Gas Liquefaction Applications, Paper No. 11.8

The Modified Linde-Hampson Cycles with GM-JT Refrigeration for Small-Scale Hydrogen Liquefaction Processes

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The Linde-Hampson cycle with a GM cryocooler was proposed to improve low efficiencies of small-scale hydrogen liquefaction processes. Normal Linde-Hampson processes consist of a compressor, a precooler using LN2, a JT (Joule-Thomson) valve and a heat exchanger (HEX) between GH2 around 80K after the LN2 precooler and GH2 around 20K returning from the liquefier. The HEX is required to be designed to cool additionally GH2 down at least 49K due to JT inversion. It is very important that the temperature of GH2 was cooled to the range 47~49K by the HEX since the liquefaction rate rapidly increases only under the prefer temperature drops of GH2. In other words, cooling GH2 below 47K increases the efficiency of JT expansion, but is not good for the liquefaction rate as the ratio of gas to liquid decreases, resulting in a lack of GH2 around 20K to cool GH2 around 80K. The simulations of processes were carried out by ASPEN HYSYS V11 and NIST REFPROP 10.0. As results, the maximum liquefaction rate was 195 kg/day, consuming the lowest electricity of 25 kWh/kg_LH2 at 47K of GH2 before the JT expansion and under 8 MPa of working pressure. This energy consumption is only 36% of the theoretical Linde-Hampson cycle (around 70 kWh/kg_LH2).