Experimental Study of an Aerospace Low Temperature Refrigerator Cooled by a PTC

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Background

In International Space Station (ISS), some experiments need low temperature for cryogenic storage of biological products, electronic components and so on. Low temperature refrigerators(LTRs) can offer cooling powers at the temperature of -40℃ ~ -150℃ and have been used in ISS. At present, SITP has designed, built and tested a single-stage coaxial pulse tube cryocooler (PTC) for cooling an aerospace LTR.

Objectives

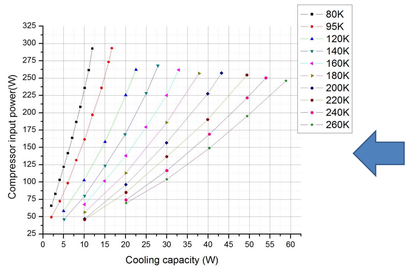
- The designed coaxial pulse tube cryocooler can offer 30W cooling power at 170K.
- The LTR can be cooled down to -90℃, whose cooling volume is about 20 liters .

Conclusion

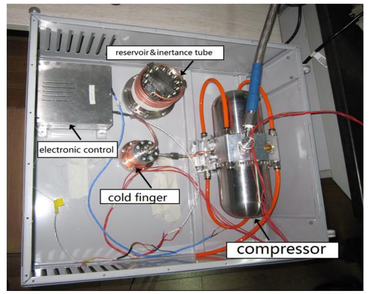
- A successful new coaxial PTC have been designed, manufactured and tested at SITP, which can offer 30W cooling power at 170K.
- Some simulations are carried out by CAD/FLUENT for helping predict LTR inside temperature uniformity. Several walls' temperature differences are less than 4℃.
- The LTR's six walls' temperatures can be cooled down to about -90℃ when the PTC input power is about 128 W.
- Simulative and experimental results are compared, which can help LTR cabinet optimized to decrease its heat leakage.

PTC System

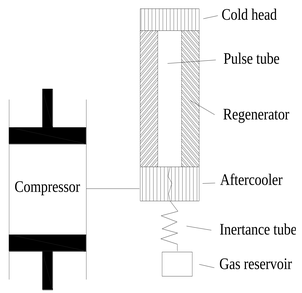
Cooling performance



PTC system



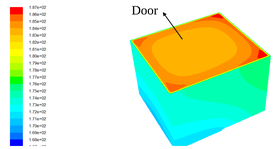
Schematic of PTC



LTR Cabinet

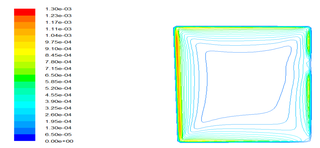
LTR cabinet

Temperature contour



- The Temperature difference between door and rear wall is about 19℃
- The air temperature difference is less than 4℃ in most areas, which is acceptable for LTR storage.

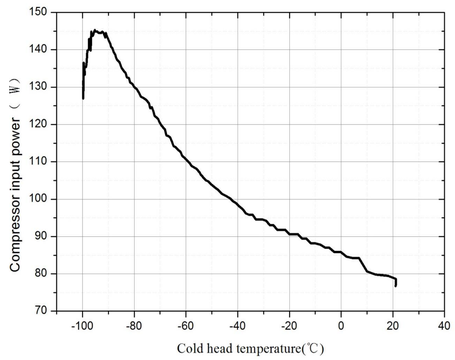
Velocity contour



The maximum air velocity is about 0.0013m/s in the boundary layer near the copper wall and the air velocity in the middle area is about zero

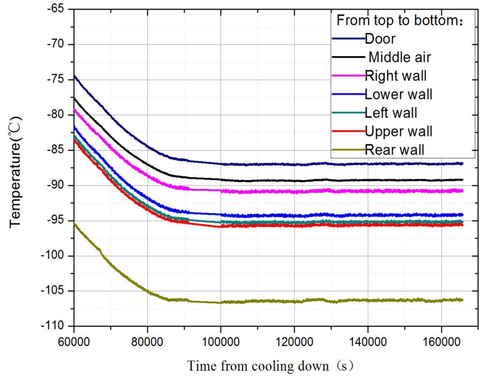
Results

Compressor input power vs. cold head temperature



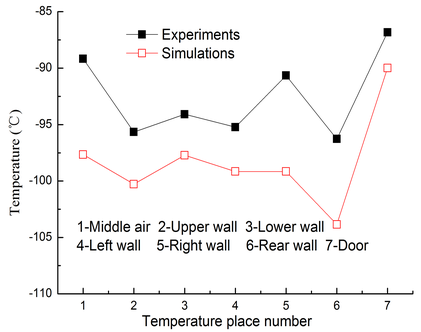
- The compressor input power increases as the cold head temperature decreases.
- When the cold head temperature is -92℃, the input power will be increased up to 144W.
- When the cold head temperature is constant -100℃, the input power will be kept with 128W.

Cool-down curves of the LTR



- When the PTC input power is increased from 115W to 144W gradually, its cold head will take about 23 hours to cool the walls' temperatures down to -90℃ around.
- The rear wall is average 14℃ lower than the others because it is directly mounted to the PTC cold head.

Simulation and experiment results



- The difference between the experimental temperatures is about 5%
- The temperature difference between copper walls is larger than predicted values, which means that the door insulation should be further optimized

ICEC 25 – ICMC 2014; University of Twente, Netherlands; Session3.1: No.C-04; 10th July, 8:30—12:45