Arctic Crude Oil Transportation System Development
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ABSTRACT
The intention to export crude oil from an offshore loading terminal at Varandey to a transshipment (FSO) location in or near Northern Russia / Norway has required putting together a transportation system which utilizes a somewhat unconventional concept of shipping operations in the Russian Arctic; an innovative approach to the tanker design; and the most advanced technology available to date. The paper describes the design basis and approach used to develop the tanker concept as a key element of the Varandey crude oil transportation system. These include the environmental and performance requirements as well as icebreaking operations concept and assumptions.

KEY WORDS: Arctic; shuttle; tanker; ice; performance; design.

INTRODUCTION
The transportation system development for the Varandey project required the performance of several steps in order to estimate:
- Direct export to market versus transshipment
- Available operational options
Each operational scenario included the tanker concept and optimization of the tanker performance requirements based on
- Tanker design
- Fleet size
- FSO size
Some steps included laboratory and computer modeling with many iterations. The selected transportation system was then validated using fleet transportation modeling and economic assessment. This paper focuses mainly on the technical aspects of the key elements of those efforts specific to the arctic shuttle tanker.

VARANDEY TRANSPORTATION SYSTEM OVERVIEW
The general concept of the transportation system was driven by Fixed Offshore Ice Resistant Offloading Terminal (FOIROT) design at Varandey, the shallow water location as well as environmental challenges at the FOIROT and the transit route.

The tanker fleet must be capable of transporting a peak volume of approximately 10 Million Metric Tons Per Annum (MTPA) of crude oil from Varandey to a transshipment location in the Northern Western territories of Russia or Northern Norway. The route from Varandey to the transshipment point is partially ice infested during 35-45% of the year. The shuttle-tankers should be designed with ice performance and other features sufficient for the year-round independent operation in the area. It is envisioned that chartered conventional crude carriers will pick up cargo from the FSO, and will carry it to market. A schematic of the transportation system is presented as Fig. 1, below.

OPERATIONAL CONDITIONS AND CHALLENGES.
Terminal location can be characterized as follows:
- 17 m minimum water depth with little slope of the sea bottom, which does not allow safe maneuvering outside of 1000 m radius off the FOIROT.
- Dynamic area of first year pack ice. The level ice thickness at the peak season of average severity usually exceeds 1.0 m but may grow in the extreme years up to 1.5 m.
- The ridge thickness may reach 9 – 10 m at a high frequency of 8-9 ridge/km
- Ice drift in various directions with the speeds up to 1.5 knots
- Air temperature as low as -40 °C with extreme values recorded as -45 °C.
- Wave height may exceed 4.2 m
- Current speed may exceed 2 knots.
- The distance of transit through the ice in the peak season of the severe year may exceed 250 nautical miles.

APPROACH
The Varandey project is being run by the LUKOIL-ConocoPhillips joint venture, NARYANMARNEFTEGAS (NMNG). The restricted project schedule and challenges previously listed required NMNG, as the charterer, to form a group of experts from all three companies to develop the ship concept, operational requirements, and preliminary design and conduct parallel work efforts in the selection of the ship builder and ship owner/operator. The tanker capacity was driven mainly...