Heat exchanger in the Ultra Colt Neutron source

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Introduction

Ultra Cold Neutron source

The UCN source will be a part of an experiment at TRIUMF that will study the dipole moment of neutrons. It will store neutrons up to 100 s. By cooling and slowing down the neutrons in liquid He^4 at about 0.8 K, their energy will not be high enough to cross the potential barrier of the vessel anymore. The most effective and cheapest way to reach this temperature is by using heat exchangers (HEX) and Joule-Thompson valves.

Heat exchanger

Different kinds of heat exchangers and condensers will be used to cool He^4 from 4 K to 1K. Because of its low condensation temperature, the isotope He^3 will be used as coolant in HEX1, see Figure 2. During the experiment the He^4 from the vessel will lose energy and evaporate. To recycle the remaining energy of this gaseous He^4, it will be used as a coolant in the heat exchanger and lower the temperature of the He^3.

Concept

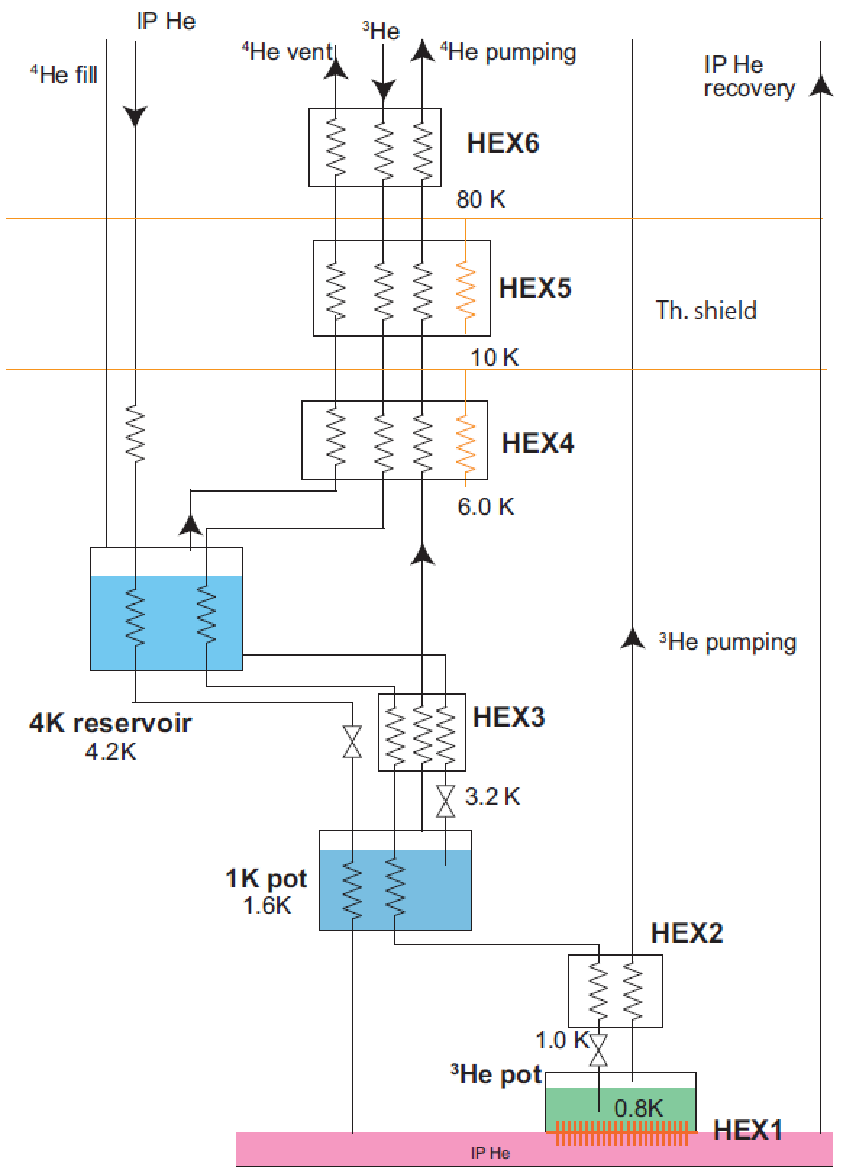


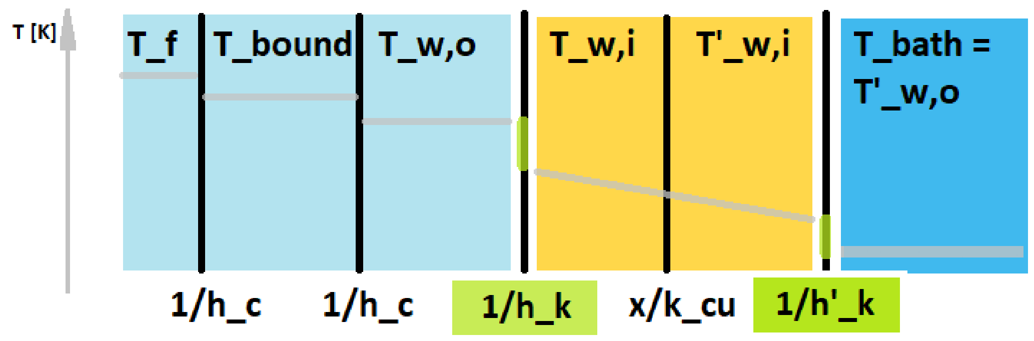
Figure 1: Flow diagram of the coolants He^3 and He^4

Cooling the He^3 with heat exchanger

Figure 1 shows a schematic flow diagram of the future cryostat at TRIUMF. In this report the heat exchanger in the 4K reservoir, 1K pot and the He^3 pot were calculated. The cryostat will be used to cool and condense He^3 to 0.8 K, so it can cool the He^4 in the last pot. In the final experiment the He^4 will be used, to slow down the neutrons. When the He^4 evaporates, due to the energy it will get from slowing the neutrons down, it will be fed as a coolant for the He^3 into the cryostat.

Subject prospect

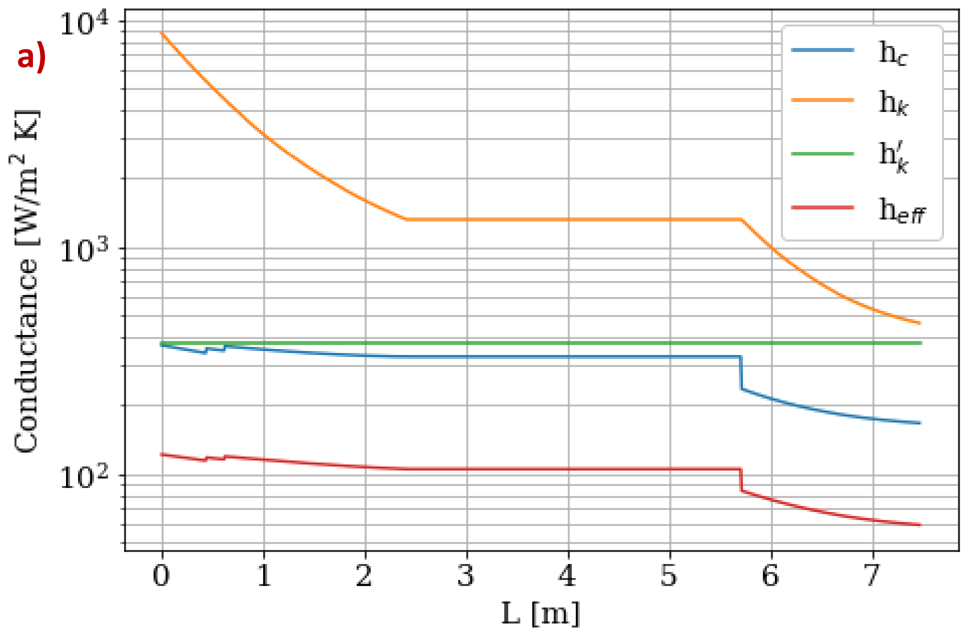
The goal is to use as few He^3 in the tube of the heat exchangers as possible. Due to the high price of this coolant, the money can be saved using this way. If the tube is too short, the heat exchangers won't extract enough energy to cool and condensate the He^3.

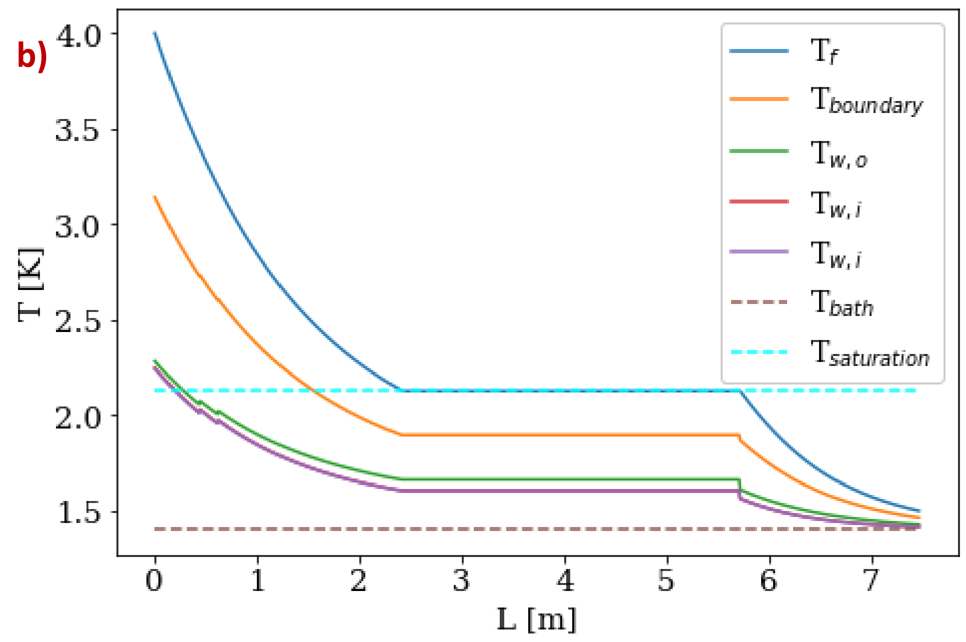


T_f: fluid temperature
T_bound: boundary temperature
T_w,o: He^3 outer wall temperature
T_w,i: He^3 inner wall temperature
T'_w,i: He^4 inner wall temperature
T_bath: bath temperature

Figure 2: This figures shows the cooling of He^3 (left part) in a He^4 bath (right part). The isotopic He^3 is surrounded by a Copper tube (middle part). The horizontal line is schematically showing the temperature distribution, where T_{bath} = 1.4 K and T_f = 4 K. The temperature jumps indicated by the short thick vertical green line, separating the different materials, are caused by the Kapitza conductivity.

Results of the heat exchangers





Different phases and phase change

These figures show the heat exchanger in the 1K pot, where the He^3 condenses.

a) The figure is showing a half logarithmic length-conductance coefficient diagram. Shown are the convective heat transfer coefficient, hc, the Kapitza conductance, hk and h'k, and the effective coefficient, heff.

b) First the temperature of the gaseous He^3 decreases, until it reaches its saturation temperature (approx. 0 m < L < 2.3 m). Then under further energy removal, the gas undergoes a phase change and condensates (approx. 2.3 m < L < 5.8 m). Afterwards the liquid He^3 decreases its temperature again (approx. 5.8 m < L < 7.5 m).

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