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## TOWARDS THE REGIONAL PARTICULARITIES OF OFFSHORE OIL PRODUCTION AND SUBSEA TRANSPORTATION IN THE ARCTIC

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Access to global market is a key issue to ensure effective oil production, therefore, transportation is a remarkable component of the petroleum industry. Depending on field location and size, different modes of transportation may be used, with some being more suitable than the others. However, it seems that all forms of petroleum transportation will potentially play a role in the energy future of the Arctic.

Various options imply different operating environments and should be designed to secure reliable transportation under the Arctic conditions, as well as to ensure proper maintenance and monitoring of the equipment. When selecting a transportation option, safety, reliability, and cost should be taken into account to find an adequate solution.

In shallow water, conventional pipeline equipment can be used in the winter season to trench through the ice and bury the line. The case in point is the BP Exploration’s Northstar pipeline, which is an example of shallow water construction technique. In deeper waters, where ice gouging is not an issue to be considered, the lines can be designed and installed on the seafloor as is done for deeper water non-Arctic offshore pipelines. Installation would take place in summer open water season. It can take several seasons to install longer pipelines, and the mobilization/demobilization or overwintering of equipment would significantly increase the cost of offshore Arctic pipelines compared to non-Arctic applications.

Additionally, the existing global fleet of vessels and barges for offshore pipeline construction are not designed for Arctic conditions. Therefore, for offshore Arctic pipelines, ice-strengthened and upgraded equipment and vessels would be required to operate in the Chukchi and Beaufort Seas.

The life cycle of an offshore Arctic pipeline is similar to onshore, but the design and installation methods also must consider strudel scour, ice gouging, thaw settlement of permafrost, and upheaval buckling. These are the issues to be considered when offshore pipelines are buried. For instance, all of these issues have been taken into account when designing the pipelines Northstar and Oooguruk.

Ice gouging or scour is the most significant and most unpredictable environmental loading condition influencing arctic offshore pipeline design. The accepted solution to protect a subsea pipeline from this threat is to bury the line deeper than the maximum gouge depth expected over the design life of the pipeline. For pipeline systems, research into safe burial depth finds that soil below the scouring keel of the ice will deform, imposing high shear and bending loads on the buried line. More recently, research to reduce overall uncertainty associated with ice keel interactions with the seabed has been directed towards understanding ice keel gouging and integrating these data with historical seabed mapping data. Upheaval buckling potential, caused by differences between installation and operating temperatures, also can be influenced by careful selection of burial depth. Subsea systems must also be protected from the extremely high ice loads. Off the east coast of Canada, glory holes are excavated on the sea floor so drill centers and subsea equipment can sit below the seabed elevation, thereby offering protection from ice impact.

Permafrost thaw settlement and frost heave can impose long-term displacement-controlled bending on a subsea pipeline, and can contribute to a pipeline being strained outside the elastic limit into the plastic region of the material deformation; thus the need for strain-based design. These unique arctic loads can be present along a buried subsea pipeline route, especially near shore where shallow permafrost is likely to exist; and also onshore, where a buried line may traverse continuous or discontinuous permafrost.

Strudel scour can occur in early spring if seasonal river outflows precede the thawing of winter sea ice, with the result that water flows on top of the sea ice. If river water atop sea ice flows into depressions or cracks in the ice, it can penetrate the ice cover and initiate a powerful downward jet of water that can erode the sea floor. Erosion by this strudel scouring may expose long sections of a buried subsea pipeline.

Burial depths sufficient to guard against ice gouging might be adequate protection from strudel scour, and some designers consider the probability of strudel scour at the location of a subsea pipeline to be quite low. However, if heat escapes during operation of a subsea flowline in shallow water and warms the sea water above the line, that fugitive heat dissipation might prevent the ice above the line from becoming as thick during winter. In the spring, such artificially thin ice could be susceptible to early cracking and, in turn, strudel scour.

Pipelines, flowlines, and subsea systems are to operate within an acceptable thermal regime and provide the necessary containment and monitoring to ensure acceptable levels of risk. For example, visual monitoring is not always a reliable way to detect strudel scours or pipeline exposure locations, and the pipeline itself must not exceed certain allowable strains. In this case, thermal monitoring system can detect operational thermal changes as well as thermal changes from pipe exposed to cooler seawater, possibly signaling an issue with upheaval buckling or strudel scour. Anyway, analysis and design of the flowline system should consider all the design and operation aspects described above in an integrated manner.

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## FLOATING AND GRAVITY-BASED DRILLING PLATFORMS

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In offshore drilling (i.e. exploration and production of oil and gas in the oil fields, so-called offshore zones) mainly offshore rigs are used. They are conventionally divided into two classes – floating and stationary (fixed). As is known, the cost of offshore oil and gas field development accounts for over 50% of all investments. Suffice to say that the value of certain oil and gas production platforms reaches 1-2 billion dollars. For example, deep gravitational field Troll platform operating now in the North Sea is estimated at over 1 billion dollars. [2] When using the mobile jack-up drilling rigs or semi-submersible platforms, wellhead equipment after drilling can be located on the bottom of the sea. In such cases, a number of companies in the US, UK, France developed a set of equipment with remote control. However, with increase in the depth of development and in the sea water areas with moving ice fields the method of bottom wellhead location is preferred. [3] Gravitational platforms differ from metal pilings ones both in construction, materials, and manufacturing, transportation, and installation in sea. The total resistance of gravity platforms under the influence of external loads from waves and wind is provided by their own weight and the ballast weight, so there is no need to mount the piles to the seabed. Gravitational platform are used in the seawater areas where strength of the sea ground provides strong resistance structures. [2] The analog of this technology is the platform "Prirazlomnaja". The Prirazlomnoe field (Khanty) is located on the shelf of the Pechora Sea, 60 km from the coast (stl. Varandey). The sea depth in the area of deposit is 19-20m. Design characteristics:

- cumulative production of oil - 75 million tons;
- profitable development period - 22 years;
- the maximum production level - 6.6 million tons / year. [1]

Prirazlomnoe field operated since 1986. In 2011, at the Prirazlomnoye oil field marine ice-resistant stationary platform of gravity type was established. It was made in Russia. "Gazprom" began to work at the Prirazlomnoye field in December 2013. The cost of the project amounted to about 100 billion rubles, including the 60 billion cost of the oil platform. The largest shipping company Sovcomflot built two Russian ice tankers with deadweight of 70 thousand. tons, which will run between Prirazlomnoye and floating terminal "Belokamenka" on the roads of the Kola Bay. [5] “The project payback begins with the yield of 16.5%”, - said the deputy of general director of "Gazprom Neft Shelf" Nikita Limonov. Managers of the company specified that to start-up such projects, their yield should be about 20%. "Gazprom Neft Shelf" are going to achieve the third complexity category of the project (currently, the Prirazlomnoe field is qualified as a project of the second complexity category of the three) to reach the payback and the rate of return of at least 17.5%. [4] The advantages of this development method:

- the construction experience;