Double, Nitrogen-Cycle Liquefaction Proposed for Offshore LNG FPSO

With the emphasis on bringing stranded gas to market, the LNG floating, storage, production and offloading (FPSO) vessel is gaining interest in several regions. An FPSO design is being promoted by Costain Oil, Gas and Process Ltd.

"Advances in offshore technology and favorable market conditions are now combining to create a 'window of opportunity' for floating LNG facilities," said Adrian Finn, Costain Oil, Gas and Process Ltd.

Under Costain's auspices, a reliable and flexible LNG FPSO plant design has been developed.

"The plant design has been tendered to shipyards and priced. Capital costs have been identified and operational costs have been assessed and detailed," he told participants at a recent Gas Processors Association meeting.

Finn presented a paper on "Effective LNG Production Offshore" at the meeting.

Costain Oil, Gas & Process and Moss Maritime engaged Merlin Production to demonstrate that an economically viable LNG FPSO can be designed, built and successfully operated.

Plant capacities between 1.2 and 3.5 million metric tons per annum (MMmta) have been considered.

Surprisingly, a double, nitrogen-expander cycle was chosen as the liquefaction technology in this LNG FPSO design.

The liquefaction process offers high flexibility to feed gas conditions, high reliability and is at least as inherently safe as an onshore LNG plant, he continued.

A proprietary design for an offshore floating, storage and regasification unit (LNG FSRU) has also been developed, based on the same hull and LNG tank configuration.

Drivers for a floating system. "A combination of factors has generated interest in offshore LNG production, nowhere more so than in the United States, which is now viewed as a primary growth area for LNG along with India and China," Finn noted.

"Ever-rising demand for natural gas for power generation is a major driver for LNG trade. This coincides with technical advances and reduction in project costs that have made offshore LNG highly attractive as a 'swing' supply source for natural gas.

"Offshore LNG production has yet to be commercialized, but widespread use of floating vessels for oil and gas production has provided confidence in a number of aspects of the technology," he emphasized.

"The development of a LNG spot market (which has resulted in a spate of LNG ship orders, especially in Korean yards) and environmental pressures to reduce flaring during associated gas production have improved commercial viability even further," he continued.

"Offshore LNG avoids the major infrastructure costs associated with onshore baseload LNG projects such as offshore platforms, harbor, jetty and site preparation. Studies have shown that this can lead to significantly reduced LNG production costs.

"LNG production economics must be compared against the costs of pipelining gas. LNG is cheaper for development of many remote gas fields, since floating LNG facilities may be easily moved to new fields as current ones decline," he explained.

LNG FPSO design. The vessel is a turret-moored floating unit designed to include a complete processing facility for liquefaction and storage of natural gas as well as condensate.

The unit has been designed for a moderate environment (such as Northwest Australia) with a design life of 40 years - 20 years before first dry-docking.

Side-by-side transfer to an LNG carrier would be the method for offloading.

"The hull is of similar principle construction as for seagoing LNG tankers with cargo storage protected by double sides and double bottom," he said.

Fig. 1 shows an artist's rendition of the LNG FPSO.

The LNG would be stored in MOSSÒ type spherical cargo tanks.

Integral tanks are allocated for water ballast as appropriate and arranged so that satisfactory trim can be maintained, regardless of the amount of LNG and condensate in the storage tanks. In addition, the ballast tanks would provide nearly constant draft and reduce longitudinal hull stresses.

The overall length is 321.9 m, width is 65 m and depth is 31 m. The

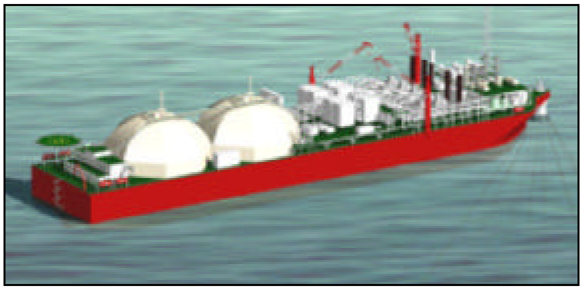

Figure 1: The LNG FPSO is designed for operations in equatorial waters.

design draft is 13.7 m. LNG storage capacity would be 181,800 cu. m total in two tanks. Another 50,000 cu. m would be used for condensate storage.

Process plant design. "Design and engineering studies have been carried out for natural gas flow rates of between 200 million cubic feet per day (MMcfd) and 450 MMcfd," he noted.

"The latter equates to an LNG production rate of approximately 3.0 MMmta based on operation for 350 days per year," he added.

"On all LNG projects, plant cost increases as the need for acid-gas removal, NGL extraction and nitrogen removal increases.

"Offshore, plant design must be robust and flexible to changes in feed gas conditions so the process design philosophy is quite different to an onshore plant that handles a specific, well-characterized feed gas.

"Plot space has been allowed for removal of up to four mol% carbon dioxide from the feed gas and for feed gas booster compression.

"It has been assumed that the feed gas nitrogen level is not more than about 1.5 mol%, so nitrogen removal is not needed," he explained.

For offshore liquefaction, the criteria for technology selection differ substantially from onshore facilities.

"The capital cost of the processing facilities is only a fraction of total project cost so technology selection and process design must be directed at the total project economics," Finn pointed out.

The first reported work on offshore liquefaction concluded 20 years ago that the most appropriate technology was a nitrogen-expander refrigeration cycle with pre-cooling by mechanical refrigeration and liquefaction in aluminum plate-fin heat exchangers.

In selecting the process, the companies looked at the Phillips Optimized Cascade technology, the mixed-refrigerant method and the

CRITERIA	CASCADE	MRC	EXPANDER
Uses proven technology	Yes	Yes	Yes
Overall space requirement	High*	Moderate*	Low
Refrigerant storage hazard	Yes	Yes	No
Sensitivity to vessel motion	Moderate	Moderate	Low
Simplicity of operation	Moderate	Moderate	High
Ease of start-up/shutdown	Moderate	Low	High
Flexibility to feed gas changes	High	Moderate	High
Efficiency	High	High	Low
Total Capital Cost	High	Moderate	Low

* Due to requirement for hydrocarbon refrigerant storage

turbo-expander process.

On the cascade process, the study showed that the "large number of equipment items and the large plot space mean that this cycle is not economically viable for offshore applications," he said.

The dual-mixed refrigerant cycle minimizes hydrocarbon inventories compared to either the single-mixed refrigerant or APCI propane-precooled cycle.

"Mixed refrigerant cycle plants are sensitive to changes in feed gas conditions as they rely on small temperature differences between the composite cooling and warming streams to give reasonable process efficiency.

"Mixed refrigerant plants inevitably take longer to start-up and stabilize than plants using other refrigerant cycles because of the need for precise blending of the refrigerant mix.

"This is a significant consideration in an environment where frequent start-up and shutdown are to be expected," he emphasized.

Some work had been done on a nitrogen-expander cycle by Linde for BHP at the Bayu-Undan field offshore Australia (see *LNG Express*, August 1997, page 8).

"A major benefit of using nitrogen as the cycle fluid is that it is inherently safe. Storage of hazardous hydrocarbons adjacent to or within the processing plant is avoided and there is no need for major hydrocarbon flaring if the refrigerant compressor trips.

"The expander cycle is simple and has fewer items of equipment than alternative refrigeration cycles.

"The nitrogen expander design is flexible to changes in feed gas conditions and requires minimal operator intervention," he pointed out.

The key selection criteria are summarized in Table 1.

"Expander cycles offer considerable advantages for offshore liquefaction and the use of two expanders avoids the need for pre-cooling by mechanical refrigeration with distinct benefits in terms of reliability, space and avoidance of refrigerant storage," he noted.

"The double-nitrogen-expander cycle requires more power than more complex cycles but the simplicity of the process makes it cheaper and safer.

"A comprehensive evaluation of the major criteria for offshore liquefaction has shown this refrigeration cycle to be optimal," he stated.

"Nitrogen cycle technology lends itself to modular design and fabrication, due to the size of the equipment and the relatively low number of equipment items," he continued.

The plant would consist of two to four trains based on permissible module and equipment sizes and on plant capacity.

With multiple trains, system reliability can be maintained in the event that one train is shutdown.

The cryogenic heat exchangers are located in cold boxes that minimize

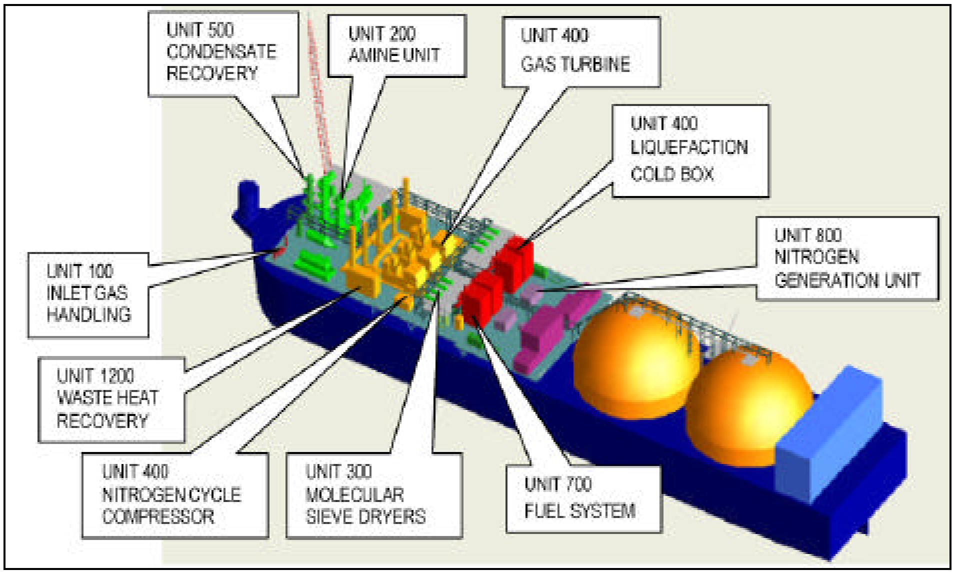

Figure 2: Process plant layout for unit using double-nitrogen-expander cycle.

heat ingress and protect the aluminum equipment from the elements.

The plant layout for a nominal 2.0 MMmta LNG FPSO is shown in Figure 2.

Offshore safety issues. Offloading LNG from offshore-based operations requires bulk LNG carriers to approach and berth alongside the floating structure (Fig. 3).

"Although similar activities frequently occur with FPSO operations worldwide, this was regarded as a major hazard concern for the offshore operation.

"In accordance with best practices for the industry, LNG transfer guidelines have now been developed for ship-to-ship cargo transfer operations.

"DNV has conducted a review of the safety and operational requirements associated with the design, construction and maintenance of a Floating Storage and Re-gasification Unit (FSRU), as developed by Merlin Production. This review included offshore LNG cargo transfer operations," he pointed out.

"Based upon the design and operation information provided, DNV has provided a provisional approval for the LNG FSRU design, assuming that the FSRU is designed, constructed, maintained and operated according to customary practice for the offshore industry," he added.

Regarding the LNG containment system, "a catastrophic tank failure and the subsequent discharge of LNG into the sea, followed by a rapid phase transition (RPT) could cause serious structural damage to the offshore facility, with possible stability loss," he warned.

"One of the most important aspects of Merlin's LNG FPSO and FSRU designs is the size of the LNG storage tanks.

"The quality of the LNG storage system is crucial to the long-term success of an offshore LNG project. Results of design work with 90,000-cu.-m tanks have confirmed that those tank sizes are achievable," he added.

Safety is of paramount importance on LNG facilities and the industry has an exemplary safety record.

"At the conceptual design stage, safety assessments from similar projects performed by Costain were used to determine plant layout and the optimal vessel/process interfaces.

"Merlin engaged DNV to conduct a review of all technical requirements related to safety and operational issues for the LNG offshore facilities.

"This report, combined with extensive research and design work, has addressed the historical barriers to offshore LNG facilities.

"The assessment was based on a qualitative review, supported by quantitative consequence analysis, for the following typical accident types: LNG release; ship collisions; dropped objects; helicopter accidents; and ballast failures.

"The DNV report showed that the LNG FPSO met or exceeded currently stipulated safety criteria.

"A more detailed safety case would be required for a specific project and this could conclude that the risk levels were somewhat higher," he concluded.

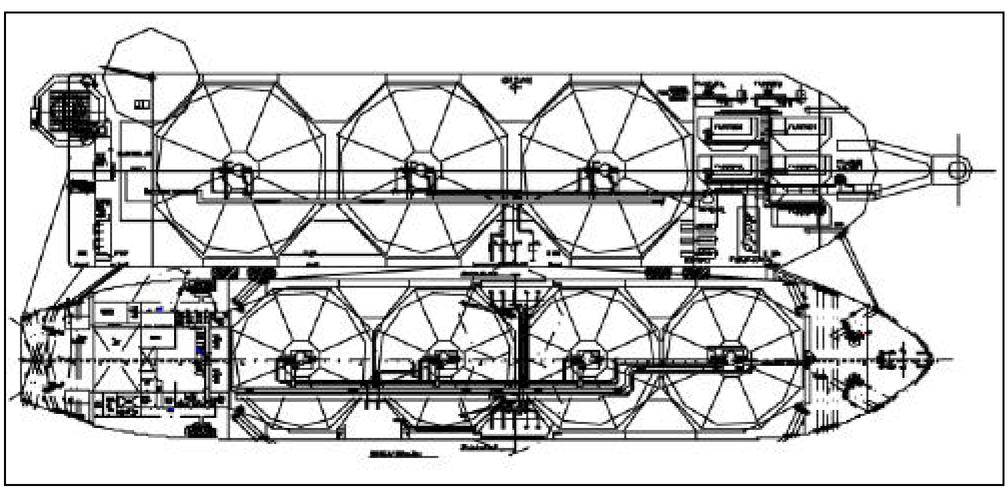

Figure 3: The mooring system is designed for side-by-side offloading.