Thermodynamic analysis of simple Linde-Hampson hydrogen liquefaction systems with G-M cryocoolers

H.M. LIM [1,2], S.Y. KIM [3], G.W. KIM [2], G.H. RHEE [2], S.W. KARNG [1,*]

[1] Korea Institute of Science and Technology, Republic of Korea
[2] University of Seoul, Republic of Korea
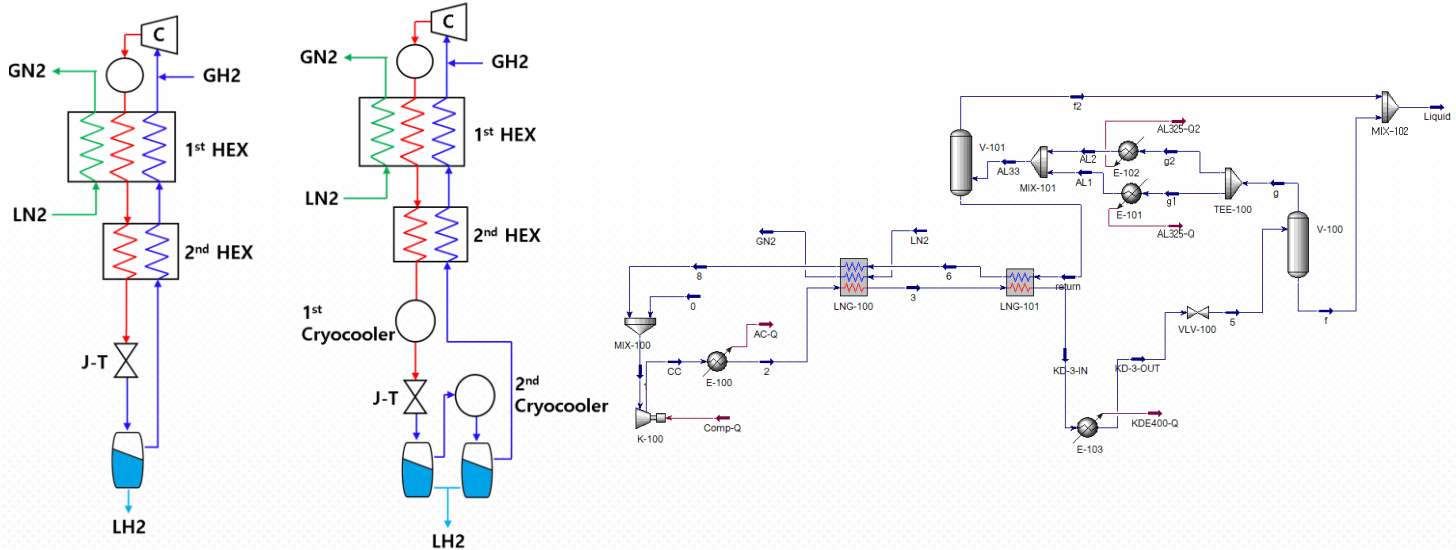[3] Hylium Industries, INC., Republic of Korea

[*] Corresponding author, email : libra@kist.re.kr

- According to 2030 milestones in the transportation sector by Hydrogen Council (2017), 0.63 million cars will be powered by hydrogen in Korea, 2030 (MOTIE, Korea).
- The economical point of hydrogen energy supplied by liquid is over 500kg/day of station's capacity and over 0.1 million cars were used in Korea (MOLIT, Korea).

<Typical L-H system>   <Modified L-H system>

- ✓ Small-scale hydrogen liquefaction considering depreciation and break-even point of the liquefaction plants in the early hydrogen market within 2025.

- ✓ The modified cycle was designed by applying G-M cryocoolers to improve the ordinary Linde-Hampson cycle.

- ✓ The target of liquefaction quantity : 100 kg/day

3. Results

	Typical L-H	Modified L-H	Remarks
Mass flow rate GH$_2$ (kg/h)	50	30	@ 9 MPa
Liquefaction LH$_2$ (kg/day)	110.5	**114.8**	
Consumption LN$_2$ (kg/day)	1240	1134	
Comp, Power (kW)	208	125	
Cryocooler Power (kW)	-	29.5	Cryocoolers, Datasheet
Total Cost (USD/day)	1,025	803	KEPCO, KPRC

✓ The modified Linde-Hampson system can produce an amount of LH2 at low costs comparable to existing systems. The costs were based on the KEPCO, KPRC data.

✓ The mass flow rate of hydrogen can be reduced in the modified Linde-Hampson cycle with the 1st cryocooler before the expansion. So that, the compressing power consumption was decreased.

✓ The inherently low exergy efficiency of the J-T valve could be overcome by a small amount of auxiliary cooling of cryocooler.
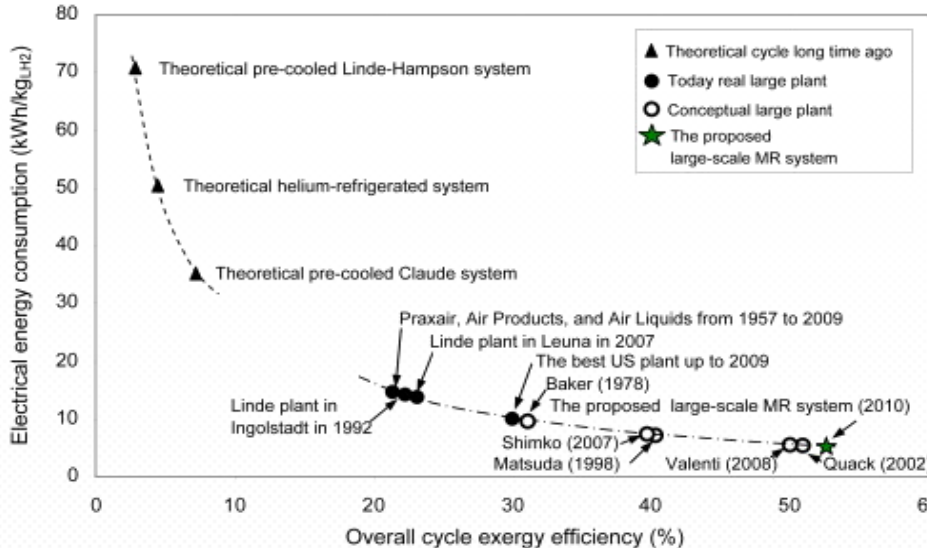
S. Krasae, J.S. Stang, P. Neksa, Development of large-scale hydrogen liquefaction processes from 1898 to 2009,
Int J Hydrogen Energy, 35 (2010), pp. 4524-4533

✓ The electric energy consumption (32.3 kWh/kgLH2) of the lowest case for the modified Linde-Hampson system is calculated at half the theoretical pre-cooled Linde-Hampson system.

✓ The modified Linde-Hampson system is the available choice of the investment of hydrogen infrastructure for the early hydrogen market at Korea, although it is not high efficiency system.