IMPROVED LNG PROCESS
BETTER ECONOMICS FOR FUTURE PROJECTS

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- Low Cost
- High Efficiency and Low Emissions
- Simple and Reliable
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 but the performance is significantly enhanced by the addition of conventional combined heat and power technology and conventional industrial ammonia refrigeration. The result is a plant cost which is around half the cost of competing technologies and at least 30% more efficient resulting in 30% less emissions and substantially improved project economics.

The plant capacity is very scalable with single train capacities that range from 0.5mtpa to 3.5mtpa or more so multi-train plants can produce 10+ mtpa of LNG. Trains can be easily added as additional gas is proven or discovered. The required plot plan is substantially less than that needed for traditional LNG plants. The execution strategy using standard equipment and modular construction reduces the construction schedule.

The total plant cost ranges from $250 to $400/tpa including storage and ship loading, depending on capacity and site conditions. This compares very favourably with recent costs of $500 to $800+/tpa for competing technologies. The total fuel gas consumption including all power and auxiliary consumption is around 6.5% of feed gas which also compares favourably with competing technologies that use over 9%.

**Simple but Efficient**

The improved process is called the Optimized Single Mixed Refrigerant (OSMR™) process and was developed by LNG Limited. The heart of the process is a very simple single mixed refrigerant cycle which consists of a suction scrubber, compressor, after-cooler and cold box. It uses a standard single stage centrifugal compressor which does not require a gear box, helper motor or inter-stage components as do most other LNG plants.

Most LNG processes waste substantial energy by not fully recovering heat from the turbine exhaust. Only one third of the fuel consumption in traditional LNG plants is converted to useful mechanical energy to drive the compressor and the remainder is wasted to atmosphere via the exhaust. 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.

The true indicator of plant efficiency is the portion of LNG loaded on to the ship compared to the feed gas entering the plant. This includes all fuel required for compression and auxiliary power generation as well as BOG and flare gas. The OSMR™ process consumes around 6.5% of the feed gas on an energy basis which is a 30+% saving compared to traditional processes which use around 9%. Most operators and process providers only quote fuel gas consumed for the main compressor drives which excludes all auxiliary power generation and other fuel users. This 30+% saving in fuel equates to a similar reduction in greenhouse gas emissions.

A new approach to LNG plant design, with an emphasis on simplicity, was employed to achieve these results. Fewer items of equipment are required compared to traditional LNG plants so high availability and low capital and O&M costs are realized. At the same time, intelligent and full utilization of the available energy results in high plant efficiency. Significant increases in plant cost in recent years can now be challenged by utilizing the OSMR™ process.

A basic understanding of combined heat and power, industrial refrigeration, gas processing and cryogenic liquefaction is required to appreciate the technical and economic benefits of the OSMR™ process over traditional processes.
Proven Technology

There are several key differences between OSMR™ process and traditional processes as follows:

- Gas turbine waste heat recovery to produce power. This has been used in the power industry for decades and poses no technical challenges or risk.
- Gas turbine inlet air cooling using ammonia. Direct cooling of GT inlet air is successfully used in a number of power plants and has technical and economic advantages over the more traditional method using chilled water.
- Pre-cooling of MR using ammonia. This is successfully used in a small LNG plant in Western Australia. Since the cold box is a very simple design with minimal streams, the addition of ammonia to cool the MR from ambient temperature down to around 0°C only, is not technically challenging.

So these low risk but important differences have been proven in other industries and are combined in the OSMR™ process to generate substantial improvements in performance. This is achieved by using fewer equipment items and a simpler configuration than that used in traditional LNG processes.

Expertise

The process has been developed over the past 5 years. During this time numerous consultants, equipment suppliers, specialist plant designers and independent LNG industry experts have been engaged and have contributed to the successful outcome of this technology. Companies such as Foster Wheeler, Shell, BP, CHIV International, CB&I, Chiyoda and others have reviewed the process. In addition to this, LNG Limited has recruited personnel with extensive experience in the LNG industry. Before joining the company, they had the opportunity to critically review the process and LNG Limited’s approach to project development.

“There have been extensive reviews by many experts in the LNG industry and despite their detailed analysis, none have been able to find any flaws in the process” says Geoff Ellison who has 27 years experience with Shell on numerous projects ranging from GTL to refineries and LNG.

First Project

The first project proposed to use the technology is the Gladstone LNG Project at Fisherman’s Landing in Queensland Australia, where the FEED and cost estimates were recently completed by SKEC and Laing O’Rourke Australia (LOR). SKEC is a world class Korean EPC contractor with a strong history in oil, gas and petrochemical projects. LOR brings the Australian construction experience to the EPC JV. LOR recently completed the $780 million Darling Downs Power
Station in Queensland which is the largest combined cycle power station in Australia. Neither of these companies has LNG experience and this was a deliberate decision by LNG Limited to bring a fresh approach to an industry which is overdue for change. Both SKEC and LOR have recruited a team of select individuals with extensive LNG experience. To further enhance the LNG capability, CB&I were appointed as Project Management Consultants to assist LNG Limited in all aspects of project execution. CB&I have a long history in numerous LNG projects.

LNG Limited believed it was important for the EPC Contractor to 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. SKEC have taken joint responsibility for the process design and process guarantee along with LNG Technologies owned 100% by LNG Limited. The EPC contract will also have the usual performance and completion guarantees. The fixed price lump sum turnkey EPC contract price for 2 trains of 1.75mtpa each including 180,000m$^3$ of LNG storage and ship loading and all other facilities required for a fully operation plant is $350/tpa.

Another benefit is the fast execution schedule. A 30 month construction period is planned for the Gladstone project from commencement of foundation works to first LNG. This is much faster than traditional LNG projects. The fast schedule and low cost is also due to the application of membrane LNG tank technology provided by Kogas. This tank has been approved by the relevant authorities in Queensland.

Gladstone Site Preparation and LNG Tank Foundation Works

**Train Capacity**

The Gladstone LNG Project uses a 1.75 mtpa LNG train based on 2 x 33MW (eg GE PGT25+G4) gas turbine drives arranged as two independent parallel single mixed refrigerant circuits. The train capacity can be vary depending on the model selection and number of gas turbines. For instance, a train based on the LM6000 gas turbine would have a capacity of 33% more than Gladstone, so a train with 3 circuits using LM6000’s would have a capacity of 3.5 mtpa.

Full and stable gas turbine power is achieved by using inlet air chilling using ammonia refrigeration. This increases gas turbine power and plant output by around 20%. In addition to this, ammonia pre-cooling in the cold box increases plant capacity by another 20%. This is achieved by precooling the inlet MR and feed gas streams with ammonia so the low pressure outlet MR stream from the cold box can return to the main compressor at a lower temperature, thereby significantly improving the compressor performance.

The effect of ammonia cooling on plant capacity and the fact that it consumes no additional fuel is much greater than first thought. Ammonia cooling causes an increase in LNG plant capacity of around 40% without increasing the size and cost of the major components of the liquefaction plant being cold box, gas turbine and MR compressor. These two simple enhancements of cooling gas turbine air and pre-cooling the MR are major contributors towards the reduction in plant cost per unit of LNG produced.
**Process Description**

**Pretreatment**
Feedgas enters the LNG plant where it is sweetened in a conventional amine plant using aMDEA to remove CO₂ and H₂S. 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 consumed by the main turbines as is normally needed in other processes. 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. Prefabricated packaged sweetening and dehydration units can be utilized where it is desirable to reduce on-site work in remote or high cost locations.

**Process Schematic**

**Liquefaction and BOG**
Sweet dry gas enters the cold box where it is liquefied at high pressure in parallel brazed aluminium heat exchangers. 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 is recovered from the LNG tank by two identical high-efficiency two-stage integrally-gear 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 constant discharge (-60°C) temperature 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 re-liquefied. The re-liquefied 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, so this system also acts as a very effective nitrogen rejection unit. Only a small portion of the cold box refrigeration capacity is used for BOG re-liquefaction, however, to avoid flaring of BOG during ship-loading, the feedgas quantity to the cold box is reduced slightly. Other LNG processes require much larger high pressure cryogenic compressors to enable the BOG to be used as gas turbine fuel gas. Flaring is also common-place with other LNG processes during ship-loading.

Refrigeration
Refrigeration for the cold box is principally provided by the single mixed refrigerant supplemented by ammonia refrigeration at the warm end (top) of the cold box. The ammonia refrigeration plant is powered by “free waste energy” generated by the CHP plant. The sizing of the ammonia refrigeration 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 substantial improvement in fuel efficiency. As an added bonus, pure 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 ammonia refrigeration uses a conventional industrial refrigeration process comprising motor driven screw compressors, condensers, separator vessels, pumps, pipework, instrumentation and control system. Alternatively, a single direct steam turbine driven IG centrifugal compressor can be used. A comparison with propane refrigeration for this application revealed substantial advantages by using ammonia including efficiency, cost and safety. Ammonia is the most commonly used natural industrial refrigerant in the world so safe practices are well established.

“A conventional ammonia refrigeration plant is used to enhance the LNG process and this is the same type of plant that is used in thousands of applications. It fits perfectly into the overall LNG process” says David Hudson who has spent 30 years in design, construction and maintenance of industrial refrigeration systems with Gordon Brothers, a 93 year old refrigeration company.

Cooling required for the MR cooler, ammonia condenser and steam condenser can be provided by water (cooling tower or once through cooling) or by air or by a combination to the two.

The single mixed refrigerant system comprises only 4 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 over 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 mixed refrigerant pumps and no mixed refrigerant metering is required; as they are for other
processes. The mixed refrigerant comprises 4 components only, namely: 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 gas turbine efficiency is approximately 40% (NHV) which is ~20% better than the GE Frame 7 or Frame 9 gas turbines used in conventional modern large scale propane-mixed refrigerant processes. Aero-derivative gas turbines are used and these are well proven in mechanical drive applications. The Darwin LNG project uses these however there are many applications of aero-derivative gas turbines driving compressors in far more arduous applications than required for an LNG process (e.g. high pressure gas injection offshore). Since this is a routine and conventional application for the compressor, a full load string test is considered unnecessary.

Cold Box
The cold boxes for this capacity plant typically comprise six parallel cores manifolded together plus a common mixed refrigerant separator vessel. Only 5 streams are required within each core so the cold box configuration is very simple when compared to alternative LNG processes and typical ethylene processes. The differential temperatures between streams and resulting thermal stresses inside the cores are within the limits required by the ALPEMA standards and comply with the heat exchanger manufacturer’s requirements under all operating conditions. Startup (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 so the compressor performance is much improved. Ammonia is the most commonly used natural industrial refrigerant in the world so safe practices are well established.

Combined Heat and Power
Proven CHP technology is employed to recover the waste heat from the gas turbine so that all the 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 powers a single pressure steam turbine generator as well as supply the required quality 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. OTSG’s are used to simplify the steam system design again reducing the number of equipment items. No bypass stack or diverter damper is required so gas turbine(s) can continue to run and produce LNG even if the OTSG(s) are not operating.

Reliability
Although the process is highly integrated, which it needs to be to achieve high efficiency, the overall plant availability exceeds 96%, as compared to 90-92% for traditional processes. This is mainly due to the fact that, if one gas turbine is down for maintenance, the plant will still run at half capacity. Also, if an ammonia compressor fails, the plant capacity simply reduces slightly.

This is far better than traditional technology such as Propane-Mixed Refrigerant where the loss of one gas turbine causes a total train shutdown.

Conclusion
In summary, the high efficiency is achieved simply by using proven highly efficient gas turbine drives for the main refrigerant compressors together with combined heat and power technology and efficient ammonia refrigeration. This results in a plant cost which is around half the cost of competing technologies and at least 30% more efficient resulting in 30% less emissions and substantially improved project economics.

For more information, refer to the website of LNG Limited: www.LNGlimited.com.au