Organizing an oil transportation system in the Arctic

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Abstract. Development of the Arctic has become the subject of intense attention due to the region’s vast hydrocarbon resources. However, severe environmental conditions and large distances greatly increase the development costs. Because of this, it is crucial to organize rational logistics routes within the Arctic communications system. In recent years, Russia has been taking on a leading role in transportation of hydrocarbons, including oil; there is growing demand from the global community for steady supply of Russian crude oil and petroleum products. At the same time, difficult weather and ice conditions along with poor infrastructure make it a challenge to establish a system for offshore transportation of oil in the Arctic. The paper reviews the Russian experience of sea transportation of oil from the Pechora Sea and the Gulf of Ob, describing a scheme using modern shuttle tankers of reinforced ice class. Apparently, ice tankers of Arc6 and Arc7 classes can be used with virtually no assistance from icebreakers provided that ice conditions are relatively favorable. The unique experience of cooperation in transportation projects accumulated by Russian oil and gas operators, shipping and shipbuilding companies, and financial organizations should prove useful for further development of natural resources of the Arctic.

1. Introduction

At present, only four states with access to the Arctic Ocean, are actively developing oil and gas projects: Russia, Canada, the USA and Norway. Denmark’s attempts to find commercial oil and gas reserves beyond the Arctic Circle in the late 1970s, in the 1990s–2000s, and finally in 2012 were unsuccessful. Other countries whose territories are fully or partially located beyond the Arctic Circle (Iceland, Norway, Sweden, Finland) have no direct access to the Arctic Ocean. This means that even though some of the transportation systems cross borders, the main routes for transporting oil and gas in the Arctic are through Russia, Canada, the USA and Norway.

The key reason for interest in developing the Arctic region is in its colossal reserves of oil and gas [1]. According to the US Geological Survey, the Arctic oil reserves alone can sustain global demand for 3 years [2]. Countries that do not border the Arctic, including India, China, South Korea, Brazil, Japan and the EU countries tend to regard the Arctic Ocean as a zone of international interests, while Russia and Canada intend to maintain national jurisdiction over both sea routes [3] and the entire Arctic region. Russia’s potential for Arctic development and, in particular, oil production in the region is a matter of considerable attention [4]; in fact, development of the Russian Arctic can lay the foundations for long-term international cooperation, improve the integration mechanisms for interaction between companies, ultimately increasing the country’s competitiveness [5].

The focus on Russia has been especially keen since 2002, when oil transportation from Russian
Arctic ports increased significantly. In 2002, 5 million tons of oil were delivered through the Barents Sea; by 2004, this figure increased to 12 million tons. Annual volumes have varied from 9 to 15 million tons since then. Foreign studies have discussed Russia’s growing role in transportation of petroleum products from the Arctic over the past decade [6], considering the unique experience accumulated by Russian companies and the trends in using complex and highly efficient logistics schemes for transportation. Tanker operations in the Baltic in winter, preparing for future transportation of large amounts of hydrocarbons from the Arctic, were analyzed in [7], reviewing the requirements for ice-class vessels that could ensure environmental safety of future shipments.

A key feature of logistics schemes in the oil and gas industry is that pipelines are primarily used for transportation of raw materials. Oil production sites are located at considerable distances from oil refineries, increasing delivery costs, so it is especially important for the industry to construct the schemes aimed at reducing costs and/or delivery times.

The main routes for transportation of hydrocarbons are by sea, by railway and via pipeline systems. Pipeline systems are leading in terms of cargo turnover, as they are the most cost-effective [8]. Oil transportation in the Arctic is mainly carried out through the well-established Northern Sea Route (NSR). The Northern Sea Route is one of the most important export channels that allows transporting large amounts of mineral raw materials to eastern and western markets, greatly reducing transportation times.

Russia has a fleet of atomic icebreakers that can transport liquid hydrocarbons, including oil, to foreign markets. However, only a small percentage of the total volume of liquid hydrocarbons transported by sea were exported by the Northern Sea Route, amounting to 5.6% in 2014. Cargo turnover amounted to 10.7 million tons in some parts of the Northern Sea Route in 2017, out of which 9.7 million tons were transported by sea vessels. The volume of traffic in the Arctic is expected to increase as a result of further development of oil and gas fields and development of port facilities in the north [6, 9].

Aside from extraction of mineral resources, including oil, the Arctic’s growing industries are shipping, fishing and even tourism [10]. Even though these sectors have experienced a number of setbacks, it is believed that their progress can contribute to sustainable economic development of the Arctic, preserving its unique environment. While many projects do not have such heavy environmental impacts as extraction and transportation of mineral resources, analysis should cover not only financial costs and benefits but take into account the effect of these projects on the socio-economic environment [11].

Problems of environmental safety impose additional restrictions on organization of oil transportation, as described in studies by both Russian and foreign scholars [12, 13, 14]. The impact of new Arctic trade routes on marine habitats and ecosystems functions, especially in coastal regions, was considered in [15]. Norwegian experience in organizing adequate emergency response systems as oil extraction and transportation intensifies in the Arctic is analyzed in [16]. A development strategy for the transport infrastructure accounting for the specifics of the Far North is given in [17]. Strategic maps were considered in [18] as a means for managing an industrial sector, aimed at preserving the environmental safety of unique Arctic nature. The factors making industrial development of hydrocarbons in the Arctic attractive for Russia were discussed in [19]. Activities in the development of the Arctic are a source of growth in the competitive advantages of oil companies but stimulate the intersectoral innovations [20]. Oil is currently transported from the Pechora Sea and the Gulf of Ob. The opportunities for developing deposits in the Arctic largely depend on whether efficient logistics schemes can be organized for oil transportation. A major obstacle hindering the development of rich northern deposits is the lack of transport infrastructure. This is a crucial problem for the Russian Arctic; an approach to solving it was proposed in [21]. Along with innovative technologies for extraction, production and transportation of hydrocarbons, generating economically viable schemes for transporting Arctic oil has become the key to development of the Arctic.
2. Experience in organizing a logistics scheme in the Pechora Sea

Oil in the Pechora Sea is offloaded from Varandey, a fixed offshore ice-resistant off-loading terminal (FOIROT) and from Prirazlomnaya, an offshore ice-resistant fixed platform (OIRFP). The Varandey Terminal (PJSC Lukoil) is listed in the Guinness Book of Records as the world’s northernmost oil terminal, in continuous operation since 2008.

The Varandey terminal includes:
- fixed offshore ice-resistant off-loading terminal (FOIROT);
- 158 km flowline;
- onshore tank farm with a capacity of 325,000 cubic meters;
- pump station;
- energy supply facilities;
- tanker fleet (3 tankers);
- auxiliary fleet (icebreaker and tug);
- floating storage and offloading unit with a capacity of 260,000 tons;
- shift camp for 180 people.

FOIROT Varandey has been operating since 2008; it is installed at a depth of 17 m more than 22 km offshore. The FOIROS is more than 50 m high and weighs more than 11,000 tons. The structure consists of a support base with living quarters for 12 people with technological systems and rotary device for mooring and loading with a crane and a helipad. The octahedral support base is capable of withstanding high ice loads. The FOIROT is mounted onto the bottom with 24 piles and connected to the shore by two submarine pipelines.

The terminal operates with zero discharge, all industrial and human wastes are collected in special containers and transported to the shore for subsequent disposal, ensuring environmental safety of the terminal’s operation. The characteristics of the tanker fleet of Varandey Terminal are given in Table 1.

Table 1. Tanker fleet at Varandey Terminal

| Name                | Deadweight | Shipyard               | Commissioned         | Ice class | Type       | Flag   |
|---------------------|------------|------------------------|----------------------|-----------|------------|--------|
| Vasily Dinkov       | 71,250 t   | Samsung Heavy Industries | January 1, 2008      | Arc6      | PANAMAX    | Russia |
| Kapitan Gotsky      | 71,230 t   | Samsung Heavy Industries | May 27, 2008         | Arc6      | PANAMAX    | Russia |
| Timofey Guzhenko    | 71,290 t   | Samsung Heavy Industries | February 24, 2009    | Arc6      | PANAMAX    | Russia |

Arc6 ice class vessels can sail in a canal behind an icebreaker in one-year Arctic ice up to 1.2 m thick in winter spring and up to 1.7 m in summer-autumn navigation. Arc6-class vessels can also travel unsupported in open one-year ice up to 1.1 m thick in winter-spring navigation, and up to 1.3 m in summer-autumn navigation. Thus, icebreaking shuttle tankers can be used along the route from Varandey Terminal in the Pechora Sea to Murmansk to transport crude oil without icebreaker assistance. Tankers have been operating since 2008, allowing to accumulate extensive positive experience in using tanker transportation without icebreaking support, which significantly reduces transportation costs.

The auxiliary fleet of Varandey Terminal is mainly intended for ensuring safety of the terminal and the tankers during maneuvers. Its characteristics are given in Table 2.

Table 2. Auxiliary fleet at Varandey Terminal

| Type/Name      | Deadweight | Shipyard          | Speed | Ice Speed | Flag     |
|----------------|------------|-------------------|-------|-----------|----------|
| Varandey (icebreaker) | 4,643 t   | Keppel Singmarine | 15 knots | 3 knots in 1.7 m | Russia   |
Oil is delivered to Varandey Terminal via oil pipelines from Lukoil’s fields in the Nenets Autonomous Okrug from:
- South Khylchuyu oil and gas field in the north of the Timan-Pechora Basin province,
- Trebs and Titov oil fields in the Nenets Autonomous Okrug.

The fields are developed by the joint venture LLC Bashneft-Polyus (25.1% stake held by JSC LUKOIL and 74.9% by PJSC ANK Bashneft).

Varandey Terminal can “mix” incoming crudes, producing a more expensive grade of export oil, called the Varandey Blend. Exports of the Varandey Blend decreased by 1.69 million tons in 2018, amounting to 6.58 million tons. Since early 2018, LUKOIL has been offloading the Varandey Blend in the Kola Bay via the Kola storage tanker that can handle 12 million tons per year. The tanker allows to simultaneously offload 100,000–140,000 ton shipments of the Varandey Blend.

Another storage tanker located in the Kola Bay is the Umba tanker owned by Gazprom Neft PJSC. The characteristics of storage tankers are given in Table 3. Umba is equipped with systems for separate storage of crudes from the Novoportovskoye and Prirazlomnoye fields, allowing for a more flexible approach to planning shipments.

Table 3. Characteristics of storage tankers

| Name      | Deadweight | Shipyard          | Commissioned     | Class notation | Flag        |
|-----------|------------|-------------------|------------------|----------------|-------------|
| Kola      | 300,000 t  | Hyundai Heavy     | August 17, 2001  | KM* AUT1 L1    | Russia      |
|           |            | Industries Ulsan  |                  | IGS-IG VCS COW |             |
|           |            | Shipyard          |                  | FSO (ESP)      |             |
| Umba      | 300,260 t  | Hitachi Zosen      | May 5, 2001      | KM* AUT1 VCS   | Russia      |
|           |            | Sakurajima Works  |                  | oil tanker (ESP)|             |

The Umba tanker is capable of accommodating simultaneous berthing of vessels on both sides. Its infrastructure incorporates systems for intake, storage and offloading of oil, its customs and border clearance, and bunkering operations for shuttle tankers and transporters. Oil transshipment is carried out around the clock; operation is in compliance with modern environmental standards and requirements. The tanker was converted for operation in the Arctic in 2015. The volume of transshipments from FSO Nord amounted to 8.24 million tons in 2017.

Using storage tankers in the transportation scheme for transshipment of large cargo to provides far greater efficiency of export deliveries, compared to direct shipment, as it shortens the duration of round trips for the tankers (reinforced ice class shuttles exporting oil from Arctic fields) [22]. This scheme is possible because the Kola Bay does not freeze.

Another unique field of the Pechora Sea, Prirazlomnoye, is currently the only hydrocarbon deposit on the Arctic continental shelf. The field is located on the Pechora Sea shelf 55 km north of the settlement of Varandey. Oil from OIRFP Prirazlomnaya is transported throughout the year to FSO Nord by double-acting oil tankers of reinforced ice class Arc 6, equipped with ice-breaking bow and stern. The characteristics of oil tankers of OIRFP Prirazlomnaya are given in Table 4.

Table 4. Characteristics of oil tankers at OIRFP Prirazlomnaya

| Name     | Deadweight | Shipyard         | Commissioned    | Ice class | Type      | Flag |
|----------|------------|------------------|-----------------|-----------|-----------|------|
| Kirill   | 70,053 t   | Admiralty        | September 10, 2010 | Arc6      | PANAMAX   | Russia |
| Lavrov   | 69,830 t   | Shipyards JSC    | February 26, 2010 | Arc6      | PANAMAX   | Russia |
| Mikhail  | 69,830 t   | Admiralty        |                  |           |           |      |
| Ulyanov  | 69,830 t   | Shipyards JSC    |                  |           |           |      |
OIRFP Prirazlomnaya, two Arctic shuttle tankers based on pioneering technologies and auxiliary vessels make up a unique production and transportation system, providing safe and reliable shipment of up to 6 million tons of crude oil to the world market with year-round navigation in severe conditions of the Russian Arctic. The tankers can travel without icebreaker assistance in ice up to 1.2 m thick in winter.

Russian oil and gas operators, shipbuilding and shipping companies, and financial organizations have accumulated invaluable experience in implementing the first Russian oil production project on the Arctic continental shelf; this experience will certainly be in high demand for further development of natural resources in the Arctic.

3. Arctic Gate: experience in implementing the project

The Arctic Gate project is dedicated to developing Novoportovskoye, an oil and gas condensate field that is one of the largest fields on the Yamal Peninsula. Recoverable reserves are classified as C1+C2 and amount to more than 250 million tons of oil and condensate, as well as more than 320 billion cubic meters of natural gas.

The project started in 2016 with development of the northern part of the Novoportovskoye license block. Oil from the field is transported to the coast (through a transfer terminal at Cape Kamenny) via a 105 km high-pressure pipeline. The pipeline consists of two branches that can transport at least 5.5 million tons of oil per year.

The Arctic Gate Project is located in Arctic latitudes, 740 km from the main pipeline infrastructure, so transporting oil by sea seems to be an effective and cost-saving solution. The Novoportovskoye field produced 5.9 million tons in 2017 and 7.2 tons in 2018. The average daily production of the Arctic Gate reached 19,600 tons of oil in 2018. Peak oil production is forecasted in 2020, projected to more than 8 million tons. The Novy Port crude, produced at the Novoportovskoye field, is exported to nine countries via the expanding Northern Sea Route.

A fleet of six Arc7 shuttle tankers is used to maintain year-round operation of the Arctic Gate Project (see Table 5).

Table 5. Tanker fleet of Arctic Gate project

| Name              | Deadweight | Shipyard                      | Commissioned   | Ice class | Type | Flag  |
|-------------------|------------|-------------------------------|----------------|-----------|------|-------|
| Shturman Albanov  | 41,455 t   | Samsung Heavy Industries, Busan, Korea | August 16, 2008 | Arc7      | MR   | Russia |
| (lead ship)       |            |                               |                |           |      |       |
| Shturman Malygin  | 41,540 t   | Samsung Heavy Industries, Busan, Korea | October 7, 2016 | Arc7      | MR   | Russia |
| Shturman Ovtsyn   | 41,500 t   | Samsung Heavy Industries, Busan, Korea | December 8, 2016 | Arc7      | MR   | Russia |
| Shturman Skuratov | 41,400 t   | Samsung Heavy Industries, Geoje, Korea | February 16, 2017 | Arc7      | MR   | Russia |
| Shturman Shcherbinin | 41,420 t | Samsung Heavy Industries, Busan, Korea | March 19, 2017  | Arc7      | MR   | Russia |
| Shturman Koshelev | 41,460 t   | Samsung Heavy Industries, Busan, Korea | June 2017      | Arc7      | MR   | Russia |
The vessels also operate with zero discharge. With the draft up to 9.5 m, the ships can freely maneuver in shallow waters of the Gulf of Ob. Arc7 class vessels can travel through ice up to 1.8 m thick running astern and up to 1.4 m thick running ahead without icebreaker assistance. The vessels are fitted with a bow-loading device compatible with the terminal. Two additional icebreaking vessels were also added to the tanker fleet of the Novy Port Project (see Table 6).

| Name             | Deadweight | Shipyard         | Speed  | Ice speed     | Flag      |
|------------------|------------|------------------|--------|---------------|-----------|
| Alexander Sannikov| 3,000 t    | Vyborg Shipyard  | 16 knots | 2 knots in 1.5 m | Russia    |
| Andrey Vilkitsky | 3,000 t    | Vyborg Shipyard  | 16 knots | 2 knots in 1.5 m | Russia    |

Icebreakers are intended for auxiliary purposes, including:
- escorting tankers of about 40,000 tons deadweight through ice to the offshore export terminal for mooring and loading and between the port of Sabetta and Cape Kamenny in the Gulf of Ob;
- ensuring that the tankers moor and offload safely;
- protecting the terminal against the impact from moving ice fields;
- rescue operations around the export terminal and providing assistance to vessels in ice conditions and in open water with sea waves up to 7 on the Beaufort scale;
- search and rescue of people in open water with waves up to 5 on the Beaufort scale and in ice conditions;
- delivering and transporting small shipments of deck cargo and maintenance personnel to the export terminal;
- extinguishing fires at offshore and onshore facilities accessible for approach from the sea;
- participating in oil spill response operations, both in open water and in ice conditions, transporting equipment and collecting water and oil products resulting from the spill.

The Arctic Gate terminal is strategically important both for development of the Northern Sea Route and for development of deposits in the Yamal Peninsula.

4. Conclusions and discussion

The experience considered indicates that if the ice conditions are relatively favorable (ice thickness up to 1.2 m), ice tankers of Arc6 and Arc7 classes can be used with virtually no icebreaker assistance. The tankers are equipped with a double hull and an Azipod-type electric podded azimuth thruster (allowing to rotate the propellers 360° relative to the hull), giving them excellent icebreaking capability. The double hull and the segregated ballast system of the tankers meet all the requirements imposed by the MARPOL Convention and by the Rules of the Russian Maritime Register of Shipping.

These transportation schemes were not commonly accepted even 10-15 years ago. According to research carried out by American experts, pipelines were estimated to be cheaper than oil export terminals built in shallow waters of the Arctic Ocean. This experience was approximated for Russia as schemes describing the technologies and logistics for oil export from Arctic fields (see, for example, [23]). Other arguments against involving the tanker fleet in schemes for transportation of Arctic oil were that it is of utmost importance to preserve the environmental status and that eliminating possible oil spills in sea waters is difficult in severe ice conditions.

Innovative technologies have made it possible to solve some of the problems; effort is also underway to tighten environmental control for the development of hydrocarbon deposits in the Arctic.

Substantial positive external effect should be taken into account in assessing the effectiveness of developing hydrocarbon deposits in the Arctic. As the above-described logistics schemes were implemented, high-tech Arc6-class vessels were constructed at Russian shipyards for offshore oil transportation in the Arctic, allowing to gain unique experience and laying the groundwork for further progress in Russian shipbuilding.
As new technologies emerging, deposits become depleted, prices for hydrocarbons change and global demand for energy resources increases, the search for new efficient schemes for transporting hydrocarbons from the Arctic remains a crucial issue [24].

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