ZR-LNG – Dual Methane Expander LNG Liquefaction Process

1 Introduction and Process Configuration

GASCONSULT's patented ZR-LNG (Zero Refrigerant LNG) process is highly differentiated; unlike competing liquefaction processes it uses no external refrigerants, using the natural gas feed as the refrigerant medium in an optimised system of expanders. Compared to competing refrigerant cycles this eliminates refrigerant storage and transfer systems, reducing the equipment count, capital cost and space requirement. Make-up refrigerant is low cost natural gas instead of nitrogen or a mixture of liquid hydrocarbons; reducing operating cost. The absence of liquid hydrocarbon refrigerant also makes for a safer operating environment. A simplified process schematic is provided as Fig 1.

Refrigeration is effected in two expander circuits, a high temperature circuit indicated in red and a low temperature circuit shown in blue. Chilled gases from expanders EX1 and EX2 are routed to the cold box for cooling duty and then returned to the expanders by the recycle compressor CP1. Flash gas is recaptured to the system by a small compressor CP2 and routed through the cold box to the suction of the recycle compressor for return to the expanders.

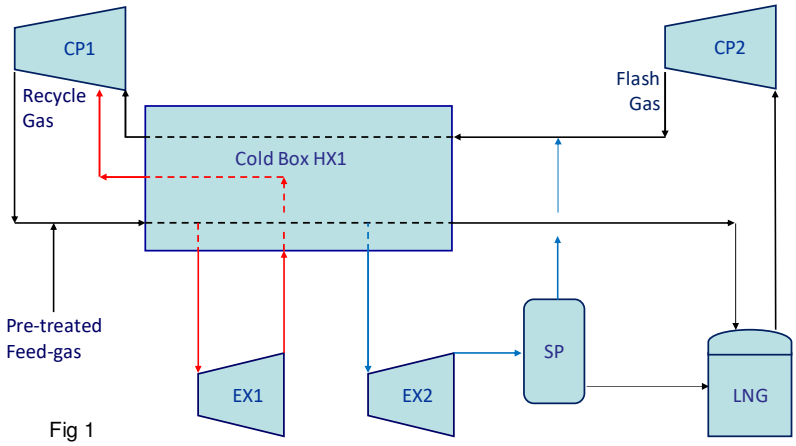

Fig 1

A patented feature is that a partial liquefaction takes place in the low temperature expander EX2 – this very efficiently converts latent heat directly into mechanical work and also permits a reduction in heat transfer area and cost of the main heat exchanger HX1.

These features, together with the optimised distribution of flows, temperatures and pressures in the expander circuits makes for a highly efficient system, around 300kWh/tonne in temperate climates; equivalent or better than single mixed refrigerant processes, and 15-30% lower than triple and dual expander nitrogen schemes. ZR-LNG achieves this without feed-gas pre-cooling, providing a very simple low equipment count facility. The low power demand also reduces CO_2 emissions.

2 Integrated Heavies Removal (IHR)

LNG liquefaction systems require removal of C5+ to <0.1 mol% and benzene to <1 mol ppm to avoid freezing and plugging of the main cryogenic exchanger. This is typically carried out in a scrub column upstream of liquefaction, operating at liquefaction pressure and heat integrated with the system. For feed-gases near their critical pressure, achieving satisfactory removal of C5+ and aromatics in a scrub column can be problematic. Leaner feed-gases with reduced levels of C_2 and C_3+ can also create instability in the scrub column due to lack of liquid reflux. Where there are concerns regarding scrub column performance a typical solution is to provide a separate upstream NGL removal unit, in which the feed-gas is expanded to a sub-critical pressure, the liquids condensed, and the depleted gas re-compressed to recover liquefaction efficiency. This adds cost and complexity. Many applications of the ZR-LNG process allow the heavy components to be removed by passing the feed-gas plus recycle gas through the high temperature gas

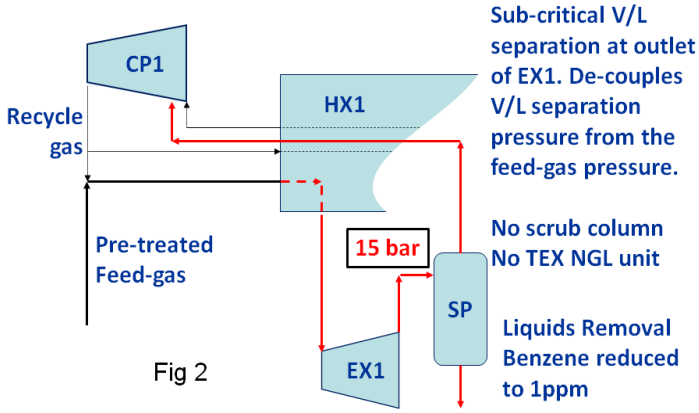

Fig 2

expander EX1 and separating the condensed liquids from the expander outlet at sub-critical pressure (see Fig 2). This IHR solution de-couples the vapour/liquid separation and feed-gas pressures and saves a large part of the equipment and cost of a separate expander based NGL removal unit. Specifically, the expander and re-compression facilities already exist in the basic ZR-LNG configuration. In addition to cost, the weight and footprint reduction is particularly relevant to FLNG applications.

3 Technology Advantages

In addition to its low power demand and reduced equipment count a further set of advantages stems from the Zero Refrigerant concept:

- There are no refrigerant logistics issues in remote or offshore locations. Import of hydrocarbons; and segregated storage to facilitate blending a mixed refrigerant are not required; and absolute security of refrigerant supply is also assured
- Well suited to lean feed-gases; no extraction of feed-gas components for refrigerant mix
- No propane or other liquid hydrocarbon refrigerants – a safety plus relative to mixed refrigerant schemes, particularly for FLNG where personnel exit options are limited
- Single phase refrigerant makes the system motion tolerant and well suited to FLNG
- Reduced cost, weight and footprint from the absence of refrigerant extraction equipment and infrastructure; and simpler C5+ removal makes the system particularly suited to FLNG
- Several operational benefits relative to mixed refrigerant schemes; no refrigerant make-up cost, no ongoing composition adjustments, shorter start-up time, reduced flaring

4 Technical Validation

The ZR-LNG process steps are well established in cryogenic gas processing plants. Two oil majors and 4 EPC companies have audited ZR-LNG and confirmed the process concept. One EPC has completed preliminary engineering to confirm the process design and produce equipment specifications, layouts, MTOs, weights and a cost estimate. The work included RAM, safety and dynamic simulation analyses. GASCONSULT has also worked with leading OEMs to confirm that all equipment operates within a window of proven operating experience. Table 1 provides a summary of matched rotating equipment for various single train capacities.

TABLE 1

Major Equipment	0.9 Mil TPA	1.1 Mil TPA	1.5 Mil TPA	2.2 Mil TPA
Gas Turbine	PGT25+G4	LM6000PF	LM6000PF+MD	Frame 7
Compressor Model/Abs Power MW	2BCL800 / 29.8	2BCL1007 / 34.8	2BCL1400 / 46.7	2BCL1400 / 81.5
Expander LT Model/Power MW	EC50-1 / 5.4	EC50-1 / 6.7	EC50-1 / 9.5	EG50-1 / 13.4
Expander HT Model/Power MW	EC60-1 / 11.1	EC50-1 / 13.8	EC50-1 / 8.6	EC60-1 / 13.8
Expander HT Model/Power MW			EC50-1 / 8.6	EC60-1 / 13.8

5 Commercial Basis of the ZR-LNG Offering

GASCONSULT offers ZR-LNG on a licensed basis through provision of front end packages of flexible scope to suit client's requirements. Licenses are available to LNG producers directly who may then arrange for plant design and installation by an EPC company of their choice. Licenses are also available to EPCs who may wish to offer the technology on a case by case project basis.