow ship-to-ship oil and gas condensate operations in sheltered coastal waters. There is presently no official operational guideline for STS operations in Norwegian waters. The operators have to develop their own operational guidelines which must be approved by different governmental authorities before an operational permit is issued. In general, these guidelines will be based on OCIMF's transfer guide, OCIMF, 2005. In the STS operations pilots will bring the vessels together.

The increased number of requests for permits to perform STS operations will probably result in the development of a template for preparing operational guidelines for STS operations in sheltered waters. In addition it will be of interest to look into weather windows for at-sea STS operations. Operational limits for lightering operations have been developed by US Coast Guard, USCG, 2006. The special conditions for cold climate operations must be reflected in future guidelines for Arctic STS operations. Specific parameters of interest will be ambient temperature, risk for atmospheric icing and the fast changes in weather conditions connected to development and motion of polar lows. The Norwegian Meteorological Office has stated that there is a need for improved weather forecasts for

the Barents Sea when oil and gas activities expand. More observations and better quality are a must for the development and validation of improved forecasts. One study has shown that by using a high resolution atmospheric model (10 x 10 km grid) it has been possible to describe the development and motion of polar lows, Norwegian Meteorological Institute, 2005. Figure 4 shows the observed polar lows for 1999 – 2004.

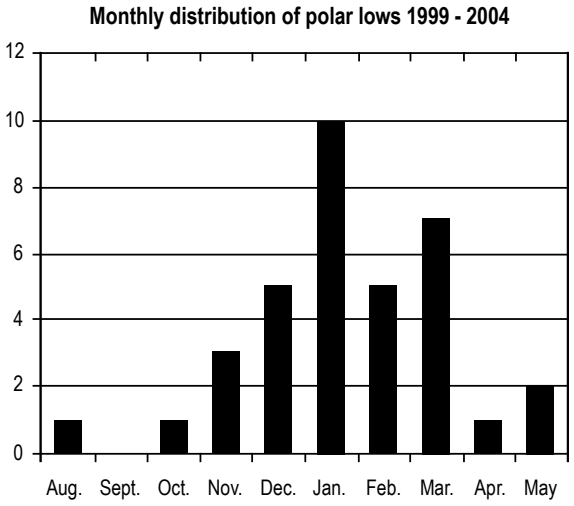

Fig. 4. Monthly distribution of polar lows (1999 – 2004), prepared by Norwegian Meteorological Institute

From a governmental point of view there is a need for further study of risk levels for at-sea STS operations. Within other ongoing projects MARINTEK has collected some knowledge on accident rates and spill size for lightering operations in the Gulf of Mexico and at other locations worldwide.

This topic is of interest for the Russian and Norwegian authorities.

3.3 *Future STS operations in open sea – off the coast of Finnmark and in the Barents Sea*

As part of ongoing projects, MARINTEK is involved in studies of both normal and abnormal STS operations in Arctic waters. For studies of normal operations it is of importance to define weather windows for safe and efficient operations as well as operational availability. Depending on the available environmental data and operation complexity two methods can be used for availability studies. The first is a direct statistical evaluation based on cumulative distributions of environment- and response parameters. The second method applies time-domain simulations of the different parts of the operational sequence – approach, berthing and mooring, cargo transfer, unmooring and unberthing and the final separation phase.

Abnormal STS operations are the topic of an ongoing R&D project on emergency operations in Arctic waters, for more information visit the website http://www.arcemop.no

One of the work packages is focused on emergency lightering operation in harsh weather at sea. In this case it is assumed that a large oil tanker is disabled and that there is a hull damage which in due time may result in a major oil spill. A ballasted shuttle tanker has been selected as a offloader in a scenario where emergency lightering is applied to offload part of the oil from the disabled tanker in an attempt reduce the stress on the hull beam and to establish a hydrostatic balance in order to prohibit a continuous oil spill from a damaged tank. The reason for the focus on this type of emergency operation is the increased volume of oil exports from northwest Russia and future oil production from new fields off the coast of Finnmark (Goliat and Nucula).

From ongoing work and discussions with different stakeholders, it has been proposed to start an activity to investigate the possibility of common Norwegian and Russian guidelines for oil transfer operations. It could be based on OCIMF's revised guidelines OCIMF, 2005. Additions will be needed to take care of special factors for low temperature environments. For operations taking place in Russian Arctic waters there will be a need to include requirements with respect to ice observation/management, especially if the STS operation is to take place in open sea close to the ice rim. Iceberg drift could be a problem in some other possible regions for STS operations.

4 TRAINING COURSES FOR STS OPERATIONS

The Ship Manoeuvring Simulator Centre in Trondheim, Norway, has for more than 10 years given dedicated training courses on lightering operations. At present these courses cover three levels:

1 Basic ship-to-ship operations

- This course gives an introduction to forces and moments between ships in close proximity
- Training scenarios are based on normal lightering operations

2 Advanced ship-to-ship operations

- The course contains operations where weather conditions are close to limiting values for initiating and aborting STS operations
- Other aspects are aborting the approach phase due to different factors such as wrong

longitudinal position, too large speed difference etc.
- Some training scenarios are based on reported near misses and actual incidents

3 Abnormal STS operations

- This is a special course developed for experienced mooring masters
- Training scenarios are based on actual incident cases and possible critical cases identified by experienced mooring masters
- Training topics are related to different types of emergency operations such as failures of rudder or propulsion systems, weather problems with wind, sea and current in different directions, multilayer currents and how to apply rudder in case the service ship starts to sheer when it begins to land on the fenders.

In the ongoing Arctic Emergency Operation R&D project studies of emergency lightering of a disabled tanker in harsh weather has been given priority. Possible training scenarios have been analysed, training objectives defined and a schedule for a possible course concept prepared. Later this year course material will be produced and reviewed by experienced mooring masters. In parallel SMS will extend the present hydrodynamic ship models to include realistic wave and interaction forces and moments. Additional work has to be done on the visual system as well for cargo hoses and the modified wave field between the two vessels.

5 PAST AND PRESENT MARINTEK ACTIVITIES CONCERNING STS OPERATIONS

5.1 *A new initiative with respect to STS operations*

MARINTEK selected ship-to-ship operations as a topic where there was need for more basic knowledge and understanding of the hydrodynamic phenomena resulting in interaction forces and moments. Starting in 2003, an internal knowledge building activity was specified. In addition to a state-of-the art literature survey an initial computational fluid dynamics study was performed. Skin-to-skin distance between the vessels was varied between 4 and 8 metres in the calculations. Heading angles between the vessels were 0 and 2 degrees. Figure 5 illustrates the calculated pressure distribution for a heading angle of 2 degrees between the ship to be lightered and the service ship. Another activity was a limited model experiment to measure interaction forces between two tankers in calm waters and waves. In these tests the smallest separation between the vessels equalled 9 metres skin-to-skin distance in full scale.

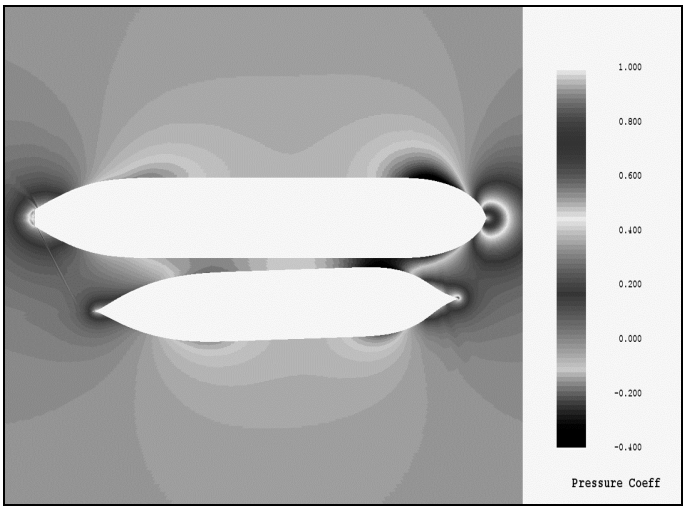

Fig. 5. CFD calculation of pressure distribution on vessels in lightering operation

In collaboration with Norwegian University of Science and Technology (NTNU) MARINTEK's towing tank has been used for master's thesis work on interaction forces for ships performing lightering operations in deep water. The state-of-the art review work was continued in 2005 as part of a pre-project to define an international cooperation project on STS operations. As part of the pre-project MARINTEK and NTNU arranged three international workshops covering the topics:

- Nautical aspects of STS operations (in Trondheim, Norway),
- Mathematical models for interaction forces (in Tokyo, Japan, in collaboration with Tokyo University of Marine Science and Technology),
- Experimental studies of STS operations (in Wuxi, China, in collaboration with China Ship Scientific Research Centre).

5.2 *New collaboration activities*

As an outcome of this pre-project MARINTEK and NTNU prepared a project proposal to the Research Council of Norway (RCN) in October 2006. In December 2006 the proposal was approved. An international consortium containing shipping industry, universities and research institutes in Norway, Belgium, Japan, China and the US is presently updating the project plan according to a revised budget from RCN. The 4 year R&D project will investigate hydrodynamic and nautical aspects of STS operations. A kick-off meeting on nautical aspects was held in Trondheim at the end of March 2007. Here experienced navigators presented their view on challenges related to STS operations for an international group of scientists to help them define

the tasks for the theoretical part of the R&D project. One of the participating mooring masters had done more than 500 STS operations. His statement was that every operation was different as it was influenced by the actual wind, sea and current conditions. In general the workshop participants agreed that there was a need for better understanding of the flow patterns and pressures distributions for STS operations.

In parallel MARINTEK is taking part in another 3 year R&D project studying ship-to-ship operations in Arctic waters. This project is owned by BW Gas and other partners are Framo Engineering, Rolls-Royce Marine, DNV, Gazprom and Gazflot.

Finally MARINTEK is acting as project manager for the ongoing "Arctic Emergency Operations" project. The project owner is Ship Manoeuvring Simulator (Trondheim). This project has some 20 partners representing governmental bodies, oil companies, shipping companies, research organizations and insurance companies. One of the work packages of this project studies emergency lightering operations in harsh weather environments (see Section 3.3).

6 CONCLUSIONS AND RECOMMENDATIONS

Based on a series of international workshops on ship-to-ship operations held in 2005 it was concluded that there was a need for further work to improve knowledge and understanding of the hydrodynamic aspects of ship-to-ship operations.

In-depth understanding of the water flows when two bodies move close to each other can only be obtained through basic fluid-dynamics studies combined with flow visualization techniques. These methods will be used in a four year R&D project starting in March 2007.

Sharing of experience from lightering operations worldwide is an important activity in work to improve existing guidelines for STS operations. Special care must be taken to introduce additional parameters for operations taking place in cold climate regions.

It is proposed that a common set of guidelines should be developed for STS operations by the Norwegian and Russian authorities. This work should be based on risk assessment and operational knowledge from STS operations and done through collaboration between the authorities, research organizations and other relevant stakeholders.

In order to improve the safety of future STS operations it is of importance to improve weather forecasts in Arctic regions. Improved forecasts will reduce the need to abort an operation due to unexpected weather changes.

For STS operations to be done in open waters in the Russian part of the Barents Sea there will be a need for an ice management service.

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- Arctic Emergency Operations,
- KMB Investigating hydrodynamic aspect and control systems for ship-to-ship operations,
- BIP Safe and effective ship-to-ship operations in Arctic waters.

REFERENCES

Bambulyak A. & Frantzen B. 2005a. Oil transport in the Barents Region. Third International Conference on "The Oil and Gas Industry and Sustainable Development of the Barents Region", Murmansk, Russia, 9-11. November 2005.

Bambulyak A. & Frantzen B. 2005b. Oil transport from the Russian part of the Barents Region, Svanhovd Environmental Centre, Svanhovd.

Norwegian Meteorological Institute, 2005. Increased activity in the Barents Sea - Do we know the weather conditions good enough?, met.no info, no. 14/2005, ISSN 1503-8017, Oslo.

OCIMF, 2005. Ship to Ship Transfer Guide (Petroleum), Oil Companies International Marine Forum, London.

US Coast Guard, 2006. Code of Federal Regulations, 33 CFR Part 156 Subpart C, 156.320 Maximum operating conditions, Washington. Revised June, 2006.