Hydrogen-Free Liquid-Helium Recovery Plants: The Solution for Low-Temperature Flow Impedance Blocking

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December 21, 2016 (HP119, STH46). Since decades there exists a known issue in low temperature cooling systems adapted to ^{4}He evaporation cryostats: the blocking of fine capillary tubes used as flow impedances to achieve temperatures below 4.2 K. This effect has been generally attributed to nitrogen or air impurities entering the capillary tubes from the main bath, but laboratory best practices adopted to maintain the helium bath clean and prevent impurities from entering the capillary tubes fail. The blocking problem often recurs with no apparent cause.

In the paper [1], we propose the underlying physical mechanism responsible for the blockages based upon the freezing of molecular H_2 traces present in the liquid helium bath. Solid H_2 is accumulated at the impedance low-pressure side and, after some time, it produces a total impedance blockage. The presence of H_2 traces is unavoidable due to its occurrence in the natural gas wells where helium is harvested, forcing gas suppliers to specify a lower bound for impurity levels at about 100 ppb even in high-grade helium.

The accepted strategy to avoid the impedance blockages was to prevent the entrance of solid impurities present in liquid helium. For this purpose sintered metal filters were placed at the impedance input to stop solid impurities entering the fine capillary tubes. But this strategy fails when the responsible of the blockages are not solid impurities, but free molecules of the only substance that has a non-negligible vapor pressure at 4.2 K: hydrogen [2].

Between the impedance input (T ≈ 4.2 K)

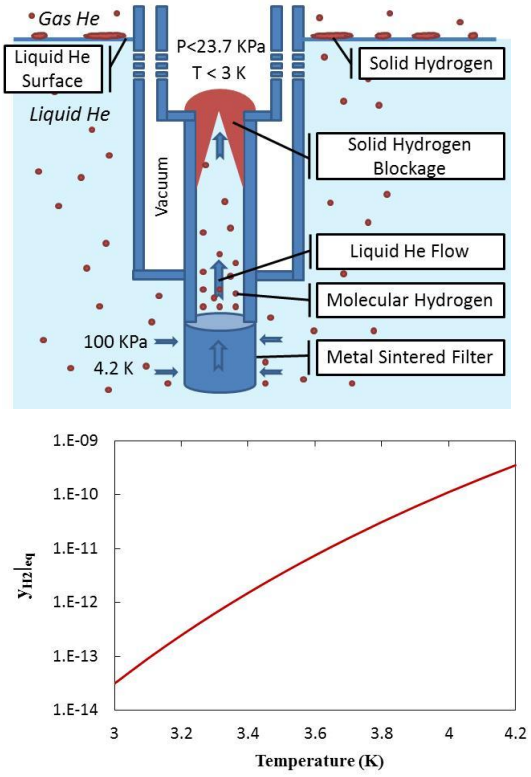

Fig. 1. Top: Schematic description of low temperature impedance blockage by molecular H_2 present in liquid He. Bottom: Low temperature H_2 molar fraction obtained from the H_2 equilibrium-saturation vapor pressure [3].

and the output (T < 3 K), the hydrogen vapor pressure decreases at least 4 orders of magnitude, and, thus, all the molecular hydrogen that enters into the impedance will be solidified inside it (Figure 1).

As an example, a typically two-phase He flow of only 1 sL/min, having 0.35 ppb of H_2 molecules (i.e. corresponding to the vapor pressure of solid hydrogen at 4.2 K), pumped through a cylindrical tube impedance of 66 µm effective diameter may produce a solid hydrogen cylinder block of 66 µm diameter that, in about 24 hr, will have 132 µm height. The exact time for the blocking to occur will depend on the exact solid hydrogen distribution in the impedance.

In the paper, we present helium recovery plants in which hydrogen is eliminated down to negligible values. For the case of small-scale (Figure 2), the purification stage is composed of two steps. First the main impurities (atmospheric gases) present in recovered (or commercial) helium are removed to negligible values by cryocondensation (T<20 K) in an Advanced Technology Purifier (ATP) [4]. The second step is specifically designed for efficient removal of hydrogen by its sorption in a getter material.

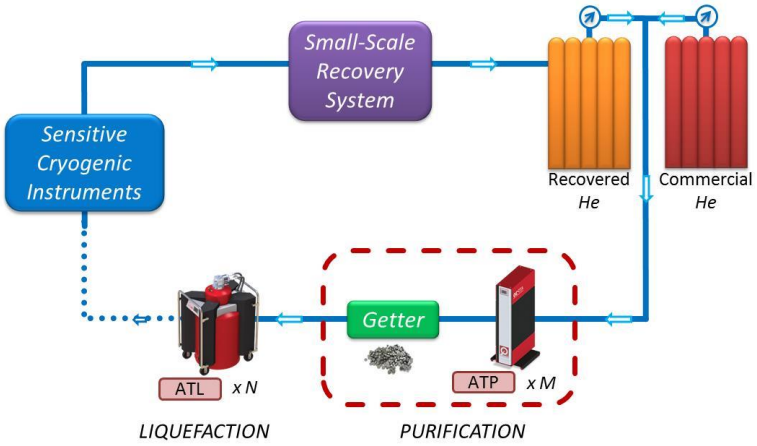

Fig. 2. Schematic configuration of a small-scale "Clean Helium" Recovery Plant.

The absence of hydrogen in the "Clean Helium" produced in this way has been checked with novel detection techniques presented in the paper, for gas and liquid phases. Further, the developed and implemented solutions are proven to be highly effective over periods of several years.

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