Executing Peru's largest industrial project safely and on schedule

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Peru LNG will be Latin America's first LNG export project when operations begin next year, with first LNG expected on schedule in May 2010. The development includes a gas-liquefaction plant, marine-export facilities, with an island breakwater, and a 408 km pipeline connecting to an existing gas line in the Ayacucho mountains.

The project is being developed by a consortium of Hunt Oil of the US (50%), South Korea's SK (20%), Repsol (20%) and Marubeni of Japan (10%). Hunt Oil will operate the liquefaction plant and loading terminal, with Stream (a joint venture of Spanish firms Repsol and Gas Natural) having the exclusive rights to market the 4.5m tonnes a year of LNG production.

The total investment for the project, including the liquefaction plant ($1.5bn) – awarded as a lump-sum turnkey engineering, procurement, construction and commissioning contract including the top side jetty, loading and utility platform to CB&I – marine and pipeline facilities (contracted to others), and the development and financing costs, is estimated at $3.8bn. Of this, over $1bn will be spent in Peru on local goods and services and around $1bn as direct investment in the Pampa Melchorita region – the location of the export terminal.

The project is expected to boost Peruvian GDP by an estimated average of 0.4% a year during the construction period and by 0.5% a year once the plant becomes operational. In addition, the project is expected to generate around $1.3bn a year of hard-currency export revenues, increasing the country's exports by an estimated 4.2%, according to a 2007 report by Apoyo, a consultancy.

CB&I and Peru LNG have formed a joint team to start-up and initially operate the 4.5m t/y plant, which is under construction at Pampa Melchorita

Safety and environment

Safety is a core value for the project. All site activities are executed to ensure the health, safety and environmental protection of every person working on the project. This commitment is demonstrated by the safety record of the Peru LNG project: in August 2007, one CB&I supervisor alone reached a personal milestone of 10 million work-hours without a lost-time incident by his crews, working over a number of projects; while the project as a whole reached 10 million work-hours without a lost-time incident milestone in February 2009. There are nearly 5,000 people working at the project site for CB&I.

The project is managed according to the strictest national and international standards of environmental protection, including those of the International Finance Corporation and Inter-American Development Bank regulations. Safety at the project site has exceeded the goals set by the project at the commencement of the contract and it remains the project's top priority.

One of the first decisions to be made was to find a suitable site for the location of the LNG facilities. Initially 17 sites were evaluated. From this selection three sites were short listed: Pampa Clarita, Punta Corriente, and Pampa Melchorita. A more detailed assessment was applied to these sites by Golder Associates, including environmental studies, onshore and offshore studies, geo-technical, archaeological, and socio-economic assessments. The evaluation eventually led to the selection of Pampa Melchorita, based on a suite of environmental, technical and economic considerations.

From the onset of the development there has been a commitment to make a positive and sustainable social and economic contribution to the communities affected by the project. This can be seen in a number of areas: employment opportunities, training, health and social projects.

Most of CB&I's construction staff of over 5,000 is Peruvian. Emphasis was also placed on hiring from communities within the area of influence of the project. All criteria established under the environmental and social obligations for the project have been met. Permanent jobs will also be generated during commercial project operations. Peru LNG is also enhancing opportunities for local businesses to sell goods and services to the project, raising the income of the local population, providing further employment and offering long-term job prospects. CB&I's rigorous and extensive training programme has touched the entire local workforce in one form or another, so far, providing over half a million work-hours of training.

The project has developed a Framework Plan for Investment in Community Development to support sustainable and community needs projects. Recent examples of programmes supported by Peru LNG and its contractors are:

- Social programmes – education and cultural development;
- Construction of public health and sanitation facilities;
- Health campaigns and screenings to promote healthcare, access to state facilities and training of health care workers;
- Veterinary campaigns to reduce diseases common to livestock to improve animal productivity;
- Supply chain management linking small and large enterprises; and
- Agriculture campaigns to improve crop productivity

Process facilities

The LNG plant has a number of unusual features and design challenges because of the nature of the feed gas, which is the residue product gas from a natural gas liquids extraction plant at Malvinas, where most of the hydrocarbons heavier than ethane have been removed. The resulting feed gas is very lean, consisting predominately of methane and ethane with a small quantity of inerts and a nominal concentration of propane. Consequently, there is no requirement for liquefied petroleum gas or condensate removal at the Peru LNG plant, either to satisfy LNG product specification or to prevent the freezing of these components in the cryogenic sections of the plant. However, this also means there is no ability to extract the necessary refrigerants required for the liquefaction process, so refrigerants must be imported.

The LNG facility has a fairly straightforward set of feed-gas-treatment processes. Acid gas contaminants, principally carbon dioxide, are removed using the BASF-activated Methyl Diethanolamine process. After acid gas removal, the water saturated gas is cooled to condense about half of the water and then passed through molecular sieve beds to remove the remaining water to less than 1 ppm by volume to prevent freezing and plugging in the cryogenic liquefaction unit. There is no known mercury in the feed gas, but, as a precaution, a guard bed using activated carbon has been included upstream of the main heat exchanger.

Liquefaction technology

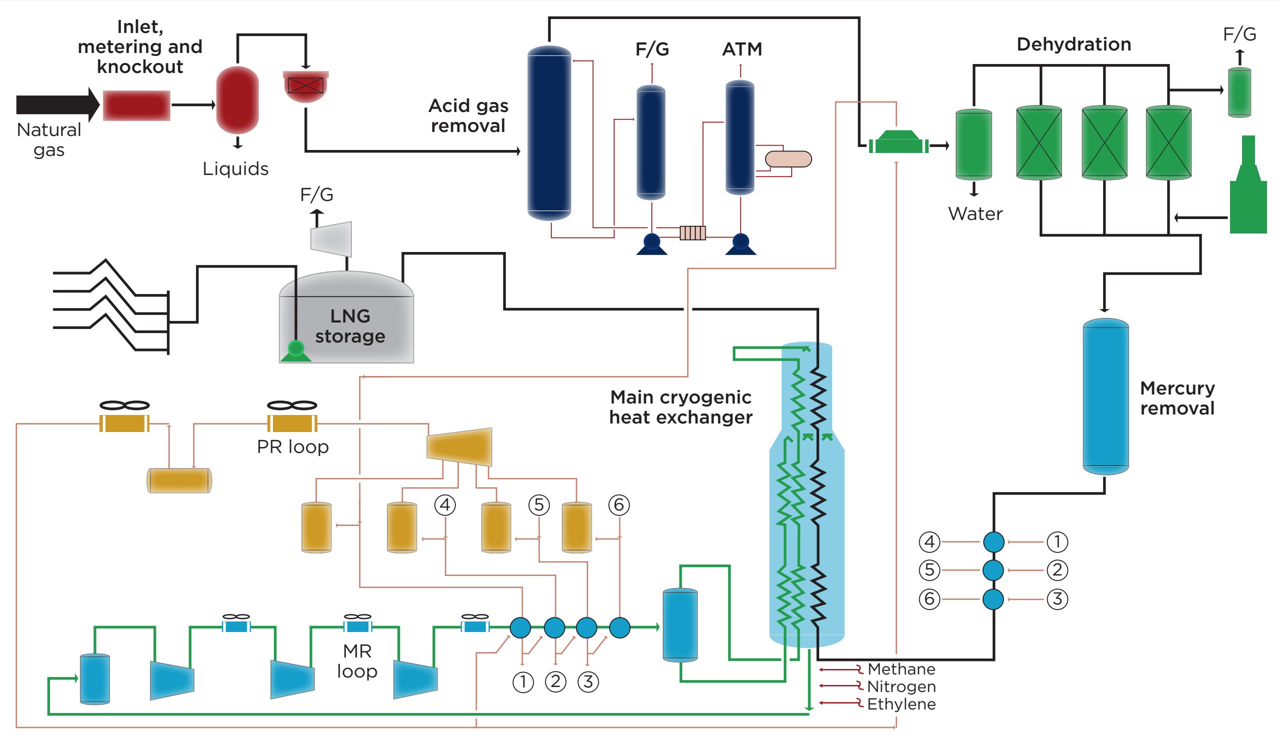
The liquefaction process is based on Air Products Split MR™, propane pre-cooled mixed-component refrigerant process. Feed gas is first pre-cooled using propane refrigerant at four descending pressure and corresponding temperature levels (see Figure 1). Once cooled by the propane refrigerant, feed gas directly enters the main cryogenic heat exchanger (MCHE); no scrub column is provided.

In the MCHE, feed gas is further cooled and totally condensed by the mixed refrigerant. The pressure of the sub-cooled LNG leaving the MCHE is reduced across a control valve and is sent to the LNG storage tanks. LNG rundown from the MCHE is stored in two, single-containment LNG storage tanks, each with a capacity of 130,000 cubic metres. The use of single containment tanks was possible because there is sufficient space available to accommodate a secondary containment area and to satisfy regulatory and safety criteria.

The facilities are self sufficient in utilities. A desalination plant provides process and potable water. Nitrogen and instrument air are produced onsite and power is generated by aeroderivative gas-turbine generators (GE LM2500+), which provide good overall thermal efficiency for the facility.

The mixed refrigerant consists of nitrogen, methane, ethane, ethylene and propane – its composition was modified to include both ethane and ethylene because of the unusual nature of the feed gas. Nitrogen is generated on site, and methane and ethane make up is supplied from the feed gas. However, the ratio of ethane to methane in the feed gas is much lower than that required in the mixed refrigerant, so ethylene is added to enable optimum performance. Ethylene provides similar process performance to ethane, but it must be obtained from remote sources. Propane must also be imported, but is available locally.

Figure 1: The liquefaction cycle at the Peru LNG project



The project's marine facilities were particularly challenging because of the high seismic conditions and associated soil movement resultant from earthquakes; the potential tsunami hazard; and because the Peruvian coastline is exposed to long-period Pacific swells during most of the year.

A trestle approximately 1.3 km long, consisting of a steel superstructure, supported by 550 steel piles and a concrete abutment, was required to connect the shore line to the LNG berthing facility and LNG loading platform. Dredging work has been minimised, but is still required for the LNG tanker navigational channel, which provides access in and out of the berth area. This channel will have a water depth of 15-18 metres, a width of 300 metres and a total length of 3,600 metres. An 800 metre-long breakwater is required to ensure safe berthing of LNG vessels and to allow year-round access.

Project challenges

Soil conditions provided an unusual challenge at the Pampa Melchorita site. The soil's high salt content, between 15% and 20%, has affected design and engineering in a number of unexpected ways, including: all foundations were constructed using sulphur-resistant concrete to prevent corrosion resulting from the saline nature of the soil; and the site is in a coastal desert environment with a low annual rainfall – an average of just 1.8 millimetres a year. Despite this, a waste-water collection system had to be installed, because, in the event of a fire, the fire water, if not captured and collected, could wash out the soil around the foundations.

Seismic considerations

The project site is in one of the most seismically active regions in the world, where the Pacific plate meets the South American plate. The movement of the plates is predictable; around 10 centimetres a year, with the Pacific plate moving underneath the South American plate. But the plates do not move smoothly past each other, leading to increasing stress and stored strain. This process continues until the strain rises to a point that enables the sliding of the plates to continue. When this occurs there is a sudden release of energy, experienced as an earthquake.

The LNG plant has been designed to withstand two seismic levels as defined by the National Fire Protection Association (production, storage and handling of LNG): the operating basis earthquake; and the safe shutdown earthquake (SSE). The Richter scale is not a metric that is normally used in the design of structures, but as an indication, just to demonstrate the significant effect seismic conditions have on the Peru LNG design, the SSE is roughly equivalent to 8.4 on the Richter scale.

The high seismic loading also required special consideration in the piping design. A balance in the design was required between the need to provide flexibility to cater for the thermal expansion/contraction of the lines and the requirements for the lines to be more rigid and heavily anchored for seismic resistance. The entire piping-support design and pipe reinforcement had to be re-evaluated compared with an LNG plant with low seismic-design criteria.

The high seismic loading also imposed height restrictions on equipment design. For example, the LNG storage tanks have an outer shell diameter of 78 metres and an outer tank height of 35 metres. Air-cooler racks were reduced in height and additional nozzle-stress calculations were performed on vessels and compressors, particularly the refrigerant compressors, to reduce nozzle loads.

The site including the LNG tanks is 140 metres above sea level, creating some complex engineering issues related to the potential surge loads on the LNG loading lines running more than 2 km from the LNG tank down to the shore line and then along the jetty. Detailed surge-analysis simulations were carried out to predict the surge loads and their implications on the piping and surge-relief design. Meeting the surge loads required the use of a non-typical piping configuration, independently initiated protection systems, elevating design pressures, and incorporating rapid open valves and a surge drum.

Delivering large and heavy pieces of equipment to remote locations is always a logistic challenge. On the Peru LNG project such large items were shipped to the Port of San Martin, around 110 km south of the site. The route from the port to the site runs along the Pan American highway, the main road running north to south along the South American continent. However, the highway was not designed to accommodate the size and weight of equipment required on an LNG project.

Significant modifications were required to the Pan American highway to enable the transfer of the equipment to the site, in particular for two of the larger and heavier pieces of equipment, such as the MCHE (pictured)

Significant modifications to the highway were required to transfer the equipment to the site, in particular for two of the larger and heavier pieces of equipment: the MCHE (45 metres long and 4.5 metres in diameter, and weighing around 250 tonnes); and the carbon-dioxide absorber (25 metres long and 3.8 metres in diameter, and weighing around 450 tonnes). An earthquake in 2007 also required repairs to be performed to the highway and the port of San Martin.

Commissioning

The commissioning of LNG plants is a crucial activity in the successful completion of a project. Commissioning lies on the critical path of every project and the duration is often compressed because of delays in engineering, extended procurement cycles, transport/delivery issues, or general construction delays. For Peru LNG, an overall strategy aiming to minimise potential delays during commissioning was developed. This strategy involves implementing two programmes known as: Build it Clean; and Build it Tight.

Build it Clean ensures all debris and rubbish is removed from all process equipment and piping, from fabrication through to installation, and to final systems closure. Build it Tight ensures all piping components and process equipment are completed in a leak-free condition that is ready for commissioning. These two programmes will minimise the time required preparing the newly installed facilities for initial operation.

CB&I and Peru LNG have formed a joint team to start-up and initially operate the plant, which is expected to be handed over to Peru LNG after performance tests in third-quarter 2010.