Exergy Analysis and Improvement of Helium Internal Purifier

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1 Introduction

To ensure proper operation of the liquefier and protect experiments from frozen trace gases that might block the capillaries, the purification process has to be adapted to these new requirements. Due to the simple working principle, high degree of automation, the internal purifier is generally processed and manufactured together with the liquefier and highly integrated into the liquefier.

Exergy analysis was carried out on the process of helium inner purifier , exergy loss of each component of the system was judged, and a new Process Flow Diagram (PFD) of inner purifier was given.

2 Model analysis

Method

Exergy Balance Equation

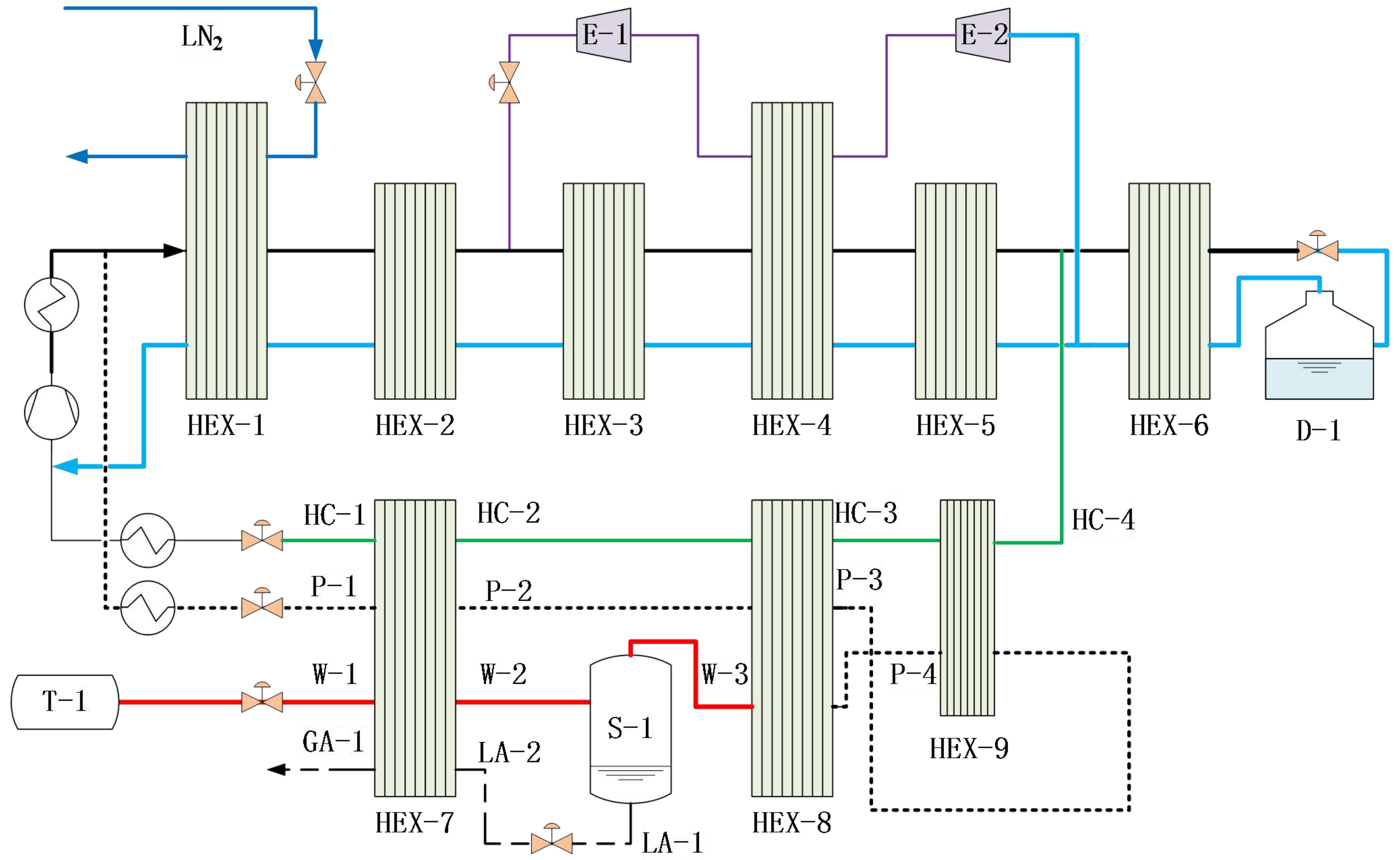
$$\sum_j Q_j\left(1-\frac{T_0}{T_j}\right) - W + \left(\sum_{in} Ex_{FLOW} - \sum_{out} Ex_{FLOW}\right) - Ex_{DEST} = 0$$

Liquid yield

$$y = \frac{m_L}{m_{CB}} \times 100\%$$

Liquefier with internal purifier

The helium liquefaction mainly includes liquid nitrogen pre-cooling stage, expander-based cooling stage and throttling expansion stage . The internal purifier is based on the gas behaviour of decreasing vapour pressure with decreasing temperature. The impure helium feed is cooled down by the cryogenic helium supplied from the liquefaction process. The main part of the contained air impurities (mainly nitrogen and oxygen) is liquefied in HEX-7. Remaining air impurities freeze out along HEX-8. The purified helium gets warmed up again to ambient temperature before joining the high-pressure stream of the helium liquefaction cycle. The cold helium gets warmed up and returns to the low-pressure stream of the helium liquefier.



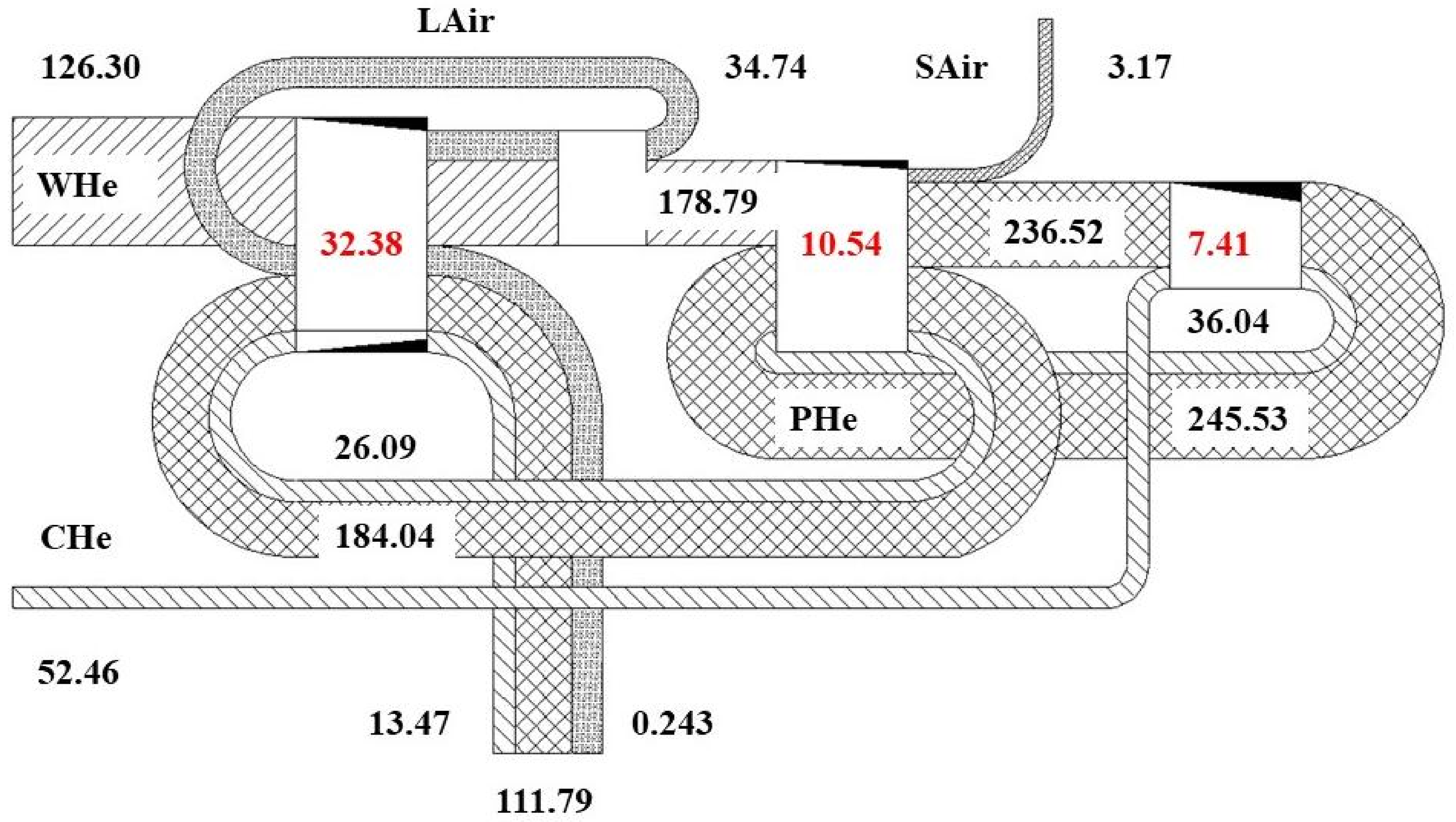
PFD of He liquifier with new internal purifier

Advantage

- The cryogenic helium supplied from the liquefaction process
- The separated liquefied air was used to cool the impure helium
- The impurity treatment range of the internal purifier has been effectively expanded.

3 Results

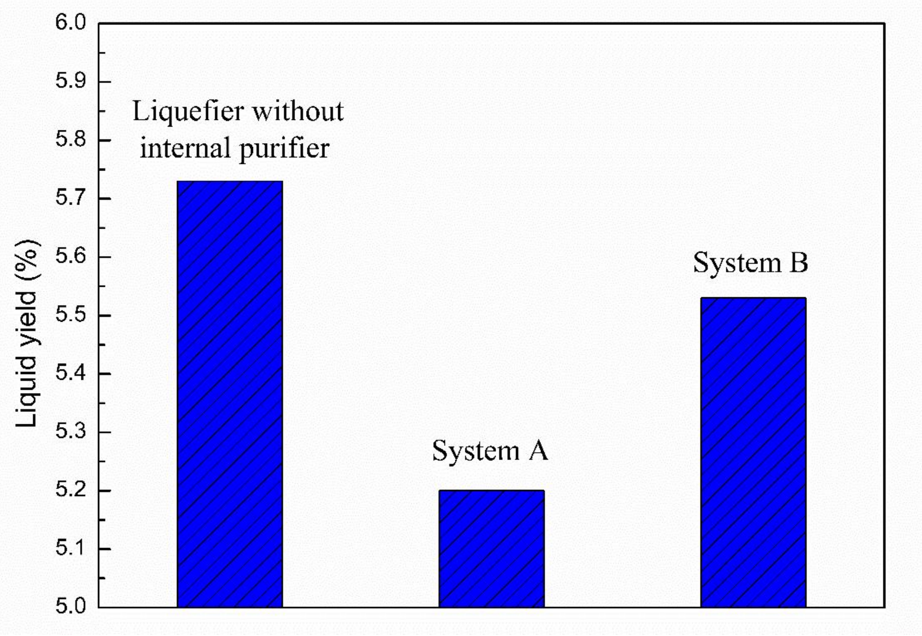
- Exergy of liquefied impurity was much higher than that of solidified impurity.
- The energy of liquefied air was almost fully utilized.
- The input exergy flow of the cold helium was significantly reduced.
- The exergy of impure helium remains almost constant, but exergy destruction of each exchanger was reduced



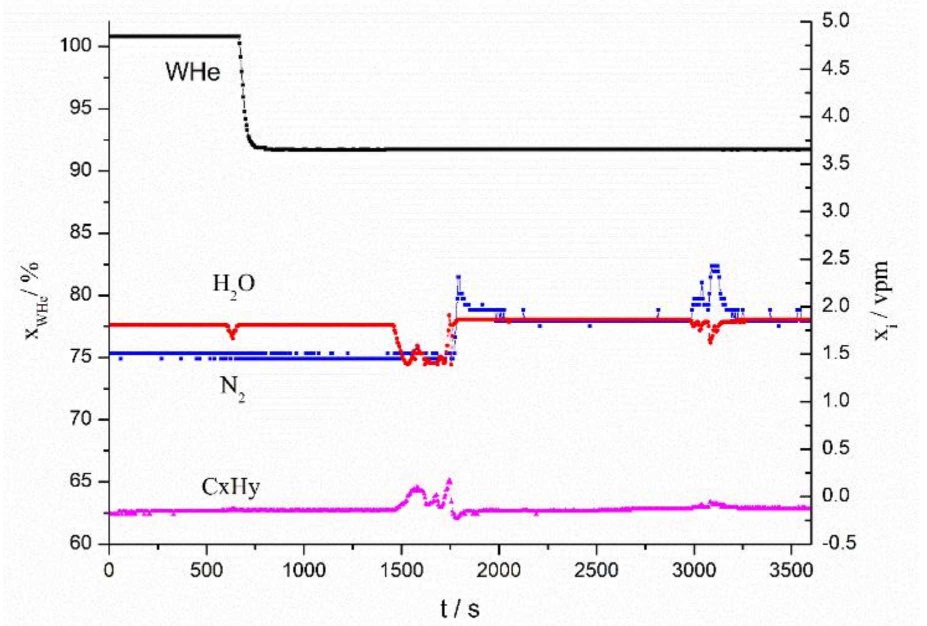
Exergy-flow diagram of internal purifier

Table 1 Exergy destruction and liquid yield of each PFD

Components	New PFD	Old PFD
compressor	8.9%	9.0%
cooler	54.8%	55.8%
heat exchangers	22.3%	20.8%
expanders	14.0%	14.4%
total exergy destruction (W)	3222.82	3154.66



The liquid yield of each system



Component analysis result

4 Conclusions

- The application of the new internal purifier can effectively increase the liquid yield than the old one. When removing air impurities at 10 mol%, the liquid yield was increased by 6.3% when the cooling capacity of liquefied air was utilized.
- The localization and distribution of exergy of liquefier are identical to those already obtained in the literature. Exergy destruction in heat exchangers of internal purifier utilized liquefied air was reduced by more than 50% .
- With the utilization of liquefied impurities, the cold helium consumption decreases, and the exergy of cold helium decreases.
- The impurity treatment range of the internal purifier has been effectively expanded. The purifier removed air impurities up to 8 mol%.

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