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Sakhalin–1: Technology Development for Frontier Arctic Projects

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Abstract

As the oil and gas industry pushes into frontier Arctic areas, new technologies and design criteria will be required to ensure safety and cost effectiveness of increasingly challenging developments. Sakhalin-1 provides a good example of a development in a frontier sub-arctic area where location-specific design criteria had to be developed and innovative technology solutions were required to deal with demanding environmental conditions including sea ice, large breaking waves and earthquakes. This paper provides an overview of the extensive work undertaken to develop project specific design criteria, including development of a Probabilistic Seismic Hazard Analysis, basin testing of breaking-wave slamming forces, multi-season on-ice measurements, remote sensing of sea ice floes and keels, and measurements of sea-bottom ice gouge depth distributions. Some of the unique technology solutions employed included retro-fit of a 20+ year old Arctic offshore platform with wave deflectors, escape, evacuation and rescue (EER) system for ice environment, conical-shaped tanker mooring platform for offloading in ice, and special burial depth criteria for offshore pipelines in areas of ice gouge and erosive seabed sediments. Other advanced technologies employed to deal with the seismicity included plastic strain-based criteria for buried pipelines and use of a tuned mass damper on the drilling derrick to dampen earthquake vibrations. The extensive preparation and innovative engineering were key to managing cost and schedule for facilities facing uniquely harsh environmental challenges.

Introduction

First production from the Exxon Neftegas Limited (ENL) Sakhalin-1 Phase-1 development of Chayvo Field began in October 2005 marking the culmination of nearly 10 years of design criteria and technology development.¹ The Sakhalin Island east coast area presents significant environmental design challenges associated with sub-arctic sea ice, waves, and earthquakes. The development concept consists of an offshore drilling platform, an onshore drilling and treating facility at Chayvo, an oil export pipeline that runs east-west across the island and Tatar Strait to mainland Russia, and a storage and tanker export terminal at DeKastri. The oil is exported by ice-strengthened tankers south through the Tatar Strait, which is partially covered by up to medium first year ice (70-120 cm) in the winter. The offshore drilling platform, Orlan, is located about 10km offshore in about 15 meters water depth. The platform is annually exposed to about 4000 km of drifting first year pack ice up to 1.5 meter (level ice) thickness, which originates in the Sea of Okhotsk north of the island and drifts south along the eastern coast. The controlling ice load features are pressure ridges, with keels extending to depths over 30 meters (2,000-yr design value). The design ice load on the 80 meter-wide, vertical-sided structure is about 385 MN. Design wave loads are generated by late summer and fall storms that can produce breaking waves at the platform location. Global wave loads are on the order of the ice loads and wave run-up and locally high slamming pressures represent design challenges. Sakhalin Island seismicity is moderate to high, with the active Piltun fault system running N-S on the island as close as 10 km from onshore facilities and 20 km from the offshore platform. The 1995 Neftegorsk earthquake, which registered moment magnitude (M_w) 7.1, had its epicenter located approximately 50 km from the Sakhalin-1 facilities. All facilities must be designed for earthquakes, and the export pipeline, which crosses multiple faults, must be able to withstand several meters of fault displacement.

¹ Exxon Neftegas Limited is an ExxonMobil affiliate. Exxon Mobil Corporation has numerous affiliates, many with names that include ExxonMobil and Exxon. For convenience and simplicity in this presentation, those terms and terms like corporation, company, our, we and its are sometimes used as abbreviated references to specific affiliates or affiliate groups. Abbreviated references describing global or regional operational organizations and global or regional business lines are also sometimes used for convenience and simplicity