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C3Po1E-03 [26]: Thermodynamic Performance Comparison of Miniature Liquid Nitrogen Generators driven by Mixed-refrigerant Joule–Thomson Cycle and Gas Expansion Cycle

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Thermodynamic performance analysis and comparison of two types of miniature liquid nitrogen generators are conducted in this paper. Feed nitrogen (or air) is cooled and liquefied by a propane precooled mixed-refrigerant Joule–Thomson (MRJT) refrigeration cycle, or a feed gas expansion process (precooled Kapitza cycle), respectively. Pure nitrogen supplement and mini air separation columns are combined with these two refrigeration cycles respectively. Feed nitrogen (or air) is charged by normal air compressors with discharge pressures no more than 9.0 bar (a). Both of these two types of processes are designed only for liquid nitrogen production. No gaseous product is accounted in the performance evaluation, which is relatively different from normal air separation plants.

It is indicated that the overall performance of MRJT type is obviously superior to Kapitza type only for liquid nitrogen production with low pressure feed gas. Firstly, the efficiency of MRJT type is higher than Kapitza type. With pure nitrogen supplement, the specific power consumption (SPC) and figure of merit (FOM, exergy efficiency) of MRJT type are 0.52 kWh L-1 and 26.86% respectively, with a contrast of 1.06 kWh L-1 and 16.04% in Kapitza type. With mini air separation column, the SPC and FOM of MRJT type are 0.78 kWh L-1 and 21.42% respectively, better than those of 1.56 kWh L-1 and 10.75% in Kapitza type. Exergy loss distribution analysis showed that the large losses in non-isentropic expansion process and after cooler are the main reasons of the inferior efficiency of Kapitza type. Secondly, for hardware, the total compressor displacement per liquid LN2 production capacity of MRJT type is 28.53% and 30.65% of that in Kapitza type, with pure N2 and column respectively. However, the total heat exchanger UA value of MRJT type is larger than Kapitza type.

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