ENGINEERING, PROCUREMENT, AND CONSTRUCTION CHALLENGES OF THE MOUNT HAYES LNG PEAKSHAVING FACILITY

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ABSTRACT

The Mt Hayes LNG Peakshaving Facility, the newest facility of its kind in North America, presented several unique design and construction related challenges. The facility is located on Vancouver Island about ten kilometers Southwest of Nanaimo, BC. It is owned and operated by FortisBC and is used both to support growing gas demand on Vancouver Island and to backstop gas supply to the British Columbia mainland. Construction of the facility began in April of 2008 with commissioning completed in April of 2011. The facility was engineered, constructed, and commissioned by CB&I. The Mt Hayes facility has a 1.5bcf single containment LNG storage tank, a 7.5mmscfd liquefaction system, and a 150mmscfd vaporization system. The facility is located about 280 meters above sea level and connects through the use of two 3.5 kilometer pipeline spurs to the main high pressure pipeline traversing Vancouver Island. The liquefaction system consists of a mixed refrigerant loop using a two stage centrifugal compressor. The LNG vaporization system for sendout of LNG from the tank to the pipeline uses shell and tube heat exchangers with remote firetube heaters utilizing a hot water-ethylene glycol heating medium. For sendout the LNG is pumped from tank pressure (1psig) to very high pipeline operating pressures (MAOP 2160psig) using two 15 stage high pressure extank submerged motor can pumps The most significant design challenges resulted from the unusually high pressure pipeline interface coupled with low summertime pipeline flow-by rates. Construction challenges resulted from the site location, which is in a high seismic zone on an island near the top of a solid rock mountain. The environment is also very wet. This paper explores the design-build challenges associated with the facility and discusses solutions employed to overcome these challenges.

INTRODUCTION

Demand for natural gas has increased across North America, and British Columbia is no exception. As the nominal natural gas demand increases the peak usage similarly rises to higher levels. Peak usage in the lower mainland of British Columbia and Vancouver Island can only be met by pipeline capacity increases or LNG peak shaving due to the remoteness of the demand from the natural gas source and the geology which prevents the development of underground gas storage. Since available pipeline capacity to meet peak demands has been reduced by higher pipeline utilization to meet normal demands, an LNG peak shaving facility is the logical choice to supply the incremental natural gas required to meet the demands. In response to the increased demand, Fortis BC Gas Company built the Mt Hayes LNG Peak Shaving Facility on Vancouver Island to handle not only the peak gas demand on the Island itself, but mainland British Columbia as well. In spring of 2008, Fortis contracted with CB&I to engineer, procure, and construct (EPC) the facility in its entirety through commissioning. All process design, equipment specification, and procurement and installation of all elements of the facility were completed by CB&I. The facility was commissioned in spring 2011 and at this time is the newest Greenfield LNG peak shaving facility in North America.

From conception of the project, several engineering and construction challenges presented themselves. The most significant of the engineering challenges were a result of the unusually high pressure of Fortis's transmission pipeline coupled with low summertime pipeline flow-by rates. Fortis's pipeline traverses Vancouver Island and connects with the mainland pipeline using an undersea link about mid point on the island. Interfacing with Fortis's high pressure transmission pipeline at the Mt Hayes facility proved challenging on several fronts. Other engineering challenges resulted from the site's location in a very high seismic zone. Construction challenges arose as a result of being located near the top of a small solid rock mountain where the environment is also very wet.

This paper explores the EPC challenges associated with the facility and discusses solutions employed to overcome these challenges.

FACILITY DESCRIPTION

The Mt Hayes LNG Peak Shaving Facility is located on Vancouver Island about 9 miles (15 kilometers) south of Nanaimo. It is inland about 3 miles (5 km) off the Trans-Canada Highway, and accessed through the use of upgraded logging roads. The facility is located in the temperate coastal mountain range that forms Vancouver Island. It is situated about 920 ft (280 meters) above sea level (near the top of Mt Hayes) and connects through the use of two 2.2 mile (3.5 km) pipeline spurs to Fortis's main high pressure transmission pipeline traversing Vancouver Island. The access road to the facility climbs almost the entire 920 ft in 2.2 miles. As a result the access road grade is approximately 8% on average.

The Mt Hayes facility stores LNG in a 1.5bscf (70,500 cubic meter) single containment, double steel wall, storage tank. The tank is surrounded by an earthen impoundment berm used for secondary spill containment. The inner tank is 9% nickel steel and the outer tank is carbon steel. The tank has a bottom withdrawal nozzle for pumpout of LNG using external LNG pumps.

The facility uses an amine chemical pretreatment system coupled with molecular sieve beds to remove CO_2 and water from the inlet gas prior to liquefaction. After CO_2 and water have been taken out of the inlet gas, heavy hydrocarbons are removed at the front end of the liquefier to prevent freeze up and plugging of heat exchangers. The heavy hydrocarbons are then sent back to the main pipeline through a tailgas line along with flash vapor from the tank generated during the liquefaction process. Dual five stage reciprocating boiloff compressors are used to raise the tailgas up to pressure for return to the main pipeline.

The facility is equipped with a 7.5mmscfd natural gas liquefaction system using a mixed refrigerant loop (MRL) driven by a two stage integral bull gear centrifugal compressor. A pair of platefin heat exchangers provides the refrigeration for both the front end heavy hydrocarbon knockout and the main incoming gas liquefaction.

The facility sendout system (for sendout of LNG from the tank to the pipeline) is a dual train 150mmscfd peak LNG vaporization system. The vaporization system uses two shell and tube heat exchangers with two remote firetube heaters. The firetube heaters heat a hot water-ethylene glycol (WEG) heating medium. For sendout, the LNG is pumped from tank pressure 1psig (70 mbar) to above the very high pipeline operating pressure (pipeline MAOP is 2160psig or 149 bar) using two 13 stage high pressure external tank submerged motor LNG can pumps. The high pressure LNG then passes through the shell and tube vaporizers where it is heated and vaporized by the hot WEG for sendout back to the main pipeline.

With the exception of main electrical power, which comes to the facility using an overhead power line from the local utility feed at the bottom of the mountain, the facility is completely self contained. The overhead electric power utility line climbs up the mountain paralleling the 2.2 mile pipeline spur right of way. The electric power system is backed up using an on-site standby diesel engine driven generator. The facility has a small lake (from local runoff) used for firewater and potable water supplies. It also has instrument and plant air systems, and a nitrogen membrane system for generating purge gas. Lake water is treated using a local reverse osmosis membrane and chemical treatment system for generation of potable water.

CONSTRUCTION CHALLENGES

Site Blasted Out of Rock:

The Mt Hayes facility is located near the top of a small mountain which is essentially solid rock. Prior to construction, the site had to first be leveled in order to commence building activities. This required a considerable amount of rock blasting coupled with crushing for compaction and leveling, and construction of the LNG tank impoundment berm. The most challenging aspect of the rock blasting was associated with the LNG spill sump located inside the LNG impoundment relatively close to the LNG tank foundation. The hole for the large sump had to be blasted out of the rock. This required small surgical blasting so as to not disturb the rock under the tank itself. After blasting of the sump hole was complete, the rock wall adjacent to the tank was then stabilized using rock anchors prior to pouring the outer concrete walls of the sump.

Steep Climb up to the Facility:

Being located near the top of a small mountain means a steep climb up to the site from the main road (Trans-Canada Highway #1). Near the facility the Trans- Canada Highway is approximately 33 ft (10M) above sea level elevation. The facility is located 920 ft (280m) above sea level and approximately 3.1 miles (5 km) from the highway, but the climb up the hill does not start until the last 2.2 miles (3.5 km). This makes the climb to the site about an average 8% grade. The climb is up a rather winding gravel logging road. This climb proved a challenge in getting both permanent process equipment and large construction equipment as well as bulk materials up to the site. Truck loads oversized in both weight and width were a potential safety hazard in addition to normal construction traffic. Both safety and logistical challenges arose. To overcome these challenges a couple of solutions were employed. First the road was improved prior to construction to stabilize, widen, and smooth large undulations. Next, a road monitoring crew was employed along the road at four equally spaced checkpoints to be sure both inlet and outlet traffic were monitored and controlled. The road monitoring crew stayed involved until the commissioning of the facility. Finally the road was graded regularly and maintained during construction activities to be sure the best possible conditions existed for vehicle traffic.

Site is Very Wet (High Precipitation):

Although the amount of precipitation received during the project was generally anticipated, the form of the precipitation was not. The only data available for typical rainfalls in the area were from lower elevations than the site (for instance at the Nanaimo airport). While the site is not far from local weather stations, there are no nearby comparable weather stations with comparable elevations. The data from the lower locations showed the precipitation as mostly rainfall. Because of the higher elevations of the site, there was much more snowfall than could have been anticipated. And a couple of record snowfalls for the area during the first winter of construction served to paralyze the project for several weeks. Although the snow loads used in the design of the facility structures were more than adequate, the unanticipated amount of snow encountered during construction caused the shutdown of construction activities on more than one occasion. There was not much that could be done in these cases other than to clear the snow as quickly as possible to enable the resumption of work.

DESIGN CHALLENGES

High Pressure Pipeline Interface:

The most significant of the engineering challenges for the facility resulted from the interface with Fortis's high pressure distribution pipeline traversing Vancouver Island. The MAOP of the pipeline is 2160psig (149 bar), thus both the feed pipeline to the LNG facility and the discharge from the LNG facility must be designed to accommodate the MAOP.

On the gas inlet side, to minimize the need for expensive high pressure equipment and materials within the facility, the Mt Hayes pretreatment system and liquefier are designed to operate at 600psig (41 bar), a rather common operating pressure for a facility of this kind. As a result, the pressure of the incoming pipeline gas is reduced immediately upon entering the facility (after metering). The high pressure pipeline gas is regulated from pipeline pressures down to 600psig using a series of pressure control valves. This large reduction in gas pressure is large enough to cause low temperatures downstream of the regulators due to the Joule-Thompson effect on gas expansion (auto refrigeration). To prevent the gas from reaching such low temperatures so as to warrant low temperature rated materials for pipe and equipment in the LNG facility, the inlet gas has to first be heated prior to the letdown. It seems counterproductive to first heat the incoming gas prior to refrigeration to cryogenic temperatures for LNG storage, but that's what had to be done to prevent the need for expensive and exotic materials such as those required for low temperature service within the facility. The inlet gas is heated with a standalone WEG heating system using a firetube heater and a shell and tube heat exchanger.

Since the fuel gas for the facility also comes directly from the high pressure pipeline, the same heating concept is employed for the pressure letdown of the fuel used within the facility (which is distributed at even lower pressures – 100psig). The fuel gas is heated by the same system used to heat the facility inlet gas, but uses a separate shell and tube heat exchanger in the same plant inlet area as the inlet gas heat exchanger.

Even pipeline gas used to routinely pressurize the facility was heated. Fin pipe heaters supply sufficient energy to heat the pressurizing gas to the appropriate level.

During the design and study phases for the project, several options were explored to try and capture the lost energy of the inlet gas pressure reduction, such as power generation or compression using a gas expander, but none of the options explored proved to be economically viable.

On the gas outlet side (sendout), the interface with the high pressure pipeline also proved challenging. The LNG pumps used to raise the pressure of the LNG from the tank to above pipeline pressure (to facilitate injection into the pipeline) are one of a kind. The two submerged motor can pumps (designed and manufactured by Ebara) are 13 stages each. No LNG pumps designed or manufactured to date have operated with such high pumping pressure ratios. The shut-in pressure of the pumps is nearly 3000 psig (207 bar) requiring the need for very high pressure ratings for the entire sendout system (equipment, piping, valves, etc.) with high pressure settings on safety relief devices downstream of the pumps. Since the LNG pumps are beyond the experience level of any LNG pumps installed at prior peak shavers, a well documented testing program was implemented at the pump manufacturer to confirm the pumps' performance. The heat generated from the pumps while running on recycle at full speed was enough to cause the tank pressure to rise rapidly and shutdown the pumps. One means of mitigating complications from the LNG pump operations was through the use of Variable Frequency Drives (VFD's). Not only do the VFD's allow for much softer starts (hence less shock to the electrical system), but they also allow pressure and flow to be controlled with minimal energy input to minimize heat generated while running the pumps on recycle. As such, the VFD's buy the operators time while bringing the pumps and vaporizers on line. The pumps operated flawlessly upon startup and have operated well since that time.

Low Pipeline Flow-by Rates during Liquefaction:

Another engineering challenge stemming from the interface with Fortis's pipeline was due to the low flow-by rates during the liquefaction season (summer). The design flow-by of 5 mmscfd would not allow a tailgas stream of any size that is outside the pipeline tariff operating range, since diluting is not feasible at such low flows. The CO_2 concentration of the gas used for design of the pretreatment system is 1%. Normally this concentration of CO_2 could easily be handled using a molecular sieve removal system. However, because of the low pipeline flow-by rates, the high peaks of CO_2 associated with regeneration of a molecular sieve system (which are sent back to the pipeline through the tailgas line) would cause the concentration of CO_2 in the downstream pipeline to exceed allowable levels. In fact, the pipeline flow-by rates were so low that at their minimum, even with perfect smearing of the CO_2 concentration spike in the tailgas line over the entire duration of the regeneration cycle, allowable concentrations of CO_2 would still be exceeded in the downstream pipeline gas. This necessitated the use of a considerably more complex and costly amine absorption CO_2 removal system in lieu of a molecular sieve system. The amine system then vents the CO_2 to atmosphere rather than sending it back to the pipeline.

High Seismic Zone:

The Mt Hayes facility is located close to the Cascadia Subduction Zone (also known as the Cascadia Fault). The Cascadia Subduction Zone is located off the coast of British Columbia to the west of Vancouver Island and stretches from the north end of Vancouver Island all the way to California. As a result, the facility is located within a very high seismic design zone. Even though the facility is built on solid rock (which mitigates the effects of a seismic event), the design of the facility is considerably affected. The tank is designed with a rather stout aspect ratio in order to decrease the overall height and spread the foundation load. Both the inner and outer tanks are anchored to the foundation. The tank is also situated on a very substantial concrete ringwall. The 1600 cubic meter ringwall foundation is sunken within a trench blasted out of the rock around the perimeter of the tank base.

Steel structures and buildings within the facility are designed and detailed using lower seismic reduction values which allows the use of "conventional construction" (standard detailing practices) instead of special seismic detailing. The use of lower seismic reduction values requires that structural members, connections, and foundations be designed for larger seismic forces. Thus, members, connections, and foundations are larger in size to accommodate the larger loads. However, the corresponding reduction in complexity and the resultant lower engineering, fabrication, and assembly costs, more than offset the cost of the increase in material.

CONCLUSION

Although the design and construction of the Mt Hayes LNG Peak Shaving Facility posed several challenges, corresponding solutions were employed to overcome all of them. In the end, the facility met all performance criteria and is operating well. The facility is expected to serve FortisBC's gas supply needs reliably for many years to come.