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SIMPLE, LOWER COST LNG PRODUCTION

Paul Bridgwood, LNG Limited and Don Hill, CB&I Lummus, USA, identify a new process that is set to change the direction of future LNG projects.

Figure 1. Artist's impression of Fisherman's Landing LNG facility.

A new, low cost, highly efficient process using simple, proven and low risk technology may benefit many future LNG projects. The process is based on a simple single mixed refrigerant cycle with the addition of conventional industrial ammonia refrigeration, and combined heat and power technology, which significantly enhance performance. The combination of process technology selection and an execution strategy maximising standard vendor packages and modular construction, results in a target plant cost that is less than half the unit cost of current LNG project developments. The process is very scalable with single train capacities that range from 0.5 to 3.5 million tpa. The highly efficient process and a compact layout result in a very small footprint, which together with the execution strategy permit a short construction schedule and low cost.

Simple but efficient

The new process, optimised single mixed refrigerant (OSMR™), was developed by Liquefied Natural Gas Limited (LNG Limited). The heart of the process is the mixed refrigerant (MR) cycle which consists of a gas turbine driven compressor with a single suction scrubber, after cooler, cold box, and MR separator. The selection of a centrifugal compressor that does not require a gear box, helper motor, or inter-stage components for the mixed refrigerant follows the philosophy of 'keep it simple and reliable,' and 'use well proven equipment.'

Figure 2. Completion of bulk earthworks for LNG tank at Fisherman's Landing.

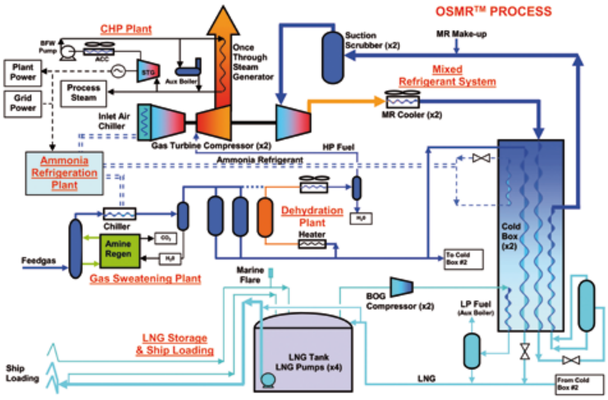

Figure 3. Schematic flow diagram of OSMR process.

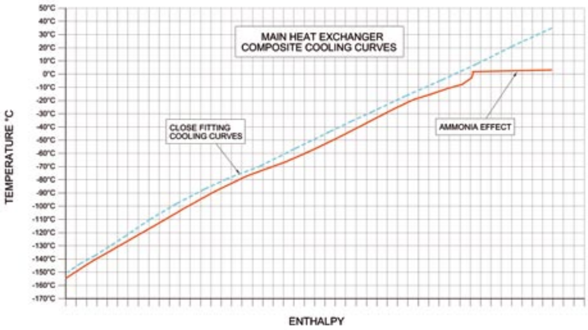

Figure 4. Composite heating and cooling curve for cold box.

LNG processes that do not fully recover the heat from the gas turbine exhaust waste substantial energy. Without waste heat recovery only one third of the fuel energy is converted into useful mechanical work. The high thermal efficiency of the OSMR process is achieved by recovering this waste heat in a simple steam cycle which is then used to satisfy all process heat, electrical power, and ammonia refrigeration energy requirements for the complete plant.

A focus on simplicity and efficiency leads to fewer items of equipment, a more compact layout and lower capital, operating, and maintenance costs.

First project

The first project to use the OSMR technology is the Gladstone LNG Project at Fisherman's Landing in Gladstone, Queensland, Australia. The FEED and capital cost estimate were recently completed by SKEC and Laing O'Rourke Australia (LOR). SKEC is a Korean EPC contractor with a strong history in oil, gas and petrochemical projects. LOR brings the Australian construction experience to the EPC JV. LOR is nearing completion of the AUS$ 780 million Darling Downs power plant in Queensland, which is the largest combined cycle power plant in Australia. Both SKEC and LOR have recruited a team of select individuals with extensive LNG experience.

To further enhance the LNG capability, CB&I has been appointed as project management consultants to assist LNG Limited in all aspects of project execution. CB&I has a long history in the LNG industry, having executed numerous LNG projects, and is currently entering the commissioning phase of the LNG liquefaction plant in Peru.

LNG Limited believed it was important that the EPC contractor undertake the FEED so they gain a good understanding of the project, and can take full responsibility for the scope and costs and roll this into the EPC contract. LNG Limited also had substantial input into the FEED, including process design and equipment selection, to ensure the outcome was in line with expectations after value engineering opportunities were fully explored. The EPC contract will have all the usual performance and completion guarantees.

A 30 month construction period is planned for the Gladstone project from commencement of foundation works to first LNG. This is much faster than conventional LNG projects, so Gladstone is due to produce LNG in Q3 2012, having commenced site preparation works in October 2009.

Train capacity

The Gladstone LNG Project train is designed to produce 1.75 million tpa of LNG using two 33 MW (GE PGT25+G4 or DR61G4) gas turbine drives, arranged in independent parallel single mixed refrigerant circuits. If one gas turbine is down for maintenance, the plant will still run at half capacity. If any of the multiple ammonia compressors are offline, the plant capacity slightly reduces.

The train capacity can vary depending on the selection and number of gas turbines. For instance, a train based on two LM6000 gas turbines would have 33% more capacity than Gladstone; a train based on three LM6000s would have a capacity of approximately 3.5 million tpa. Full and stable gas turbine power is achieved by using ammonia inlet air chilling.

Process description

Feed gas enters the LNG plant where it is sweetened in a conventional amine plant using aMDEA to remove CO_2 and H_2S. The warm saturated gas exiting the amine contactor is cooled using ammonia refrigerant, to remove the bulk of the water prior to being dehydrated in a conventional molecular sieve plant. The removal of bulk water is needed to reduce the size of the dehydration plant, and to allow regeneration to occur at high pressure thus avoiding compression of fuel gas for the gas turbines. Bulk water removal also ensures that the regeneration gas quantity is less than the fuel gas demand for the gas turbines, so no recycle compressor is required. Additional make-up fuel for the gas turbines is provided by the dry gas stream. Steam generated from gas turbine waste heat is used as the 'free' heat source for the amine reboiler, molecular sieve regeneration heater, and fuel gas superheater.

In line with the strategy to maximise the benefits of standard vendor packages, prefabricated packaged sweetening and dehydration units can be utilised where it is desirable, to reduce onsite work in remote locations.

Sweet dry gas enters the brazed aluminium heat exchanger in a cold box where it is liquefied at high pressure. The LNG exits the bottom of the cold box and flows to the LNG tank where it flashes to low pressure. No flash vessel or LNG pumps are needed. The flashed vapour and boil-off gas (BOG) are recovered from the LNG tank by two identical high efficiency, two stage, integrally geared BOG compressors. Only one compressor operates during normal operation while the second unit is started during ship loading. LNG is sprayed into the vapour return line from the ship during loading to maintain constant vapour temperature entering the LNG tank, and therefore constant suction (-150 ˚C) and discharge (-60 ˚C) temperatures on the BOG compressors.

The BOG and flash vapour is compressed to only 7 bara and returns to the cold box where it is substantially reliquefied. The two phase reliquefied BOG is separated and liquid methane returns to the LNG tank. Nitrogen concentrates in the flash gas, which is used as low Btu fuel gas for the auxiliary boiler. This system acts as a very effective nitrogen rejection unit. Only a small portion of the cold box refrigeration capacity is used for BOG reliquefaction; however, the feed gas quantity to the cold box is reduced slightly to avoid flaring of BOG during all normal operating conditions including ship loading.

Refrigeration for the cold box is principally provided by the mixed refrigerant, supplemented by ammonia at the warm end (top) of the cold box. The ammonia refrigeration plant is powered by 'free waste energy' generated by the combined heat and power (CHP) plant. The sizing of the ammonia plant is based on the spare power available from the CHP plant, after all other heat and power users in the plant have been met. This ensures optimum use and balance of all available energy. The ammonia refrigerant is firstly applied to cooling wet gas from the amine contactor, secondly applied to cooling inlet air to the gas turbines to increase power, and the remainder is used in the cold box for precooling the mixed refrigerant. The result is a substantial increase in plant capacity and a significant improvement in fuel efficiency. As an added bonus, water is condensed and produced when gas turbine inlet air is cooled with ammonia and this is more than enough to feed the demineralised water plant.

The single mixed refrigerant system comprises only four components: compressor, MR cooler, cold box and suction scrubber. The compressor is a standard single stage barrel/bundle type centrifugal with a polytropic efficiency of more than 86%. The compressor is directly coupled to a standard mechanical drive aero-derivative gas turbine package. No gearbox, no helper motor, no interstage cooler, no interstage scrubber, no discharge separator, no liquid MR pumps, and no MR metering are required. The mixed refrigerant consists of methane, ethane, butane, and nitrogen. The refrigerant composition, flow rate, and pressures are carefully selected to provide an excellent match of the composite cooling curves, as well as allowing major equipment such as the cold box to be economically sized.

The aero-derivative gas turbine efficiency is approximately 40% (NHV) which is approximately 20% better than the industrial Frame 7 or Frame 9 gas turbines used in many large scale base load LNG liquefaction plants.

Proven CHP technology is employed to recover the waste heat from the gas turbine, so all the process heat and electric power requirements for the plant are met, including all power for the ammonia refrigeration system. Steam is generated via 'once through steam generators' (OTSG) which power a single pressure steam turbine generator as well as supplying the required quantity of steam to various process heat users.

Approximately half of the electric power is used for the ammonia compressor drives while the remainder is consumed by various plant users. OTSGs are used to simplify the steam system design, again reducing the number of equipment items. The gas turbine(s) can continue to run and produce LNG even if the OTSG(s) are not operating, so no bypass stack and diverter damper are required.

The cold boxes for this capacity plant typically consist of six parallel cores manifolded together plus a common MR separator vessel. Only five streams are required within each core so the cold box configuration is very simple.

The differential temperatures between streams and resulting thermal stresses inside the cores are within the limits recommended by the ALPEMA standards, and comply with the heat exchanger manufacturer's requirements under all operating conditions. Start up (including cooldown) and shutdown procedures and control systems ensure thermal stresses are kept within limits during all operating conditions including process upsets. The ammonia cools the high pressure MR stream as well as ensuring the MR suction temperature is low to optimise the compressor performance.

The ammonia refrigeration uses a conventional industrial refrigeration process comprising motor driven screw compressors, condensers, separator vessels, pumps, pipework, instrumentation and control system. The use of ammonia for this application provides substantial advantages over propane refrigeration.

Conclusion

The improved performance of the OSMR liquefaction process is achieved by using proven, highly efficient gas turbine drives for the main refrigerant compressors, together with combined heat and power technology and efficient ammonia refrigeration. Although the process appears to be highly integrated, the overall plant availability is maintained by using reliable equipment, by configuring the train with two independent refrigeration circuits, and by providing back up power and heat for upsets and start-up.

The development of the LNG Limited Gladstone LNG Project has focused on simplicity, efficiency, and reliability. Single pressure OTSGs have been adopted to keep the combined heat and power plant as simple as possible, while maximising waste heat recovery. The mixed refrigerant system has been kept basic, choosing to exclude additional efficiency measures that would have added complexity, equipment and cost. Parallel refrigeration systems have been applied using proven equipment of sizes readily available in the market place, to ensure reliability and low cost. Where possible, vendor standard packages and modular execution have been selected, which are advantageous to both cost and schedule. **LNG**