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Sakhalin II: The First LNG Storage Tanks in Russia

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The authors describe how the planning, design and construction of the LNG storage tanks in the Sakhalin II project have taken into account the Russian approval process, the harsh weather conditions and other site characteristics.

On the remote island of Sakhalin, construction of the first LNG facility to be built in Russia is underway (see Figure 1). Sakhalin II, which has become known as the project of many firsts, is paving the way for additional Russian LNG projects that will follow.

Figure 1: The initiation of steel construction on the first LNG tank in Sakhalin

Contrary to the typical LNG story - where natural gas is stranded due to the absence of a pipeline network to transport it to market - Russia has an extensive pipeline grid that extends to every part of the country and into Europe. However, with more than 47.6 trillion m^3(st), Russia has the largest natural gas reserves in the world and is also the largest exporter of natural gas. Adding LNG export facilities to pipeline transportation provides Russia with more flexibility in its export options and opens up markets throughout Asia Pacific, Mexico, and the United States.

Because of the remote location, the harsh climate, the level of seismic activity and the absence of national codes for LNG structures, the construction of LNG facilities on Sakhalin presents a number of challenges. A look at one of these projects - the construction of two LNG storage tanks with a capacity of 100,000 m^3 each - provides an opportunity to examine how some of these challenges are being met.

The Sakhalin Tanks

Over the past decade, LNG storage tanks have been increasing in size to capture economies of scale. Today's LNG storage tank typically has 100,000 m^3 or more of capacity and is designed to facilitate a process that works with the laws of physics to keep the temperature inside the tank from warming. The process, called autorefrigeration, keeps the temperature of LNG constant through LNG vapor release.

Because LNG storage tanks have never before been built in Russia, codes that regulate the design and construction of these facilities did not exist. For this project to proceed smoothly, it was important to combine experience in the design and construction of LNG projects with experience in Russian construction, climate and, especially, business practices. Sakhalin Energy Investment Company Ltd., the owner of the Sakhalin II project, took the lead in developing the overall Project Specific Technical Specification for the LNG tanks, a document that provided the specifics for what kind of tanks would be built, what materials would be used, etc. They then took this document to the Russian Federal Government to obtain the necessary approvals. Once the Federal Government approved the document, it was the responsibility of the contractor awarded the job to develop the detailed design and technical specifications that provided the in-depth processes and procedures for how the tanks would be constructed. It was important in developing this detailed documentation to ensure that it conformed to the owner's requirements, the Project Specific Technical Specification approved by the Federal Authorities, and all applicable Russian National Standards. It was also necessary to obtain Federal Government approval of this detailed technical documentation, since it was the first developed for LNG tanks in Russia.

Developing the technical documentation for this work can be time intensive and the approval process can be long if not handled appropriately. CB&I, an engineering, procurement and construction (EPC) company that had previously conducted EPC work in Russia, also has extensive experience working with LNG facilities. The company, along with the project's general contractor - the consortium of Chiyoda, Toyo Engineering, and NIPIgaspererabotka - was responsible for the design and construction of the LNG tanks.

The first step was to develop technical documentation for LNG tanks that met all the criteria requested by the owner as well as Russian requirements. Next, Russian Design Institutes were asked to review it for specific design criteria to ensure that it complied with Russian regulations and standards. It incorporated worldwide knowledge and best practices for LNG tanks while also complying with all the standards for steel and concrete structures that have evolved within the Russian construction industry.

Realizing that the approval process was on the critical path for scheduling this project, the activity required to complete this process was planned and coordinated as part of the overall project schedule. The project received approval from the Federal Government to proceed with the tank construction in February 2004, well within the timeframe that had been planned for this phase of the project. Once this federal approval was given, it was then necessary to prepare for the construction phase that would follow, including the need to obtain the permits required to proceed with the project, as well as visas and work permits for personnel needed on site when specific skills sets were not available locally.

Building Preparation

Because of the remote location, the lack of infrastructure, and the cold winters, the planning of this project was critical to its success. Sakhalin Island is located in the far eastern part of Russia, where the land mass ends at the Pacific

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Figure 2: Map of Sakhalin

Ocean (see Figure 2). In the southern portion of the Sea of Okhotsk, approximately 40 km north of Japan, Sakhalin Island is roughly 950 km long and peaks at 160 km wide. The climate on the island is harsh and the area is seismically active.

Planning the project included a determination of how to successfully work around inevitable weather delays so that the project would be able to proceed on schedule throughout the year. The nearest town, the Port of Korsakov, is 17 km from the site, with only a gravel road connecting the site to the port. The settlement of Prigorodnoye is located a short distance beyond Korsakov. With no infrastructure nearby, all of the equipment had to be obtained from other places and shipped to the site. And, because of the long lead time to get materials and equipment flown in and cleared through customs, contingencies had to be developed for potential malfunctions and urgently needed replacement parts. A camp had to be built to provide accommodation for the crew and arrangements had to be made for obtaining and preparing daily meals. Finally, the crew had to be hired, transported to the site and settled before the construction could commence.

Planning the project also included analyzing the soil at the site. When the soil was tested, it was discovered that competent soil existed beneath the ground surface. However, for the soil to provide the necessary support to hold the two tanks and their contents, it was necessary to excavate up to 3 m of soil over the entire site for both of the LNG tanks - each of which is 70 m in diameter - and then fill in the excavated sites with a lean concrete.

The first order of business for the construction activity was to address various infrastructure needs. Two 65 m^3/hour concrete batching plants were erected to provide all of the concrete needed for the tanks. While one plant would have been sufficient during most of the project, at times the volume needed would exceed the capacity of a single plant. Not only was it necessary to provide enough concrete for the base slabs, the tank walls and the roofs, but concrete was also needed to create the filler material to reinforce the soil.

Additionally, building a second batch plant provided a back-up facility, since concrete could not be purchased in neighboring areas and transported to the site in any way that was cost-effective for the project. This was just one of the many contingencies that was developed to plan in advance for outages that might occur. The concrete batching plants have been winterized but still will not be able to be used during the harshest part of the winter.

The civil work, including site preparation, excavation, replacement of soil by lean concrete filler material, and slab construction, was subcontracted to a local Russian company. This crew had extensive experience not only working within the Russian construction industry, but also working in the weather conditions experienced on Sakhalin. The partnership between CB&I employees with LNG experience and the Russian crew with local experience was deemed to be a vital component in developing the synergies necessary to make this project successful.

Tank Design

LNG tanks are generally built as either single containment tanks or full containment tanks. Both types are required to provide a secondary containment area that will hold all of the LNG in the event of a leak or failure in the primary containment system. The difference between a single and a full containment tank is that, for a single containment tank, the secondary containment is provided by an earthen dike and therefore requires more available land.

The Sakhalin tanks are full containment LNG tanks, which are built with an inner and an outer tank that are both capable of independently containing the stored LNG, separated by a meter or two of space (see Figure 3). In addition to providing a secondary liquid containment, the outer tank also provides controlled release of the vapor, making it the primary vapor containment system. This is important for the autorefrigeration process to work effectively. Relief valves are provided to release gas in the event that pressure builds up inside the tank. The inner tanks are constructed from 9% nickel steel, which is a highly resilient material for storing cryogenic fluids. The outer tank is a concrete structure, consisting of a reinforced concrete floor slab (see Figure 4), a pre-stressed concrete wall, and a reinforced concrete roof. The LNG storage design temperature is -165°C.

On most LNG tank projects, the concrete work is on the critical path. However, since Sakhalin's climate is so harsh, an innovative technique was developed to actually take the concrete work off the critical path and avoid the difficulties associated with curing concrete in wet or extremely cold conditions. In this way, the project will be able to stay on schedule because the number of weather delays associated with large amounts of concrete work will be significantly reduced. Also as a result of this plan, the construction work will be able to move forward throughout the year, while the concrete work can be performed in the warmer months, as conditions permit.

An important design consideration for the Sakhalin tanks is the level of seismic activity in the area. Because of the high level of seismic activity, which once resulted in an earthquake that reached 7.5 on the Richter scale, the Sakhalin storage tanks were required to be designed to withstand a horizontal peak ground acceleration SSE (Safe Shutdown Earthquake) of 0.47g. The inner tank is configured to provide a nominal operating height margin of 1.27 m at the top of the inner tank to avoid spillage of LNG into the annular space in the event of an earthquake. The carbon steel

Figure 3: Schematic of a Full Containment LNG Tank

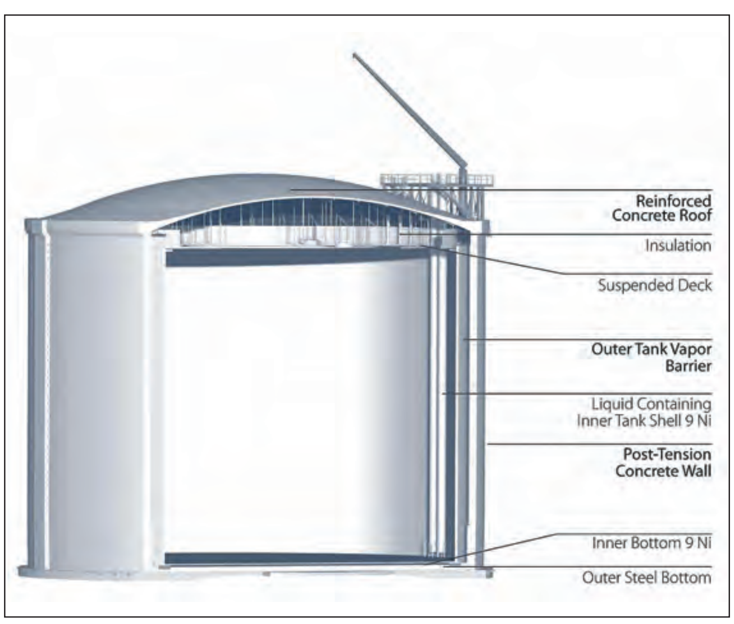

Figure 4: Pouring the slab for an LNG tank on Sakhalin

liner plates will be in direct contact with the concrete slab, wall and roof, providing a gas tight barrier. The bottom slab and lower portion of the wall will be protected from direct exposure to product temperature, in case of a spill, by the secondary bottom and thermal corner protection (TCP) system (see Figure 5).

Insulation also plays a prominent role in the storage of LNG. On the Sakhalin project, the tanks will be insulated with rigid foamglas® beneath the inner tank, a layer of fiberglass insulation placed on a deck suspended over the inner open top steel tank, and expanded perlite together with resilient fiberglass blanket in the annular space between inner and outer tank walls. Even though the tanks are being built below the frost line due to the excavation, it was also necessary to include in the design a means to prevent the LNG in the tanks from freezing the earth beneath, expanding the soil mixture and compromising the tank foundations. To prevent this, foundation heaters are placed below the tanks to provide a constant source of heat to the earth beneath.

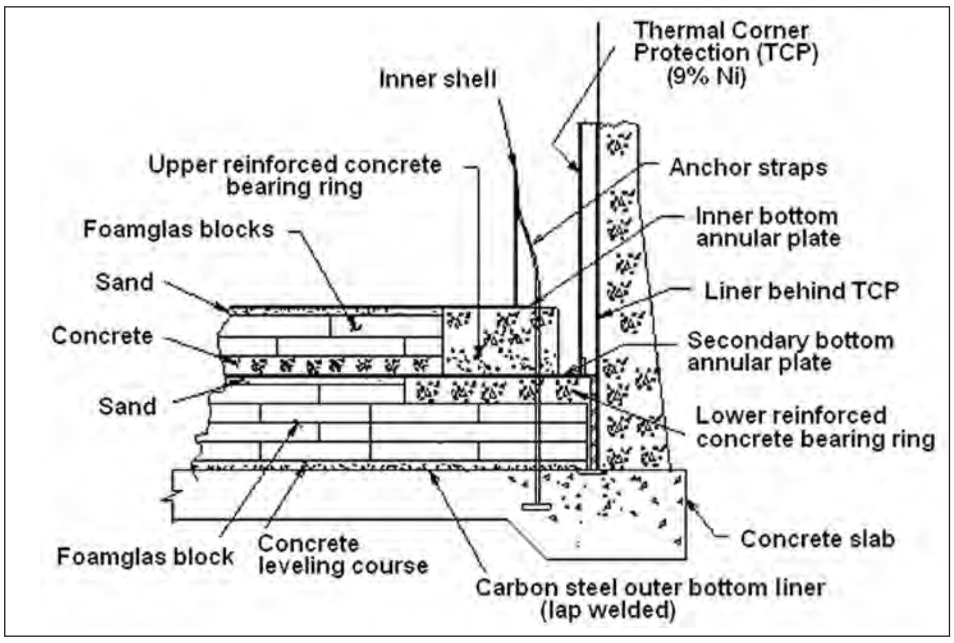

Figure 5: Inner Tank and Insulation Geometry

Construction Activity

The Sakhalin II LNG tanks are currently under construction (see Figure 1). In Russia, the owner and the state and local governments provide oversight for construction activities. Russian Design Institutes have been engaged to ensure compliance with all local and state regulations throughout the construction of the tanks. Construction will take place year round and is scheduled to continue for more than three years.

Work on the tanks alternates from one tank to the other, so that specific skills sets on the part of various crew members can be used most effectively. This technique allows the resources to be used where they are most needed, optimizing production time, and it also reduces equipment needs and allows for efficient use of supervisory personnel. Each tank has two stationary tower cranes in place, and five additional cranes are available to support the construction activities.

One of the most significant challenges faced in the construction effort is dealing with the harsh winter conditions on Sakhalin. Construction crews face winters on the southern portion of Sakhalin that have an average low temperature in January of -14°C. Although precipitation is generally moderate, 3 m of snow is not uncommon and winds are persistent. The wind chill effect combined with the cold temperatures contributes to the challenging construction environment. A steady wind of 15 miles per hour combined with a temperature of -15 °C produces a wind chill factor of -39 °C, a temperature that can freeze exposed skin in 10 minutes. To deal with these challenges, the team for this project is led by individuals from Russia, Canada, the United States, and the United Kingdom who have experience working in similar conditions on projects located in Canada, the upper Midwest of the United States, Norway, Poland, Russia, and Kazakhstan.

Safety will be at the forefront of the construction effort, as always. In this case, in addition to the usual construction safety safeguards and training, the crew will be trained to work safely in extremely cold weather. Most of the crew has experience working in Russia or in other regions in the world with a similar climate, which will greatly aid this effort. Work areas will be enclosed as much as possible, and tarpaulins/galvanized sheeting will be used to serve as a barrier, providing protection from the wind. Procedures to prevent ice build up on tanks and equipment along with keeping walking surfaces free of ice will also be implemented. As the steel liner is erected, it will provide a weather barricade to protect the crew from the elements. Winter weather gear specifically designed for this type of activity has been purchased. With the appropriate clothing, training, and supervision - as well as a construction technique that takes the concrete work off the critical path - the climate conditions on Sakhalin should not unduly hinder the construction progress, allowing construction activities to continue safely throughout the winter.

Martin Brockman is a Project Director with CB&I and has more than 18 years of project management experience in various countries worldwide, including Kuwait, Saudi Arabia, the United States, and Russia. He is currently Project Director of CB&I's LNG project on Sakhalin Island. He received a Bachelor of Science degree in Civil Engineering and completed a mini-MBA program at Purdue University. He is a licensed professional engineer.

Brian Rooney is the CB&I Project Engineering Manager for the Sakhalin Project and has more than 20 years experience designing low temperature and cryogenic storage tanks, including full containment cryogenic tanks, spheres, and insulation systems. In his current position, he is responsible for work associated with all aspects of the engineering effort on the project. He received a Bachelor of Science in Mechanical Engineering at Marquette University.

Paving the Way

The key to a successful engineering, procurement and construction project in Russia is the ability for a contractor to be global and local at the same time. Global experience with projects such as LNG facilities that have not been previously built in Russia provides valuable knowledge and expertise not available in the country. Local resources, such as construction subcontractors and Russian Design Institutes, provide essential expertise and skill sets needed for doing business in Russia. Together, these elements create the framework for developing designs that combine the best practices of the LNG industry worldwide with the best practices of the Russian construction industry.

The slab construction for the LNG tanks started in May 2004, and the project is on schedule to complete the tank construction by the spring of 2007. LNG cargo is scheduled to be loaded in November 2007, as Russia for the first time produces LNG and begins to export some of its vast natural gas resources to the Asia Pacific, North America, and Mexico. ■