Numerical Simulation of Heat Transfer for Wall-type and Fin-type Heat Exchanger

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Abstract

Wall-type heat exchanger(WTHX) and Fin-type heat exchanger(FTHX) are attached to the first and second stage cold head of two G-M crycoolers respectively in the simulating experimental platform of the internal purifier(SEPEIP). WTHX and FTHX play a significant role in SEPEIP, WTHX is designed to remove heat from helium and freeze-out extremely few impurities, FTHX is for further cooling the helium. In this paper, numerical simulation and theoretical calculation for WTHX and FTHX are carried out. However, Numerical results are not so well consistent with the theoretical results. The cause of error is also investigated.

Conclusion

The WTHX and FTHX can be used in small scale helium liquefaction system and small scale helium refrigeration system. Comparing with coiled copper tube welded on the cold head, WTHX and FTHX are easily installed. And most importantly, WTHX and FTHX need not to be welded on the cold head, so the cold head will not be damaged by the high temperature of welding. However, the performance of heat exchange of WTHX and FTHX are not so good as coiled copper pipe.

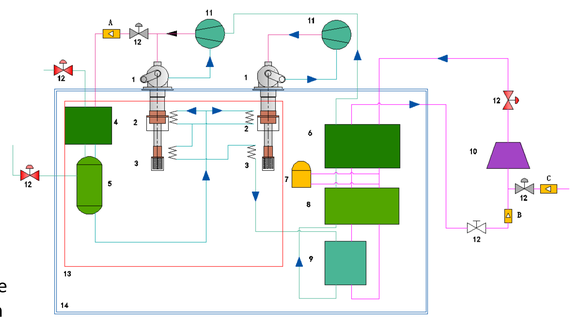
Introduction and Design

The reason of Built IPSEP

Internal purifier is an essential part in the Helium Cryogenic Refrigeration System(HCRS) and Helium liquefier System(HLS).

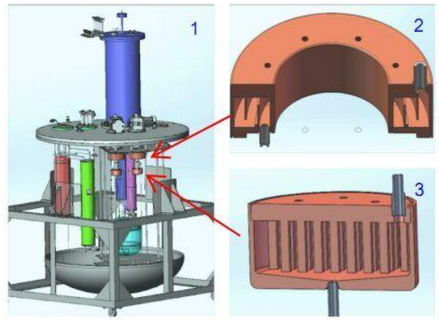
Internal purifier is necessary to be arranged in the system, to remove impurities, like, N_2, O_2, Ar, etc, from helium gas stream to about 1PPM level

In order to test the purification performance of the internal purifier, we have built a Internal Purifier Simulation Experimental Platform(IPSEP).



Schematics of Internal Purifier Simulation Experimental Platform(IPSEP)

The Construction of IPSEP

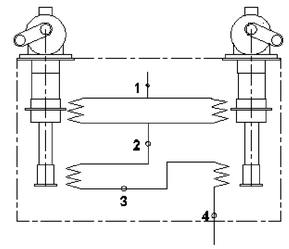


The IPSEP consists of two parts, one part mainly providing cold load to internal purifier is called Cold Box Section, another part is called Internal Purifier Section.

WTHX and FTHX are screwed on the first-stage and the second –stage of the cold head respectively.

WTHX and FTHX are all made of copper, because of the excellent conductivity of copper at cryogenic temperature.

Heat Exchange of Cold Head

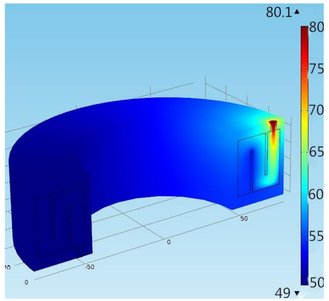


Point	Temperature(K)
1	80.04
2	47.85
3	21.76
4	12

The temperature of the four points on the cold head, they are used for calculating the heat transfer area of the cold head.

Simulation results

Simulation of WTHX and FTHX



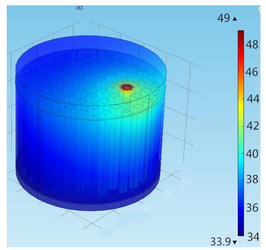
We have already known the Mass Flow of the system, it's 0.1214 g/s. And the inlet temperature of the WTHX is 80.04 K.

The cold load of the cold head is also defined. Other basic assumptions were as follows:

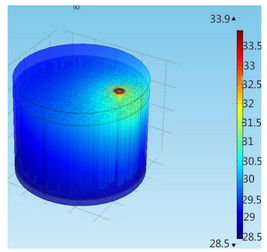
- Axial heat conduction is not concerned
- Constant wall temperature at the 1st and 2nd stage heat exchangers
- Boundary and variable parameters effects are neglected
- Laminar flow conjugated with heat transfer

The simulation is stationary and the grid is unconstructed. Finally, temperature field of the WTHX is gotten. The temperature drop at the WTHX is almost 30 K, and it is very closed to the theoretical calculation.

FTHX 1



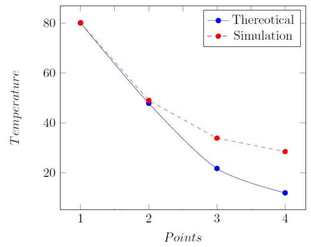
FTHX 2



The modeled FTHX is also copper material cavity, moreover it has lots of fins within it which can increase the heat transfer capacity of FTHX. The temperature of the inlet of FTHX 1 is taken the outlet temperature of WTHX, namely it is 49 K. Then we choose the same simulation model as WTHX, and the temperature field of the FTHX 1 and FTHX 2 is obtained.

Discussion

Comparison



Simulation results are not in good agreement with theoretical calculation, which are much higher than theoretical calculation. Figure 10 can clearly show us the difference between theoretical results and simulation results. The theoretical and simulation results of WTHX agreed well, but the results of FTHX 1 and FTHX 2 are not so good as WTHX. There are several reasons resulting in the inaccuracy of simulation results.

- The physical properties are variable with the temperature, but we choose the physical properties of the point at mean temperature.
- The laminar flow conjugated with heat exchanger simulation model may suit for simulating the heat exchanger of the WTHX, but not so perfect for the FTHX
- Theoretical calculation of FTHX is using free convection method which may cause so large error between theoretical results and simulation results
- The density of helium is increasing as the temperature decreasing, so the velocity of helium is slow down, which also has a impact on the inaccuracy.

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