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The Trans Alaska Pipeline System (TAPS) and Comparisons with the Sakhalin II Pipeline Transportation System

A Briefing Paper By Sakhalin Energy Investment Co. Ltd.

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1 INTRODUCTION

The Trans Alaska Pipeline System and the Sakhalin-II project pipelines are two major pipeline systems that traverse largely uninhabited environments in remote areas. It is generally believed that both pipeline systems have significant synergies in terms of design to mitigate the effect of severe environmental conditions. The purpose of this paper is to highlight the major similarities and differences in the pipeline systems and environmental conditions and to summarise the design approaches taken by Sakhalin Energy in consideration of the specific conditions occurring on Sakhalin Island.

This paper shows that while there are indeed similarities between the two systems, the differences are significant and that a direct comparison of design approaches is not entirely appropriate. This is particularly the case when comparing the use of above ground and below ground construction techniques. These issues are discussed in further detail below.

The Trans Alaska Pipeline System (TAPS) was designed and constructed between 1970 and 1977, and at the time was the largest single investment ever to be undertaken by private enterprise. The TAPS system runs between Prudhoe Bay in Northern Alaska to a terminal situated at the head of Prince William Sound near Anchorage - a total distance of around 1280 km (800 miles). The system transport capacity is over 2 million barrels of oil per day through a single 48 inch (1200 mm) diameter pipeline and crosses permafrost, rivers and areas of high seismic activity. The pipeline was constructed in a very remote area that had little or no infrastructure for the majority of the route and was the first time that Western oil operators had constructed anything of this scale in an Arctic environment. It is worth noting, however, that Russian companies have been undertaking large-scale pipeline construction in similar Arctic environments since the 1950's.

The Sakhalin II Pipeline System is the first large scale Western Oil and Gas investment in the Russian Far East. The pipeline will be constructed on the Island of Sakhalin, which while being south of the Arctic Circle, has similar conditions to Alaska, notably remote areas, sensitive environment and areas of high seismic activity.

Information used in this paper was obtained from publicly available sources including published papers and the internet.

2 BASIC DESIGN DATA

2.1 TAPS

The TAPS pipeline system is 1280 km long and is built using pipe with an outside diameter of 48 inch (1200 mm). It is a single pipeline with 11 intermediate pumping stations and 3 pig launching / receiving stations. The design pressure is 70 bar and it has a capacity of over 2 million barrels of crude oil per day.

TAPS has 177 block valves installed, of which 62 are remotely controlled.

Of the 1280 km of pipeline route length, 672 km was constructed above ground in permafrost areas. Around 6.5 km was constructed below ground in permafrost using a refrigeration system in the trench. Apart from 3 fault crossings, the remainder, in the non-permafrost areas (around 600 km) were constructed using conventional below-ground (trenched) techniques.

The above ground pipeline was constructed on specially designed supports. The supports are generally located every 60 feet (18 metres) along the above ground pipeline, and allow some movement of the pipeline to mitigate the forces caused by expansion and contraction of the pipeline. They also serve to insulate the permafrost from the heat generated by the pipeline.

TAPS crosses over 900 rivers and streams. Of the water crossings 70 were classified during the design as being “significant”. The classification was based on hydrological studies and designs that took account of river depth and width, water flow, erosion and flooding potential. Each of the “significant” crossings required individual designs rather than standard designs that were used elsewhere. Apart from 13 bridge crossings, where the pipeline was supported by differing types of bridge construction, all “significant” crossings were open trenched.

Many of the smaller crossings in the above ground area were spanned using the standard above ground pipeline supports, particularly where the crossing width could be accommodated in the normal spacing of the supports. The vast majority of all crossings however were crossed using the trench technique.

In order to maximise below ground construction of the pipeline (the supports cost $9000 each) the pipeline was routed were possible in areas of having less than 6% silt or finer material content. River and floodplain areas are generally comprised of granular material and thus were extensively utilised for buried pipeline routing. This leads to the pipeline running parallel to major river flood plains for significant distances. In order to minimise erosion damage to the pipeline from migration of the river channel, artificial training structures were installed (spurs) that were designed to avoid the main river current eroding the banks at curves.

TAPS was mostly constructed during the winter season to minimise damage to the tundra. Most of the rivers were crossed in the winter when the streams were completely frozen. None of the streams was crossed by directional under-drilling.

TAPS crosses 3 active seismic faults (Denali, McGinnis Glacier and Donnelly Dome). The faults are crossed using specifically designed slider bars so the pipeline can move with seismic activity. The TAPS Seismic design considers specific earthquake forces in zones along the pipeline route which the pipeline and slider bars are designed to withstand. TAPS also has a seismic monitoring system based on accelerometers that predicts damage to the pipeline system in the event of seismic activity, and a leak detection system that can identify leaks less than 1% of the pipeline flow.

2.2 Sakhalin-II Pipelines

The Sakhalin-II pipeline system comprises of two distinct sections, each with an oil and gas pipeline to be laid parallel to each other. The most Northerly section (from Piltun landfall to the Onshore Processing Facility (OPF)) is 171 km long. The parallel oil and gas pipelines both have an outside diameter of 20 inch (500 mm). Two pig launching / receiving stations will be installed on each pipeline. The design pressure is 100 bar and the pipelines will transport around 140,000 barrels of oil and 3.8 million cubic metres of gas per day.

The Southern section, which comprises of the main oil and gas export trunk pipelines (from OPF to the Liquefied Natural Gas (LNG) plant / Oil Export Terminal (OET)) is 636 km long. The oil pipeline has an outside diameter of 24 inch (600 mm) and the gas pipeline has an outside diameter of 48 inch (1200 mm). Three pig launching / receiving stations will be installed on each pipeline. The design pressure is 100 bar and the pipelines will transport around 195,000 barrels of oil and 50 million cubic metres of gas per day.

The Sakhalin-II system has 150 block valves (107 oil and 43 gas). All the block valves will be remotely controlled and monitored using a state of the art Supervisory Control and Data Acquisition (SCADA) system.

All of the 807 km of pipeline route length will be constructed using conventional below-ground (trenched) techniques. There are no areas of permafrost on Sakhalin Island that would require above ground construction techniques to be used. The use of trenched pipelines in this environment is in accordance with Russian Design codes and normal (western) industry techniques for areas where permafrost is not present.

The Sakhalin-II pipeline system crosses over 1100 rivers and streams. Of the rivers and streams to be crossed, 63 have been classified as being sensitive Salmon spawning rivers requiring specific designs and construction methods. This classification was based on data and surveys of salmon (and other fish) upstream and down stream of the pipeline crossing. 8 crossings, all at sensitive rivers, will be constructed using horizontal directional drilling (HDD) techniques. The remainder will be open trenched.

The Sakhalin-II pipeline system will be constructed year round. No work, however, will be undertaken during the spring thaw. All sensitive rivers crossed using open trenching will be crossed during the winter, when the river and surrounding ground has frozen. In addition the construction plan is such that as many of the remaining, non-sensitive rivers as possible will be crossed during the winter construction seasons.

The Sakhalin-II pipeline system crosses 24 active seismic faults. All of crossings of active faults are designed to be crossed using below ground techniques. The design envisages the installation of a snaking pipeline within specially designed trenches and protected using foam blocks placed around the pipeline. The maximum strain of the pipeline at the fault crossings has been analysed against the seismic design criteria. Two levels of seismic activity have been designed against (Safe Level Event or Earthquake (SLE) and Design Level Event or Earthquake (DLE)) which are based on the period of earthquake return derived from microzoning studies at specific locations. The Design Level Event is based on an earthquake return period of 1000 years. The corresponding Design Contingency Earthquake (DCE) used by TAPS is a “rare, intense earthquake with an estimated return period of several 100 years or more”.

The Sakhalin-II pipeline will have a seismic activity monitoring system installed which envisages the installation of strain monitoring devices to directly identify potential damage to the pipeline due to seismic activity. The details of the system are being investigated and will be studied further during Detailed Design. The Sakhalin II pipeline will have a leak detection system that can identify leaks at less than 1% of the pipeline flow.

2.3 Data Comparison

As a single pipeline, the TAPS is longer than the Sakhalin-II system by some 480 km. It can transport significantly more oil (about 2 million barrels vs. 195,000 barrels) and is elevated above ground for around 50% of its length.

TAPS uses similar construction techniques as the Sakhalin-II system in non-permafrost areas where both pipelines are trenched and buried. The construction of the Sakhalin-II pipelines will use horizontal directional under-drilling techniques (HDD) for sensitive river crossings. There is no permafrost on Sakhalin Island.

The magnitude of river and stream crossings on both systems is similar, as is the number of non-trenched crossings and specifically designed crossings for sensitive rivers.

The Sakhalin-II system has considerably more block valves at shorter distances between the valves on the oil pipelines and all valves are remotely controlled.

There are significant differences between the seismic fault crossing designs and design criteria used, however the maximum strength earthquake that the Sakhalin-II pipeline is designed to withstand is similar to the TAPS criteria.

3 RIVER CROSSING DESIGN ISSUES

The Alyeska (TAPS operator) Pipeline Design for River Crossings is understood to concentrate on factors which could cause the pipeline to become exposed - such as riverbed scour and degradation, flood plain erosion and lateral channel migration. The designs specifically consider terrain features, soil conditions, existing structures, environmental concerns, technical feasibility and economics. In order to achieve the objectives, TAPS utilised buried crossings wherever possible.

The Sakhalin-II Project Basis of Design mandates the following criteria for river and stream crossing designs:

“Special construction techniques will be used to cross salmon sensitive streams and other water courses. Evaluation of streams shall include consideration of size of salmon run at the crossing, location of spawning grounds, and the surveyed width and depth of the crossing.”

Sakhalin Energy has concentrated the choice of crossing technique on the potential impact to fish, and then ensuring that the chosen crossing technique meets erosion and pipeline protection requirements.

During the Front End Engineering Design for the Sakhalin II system, various construction methods were considered for river crossings. These included open trenching, elevated crossings and HDD. Whilst some of the sections of the pipelines could cross the streams or marshy areas using elevated crossings, Sakhalin Energy has taken the position that due to security, public safety, environmental, and visual impact reasons overhead construction methods will not be used. This is important to ensure that there is no opportunity for third parties to cause damage to the pipelines, particularly the oil pipeline which has the greatest potential environmental impact in the event of damage. In terms of environmental impact during construction, elevated crossings have generally speaking a lesser impact than open trenching and more impact than HDD. With regard to the rivers on Sakhalin, however, due to extensive flood plains, possibility of liquefaction and potential scouring, this type of crossing would require significant foundation construction, with the associated environmental disturbance, to support the pipelines. This type of crossing also carries additional maintenance requirements over and above the routine maintenance for buried pipelines. Particularly with the oil pipeline, the exposure to the extreme air temperatures would lead to the requirement for insulation which in its self adds to the maintenance requirements as this can lead to greater difficulties assuring corrosion protection and additional environmental exposure. Compared to open trenching, the construction for elevated crossings requires additional time and hence a longer period of impact.

The preference against overhead crossings has also been expressed by Russian Federal Regulators (TSUREN) as a condition for approval of the crossing methodology. This was based on the experiences with the Kamchatka Gas Pipeline Project where the use of elevated crossings caused significant environmental impact during construction.

In view of the above, the Sakhalin-II Project have discounted the use of overhead crossings for rivers with the design of the pipeline system.

The Sakhalin II project will install HDD crossings at 8 locations, the remainder will be open trenched.

TAPS did not use HDD as the technology had not sufficiently developed in the early 1970’s to allow it to be used in confidence. Recent experience in the U.S. Arctic (ARCO Colville River Crossing) has only now proved the technology in Permafrost conditions. This project was executed in 1997 / 1998 and took two seasons rather than the single season planned. The analysis of the crossing type (bridge, trench, HDD) used similar methodology as used by Sakhalin Energy. HDD was chosen as being least expensive (at the time, based on a single season construction). TAP also crosses many areas with boulder entrained soils which would still preclude the use of HDD.

4 GENERAL TAPS INFORMATION

Alyeska officials have been quoted as estimating environmental protection costs as being $2.8 billion – it is assumed (although not specifically stated) that this includes the costs of the above ground supports and at least some of the inflation costs due to the Environmental Impact Assessment delays.

TAPS has experienced several serious leaks. Two occurred soon after commissioning, one at a pump station that released 16,000 gallons (operator error) and one following an act of sabotage (bomb) that released 600,000 gallons.

Recently a gunman shot a hole in the pipeline. An article written in 1977 discussed some of the concerns around the TAPS system including the possibility of a shot being fired at the pipeline and stated the following: “The pipe itself seems designed to withstand almost everything but an armour-piercing bullet at a one-foot range. But the gunman would be boiled in oil.” Following the recent incident, the hole and subsequent leak from the pipeline was detected rapidly by Alyeska personnel and plugged. The gunman was rapidly located and arrested. There are no reports of the gunman having sustained injuries from hot oil.

5 LEGACY ISSUES

Problems have been encountered with the opening up of access to previously inaccessible areas. A commercial website advertising fishing activities in Alaska states:

“The Brooks Range and Alaska's North Slope were, until some years ago, accessible only by aircraft and other means of wilderness travel. Completion of the trans-Alaska oil pipeline and the Dalton Highway made it possible to travel north of the Arctic Circle and to reach some of the most remote areas in North America with relative ease and a minimum of expense.

Streams along the Dalton Highway have been fished regularly by anglers for more than 15 years since the construction phase of the trans-Alaska pipeline was completed in 1978. Personnel stationed at State of Alaska road maintenance camps, pipeline pump stations, and in the oil fields as well as long-haul truck drivers and the general public have participated in the fishery. Fishing quality, as judged by average size and catch rate, in many of the streams and lakes accessible from the highway has declined since the pipeline corridor was opened for sport fishing. Fish and wild game animals have been used for generations by subsistence hunters and fishermen residing nearby. Their demands were light and use was spread out over a vast area without roads. Now roads tend to concentrate effort to a few locations."

Sakhalin Energy is concerned that the construction of the Sakhalin-II pipelines allows access to currently inaccessible rivers and to the pipeline ROW. In order to mitigate this as far as possible, all access during construction activities will be via currently existing roads and tracks, the majority being currently used by the lumber extraction industry. Post Construction, it is the intention to minimise the use of permanent access roads to the pipeline ROW and only install or upgrade roads to block valves on the gas pipelines. Where permitted by the Regulatory Authorities, it is the intention to install helipads where the installation of a road would entail the construction of bridges and hence access to rivers. Access to oil block valves not co-located with gas valves, will be managed by using existing tracks and specialised all terrain vehicles. This philosophy is based on the need for access to be mainly to undertake routine light maintenance activities.

Where permitted by the owners of permanent tracks used during construction, the access will be removed once construction is completed. This removal will include restoration and re vegetation. Where necessary, and until the re vegetation is completed, Sakhalin Energy will install barriers to prevent traffic access.

Alyeska has recently been granted an extension to their operating permit by the Alaska State Government (for another 30 years). The Federal Government is expected to also agree with the extension early in 2003.

Table 1

Summary of Main TAP and Sakhalin Pipeline Characteristics

	TAPS	**Sakhalin II**
Pipeline Diameter	48 inch (1200 mm)	2 x 20 inch (500 mm) - oil and gas. 1 x 24 inch (600 mm) - oil). 1 x 48 inch (1200 mm) - gas
Product	Oil	Oil and Gas
Design Pressure	70 bar	100 bar
Length	Above-ground - 420 miles (673 km) Conventional below-ground - 376 miles (601.6 km) Refrigerated below-ground - 4 miles (6.4 km) Total – 800 miles (1280 km)	636 km (397.5 miles) - main export 171 km (106.88 miles) - North area 807 km (504.38 miles) - Total
Buoyancy Control	Pipe coating at river crossings. Saddles within flood plains.	All crossings at flood plains and wetlands with saddles.
River Crossings	Over 900 rivers and streams 70 Significant Streams	1103 rivers, streams, canals and lakes 63 sensitive crossings Dry courses – 161 Brooks – 486 Ponds – 8 Irrigation Canals – 251 Springs – 3 Small water courses – 86 “Salmon” rivers - 108
Pipe Bridges	Orthotropic box girder - 1 Plate girder - 9 Suspension - 2 Tied arch - 1	None

	Total – 13	
HDD	None	8 Rivers: Buyuklinka Firsovka Val Tym 1st crossing Naiba Tym 2nd crossing Nabil Vazi
Trenched Crossings	Remainder	Remainder
Burial depths	Ditch from 8 ft. (2.3 metres) to 16 ft. (4.8 metres) deep in most locations, but up to 49 ft. (14.7 metres) deep at one location.	Minimum 1 metre (3.28 ft) cover, up to 10 metres (32.8 ft) at river crossings and flood plains.
Access roads	120 ft. (36 metres) to 7.5 miles (12 km) long; 28 ft. (8.4 metres)wide, minimum 3 ft. (0.9 metres) gravel base Total 225, linking state roads with pipeline, pump stations and airfields	3.5 metres (11.48 ft) wide (Class 5 B) Up to 350 km (218.75 miles) of roads required if all Block Valve Stations to be fully accessible by vehicle.
Pig launching/receiving facilities	3 (PS 1, 4, and Marine Terminal).	5 (Piltun landfall, OPF, Booster Station 2 (future), OET and LNG)
Pump stations, operating	11 (10 pump stations, 1 relief station)	Oil: 1 at OPF and 1 at OET. Gas: 1 at OPF and 1 planned at mid point between OPF and LNG plant (Booster Station 2)
Pipeline Valves, types and number	Check - 81 Gate - 71 Block - 24 Ball - 1 Total - 177 Total remote control - 62	Oil – 107 Gas – 43 (All ball valves) Total remote control – 150

Seismic Crossings	Above-ground sections of the pipeline are built in a zig zag configuration to allow for expansion or contraction of the pipe because of temperature changes. The design also allows for pipeline movement caused by an earthquake	Buried using special trench design and backfill. Also with insulated foam blocks to absorb movement. Strain based design methodology.
Earthquake Design	Earthquake magnitude pipeline system designed to withstand 8.5 Richter Scale (maximum). Range from 5.5 to 8.5, depending on area.	Safe Level Earthquake (SLE) – 200 year return Design Level Earthquake (DLE) –1000 year return
Faults crossed by pipeline	3 - Denali McGinnis Glacier Donnelly Dome	24
Earthquake Monitoring	Alyeska's Earthquake Monitoring System (EMS) consists of sensing and processing instruments at all pump stations south of Atigun Pass and at the Valdez Terminal. A central processing unit at the Operations Control Center (OCC) is linked to the Pipeline and Terminal operator consoles. The EMS is specifically designed to process strong ground motions, to interpolate or extrapolate estimates of earthquake accelerations between the sensing instruments and to prepare a	Under design, however will probably consist of strain monitoring spools inserted into pipeline at major fault crossings. Strain levels will be transmitted to central control room via SCADA.

	mile-by-mile report comparing the estimated accelerations along the pipeline with the pipeline seismic design criteria. The instrumentation at field locations consists of accelerometers mounted on concrete pads which measure strong ground motions in three directions (tri-axial) which are connected to a Digital Strong Motion Accelerograph (DSMA). The DSMA, generally located in the Pump Station control room, processes the signals from the accelerometers in real time and reports alarms and selected data to the central processor at the OCC.	
Leak detection	Leak alert systems, number -- 4 Leak alert systems, types- Pressure deviation, flow rate deviation, flow rate balance and line volume balance.	Under design, but will be statistical mass balance system to detect leaks less than 1% of flow rate.
Oil Spill Response Plan Equipment	Boom, containment - 46,700 ft. (14,010 metres) Boom, fire - 2,150 ft. (645 metres) Store capacity - 22,630 bbl.	As detailed in Oil Spill Response Plan

	Boats/Rafts - 35 Vacuum trucks - 12 Mutual Aid Agreements - provides additional equipment and resources for oil spill response. Personnel Pump station personnel trained in oil spill response Each pump station has 24-hour oil spill reconnaissance capabilities. Drills Field drills are conducted to evaluate preparedness to react to an oil spill. The drills permit evaluation of the training program, particularly oil spill skills such as reconnaissance, assessment and response.	
Communications	Primary: microwave Backup: satellite Components: backbone communication system, remote gate valve, ARCS - alternate route communication system Control systems are provided for supervisory control and telemetering, seismic monitoring, and remote gate valve status monitoring and control.	Primary: Fibre Optic Cable. Backup: Satellite Control systems are provided for supervisory control and telemetering, seismic monitoring, and remote gate valve status monitoring and control.
Testing, hydrostatic pressure	Maximum, equivalent to 96% of specified minimum yield strength.	Maximum, equivalent to 100% of specified minimum yield strength. Minimum 90% of

	Minimum, 125% of operating pressure or 750 psi, whichever was greater.	specified minimum yield strength.
Welding	Field girth welds, all welds 100% x-rayed	Field girth welds, all welds 100% x-rayed.
Lives lost	31	

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