GASCONSULT OHL HYDROGEN LIQUEFACTION TECHNOLOGY

EXECUTIVE SUMMARY

Gasconsult has developed technology for mid to large-scale hydrogen liquefaction. Relative to competing technologies Gasconsult's process, OHL (Optimised Hydrogen Liquefaction) provides the high energy efficiency and high capacity required to make a meaningful and economic contribution to the scale of decarbonisation inherent in the energy transition. OHL achieves a power demand some 40% lower than current new-build practice with a projected 20% lower capital cost.

The technology enjoys significant patent protection. Please see Appendix 1.

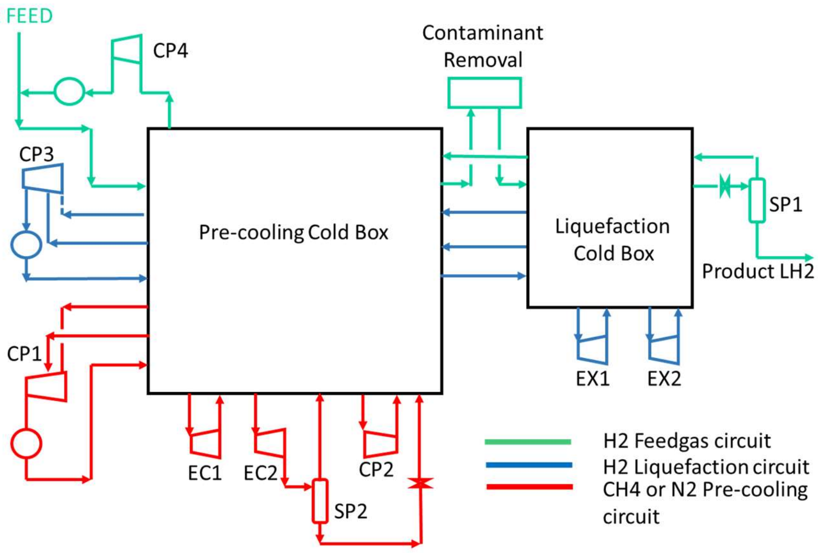
The design and configuration of OHL have been independently validated by both McDermott and Costain, leading engineering companies expert in cryogenics. The validations covered the process design, control scheme development, evaluation of mechanical equipment availability/performance, design safety issues and environmental impact. An index indicating the depth of the validation work is included as Appendix 2.

THE TECHNOLOGY

OHL – OPTIMISED HYDROGEN LIQUEFACTION

A schematic of OHL is provided below.

CP1	C1/N2 Refrigerant Compressor
CP2	C1/N2 Recycle Compressor
CP3	H2 Refrigerant Compressor
CP4	H2 Recycle Compressor
EX1	Warm H2 Expander
EX2	Cold H2 Expander
EC1	Warm Expander-Compressor
EC2	Cold Expander-Compressor
SP1	Separator
SP2	Separator
PCB	Precooling Cold Box
LCB	Liquefying Cold Box



OHL is a two-stage scheme comprising pre-cooling and liquefaction steps. The dual-expander pre-cooling configuration uses a single refrigerant, either natural gas or nitrogen, and avoids the infrastructure needed to transfer, store and blend conventional liquid refrigerants. The low temperature expander EC2 operates in a partially liquefying mode, improving cycle efficiency. This partial liquefaction reduces the total power demand of the hydrogen liquefaction process and is a distinctive and patented feature. For final cooling and liquefaction, the cycle uses the hydrogen feed as refrigerant.

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The process achieves a power demand, including ortho/para conversion, of <7.0kWh/kg LH2, some 40% lower than current practice. Engineering development has established OHL as viable at capacities up to 350 tonnes per day (125,000 tpa), a high level relevant to the demands of the energy transition

The pre-cooling refrigerants, nitrogen or natural gas are readily available and low cost. The liquefaction step uses hydrogen which is integral to the process. There is no requirement for exotic and high-cost neon or helium, or the complexity of mixed hydrocarbon refrigerants.

A number of features are patented and contribute to the reduced power demand.

APPENDIX 1 - PATENTS

Technology	Awarded Patents	Patents Pending
OHL (Optimised Hydrogen Liquefaction)	2022 – UK: GB 2601173 2026 – JP: 7809364 2023 – UK: GB 2609503	EU 21811420.5 (PCT/GB2021/000117) Plus: AU, CN, KR, US GB 2205939.8 (Exchanger Design) Plus: CN, JP, KR,
H2 Cold Exchanger		PCT/GB2023/000014 plus CN, JP, KR Optimised exchanger configuration
Production of H2 Gas		2025 GB2512659.0 Gaseous H2 production with 60% lower power demand than electrolysis

APPENDIX 2 – INDEX OF ENGINEERING VALIDATION WORK PERFORMED BY MCDERMOTT

A comparable study was also undertaken by Costain on behalf of an oil major. It covered additional safety and environmental issues. It confirmed McDermott's analysis.

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