In 310-80 K pre-cooling stage, the temperature of the HP helium stream reduces to about 80 K with achieving 73 % of total enthalpy drop.

Among the cryogenic systems having been completed in the last ten years, SNS, EAST and JT-60SA cryogenic helium systems adopt liquid nitrogen to cool HP helium stream to about 80K. KSTAR cryogenic system uses turbine expander-based cooling stage that replaces the pre-cooling stage. Wendelstein-7X cryogenic system has liquid nitrogen pre-cooling as well as turbine expander-based pre-cooling.

In this study, exergy efficiency, total UA of heat exchangers and operating cost of two 310-80 K pre-cooling configurations are computed and compared. This work will provide a theoretical guide for choosing 310-80 K pre-cooling stage configuration.

2. Thermodynamic model of 310-80 K pre-cooling stage

Assumptions
- The system is in a steady state.
- The isothermal efficiency of compressor and isentropic efficiency of turbine are constant.
- Pressure loss in oil remove system, heat exchanger and pipes is negligible.
- No heat leak of heat exchangers.

Initial parameters
- T1=T5=310 K, T2=T6=80 K, m2=m6=100 g/s;
- Temperature difference of hot end in HX2 & HX4 is 2 K;
- Temperature difference of hot end in HX1 & HX3 is 10 K;
- Turbine 5-6 cryogenic system has liquid nitrogen pre-cooling as well as turbine expander-based pre-cooling.
- In this study, exergy efficiency, total UA of heat exchangers and operating cost of two 310-80 K pre-cooling configurations are computed and compared. This work will provide a theoretical guide for choosing 310-80 K pre-cooling stage configuration.

3. Results and discussions

3.1 Refrigeration mode

3.2 Liquefaction mode

3.2.1 310-80 K pre-cooling stage with LN2

4. Conclusions

- Both in refrigeration and liquefaction mode, exergy efficiency of 310-80 K pre-cooling stage with liquid nitrogen is higher than with turbine, while the demand of total heat exchangers UA is smaller due to larger heat transfer temperature difference.
- Apart from the turbine isentropic efficiency, isothermal efficiency of the compressor, acquisition cost of liquid nitrogen and price of the local electricity will have great influence on their economical performance.
- Higher compressors’ discharge pressure leads to higher exergy efficiency for 310-80 K pre-cooling stage with liquid nitrogen. However, discharge pressure almost has no effect on its total UA and operating cost.
- For large-scale helium cryoplant, it is more economical to set up liquid nitrogen cryoplant to provide liquid nitrogen to cool the HP helium stream because of very low production cost of liquid nitrogen.

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