Cryostats that use the rare isotope He³ as a cooling fluid to achieve temperatures below 1 degree K can be very complex to operate. A prototype of a user-friendly, “table-top” Helium 3 cryostat has been designed and built recently at NEEL Institute in order to satisfy a research team’s needs for frequent electrical characterization measurements at very low temperature. This cryostat can cool samples down to 300 mK very quickly, in about 3 hours.

Josephson junctions, two superconductors coupled by a thin insulator barrier, are the building blocks of low temperature superconducting quantum circuits. Their fabrication implies the use of high quality superconductor thin films whose properties must be very well characterized. Especially, the temperature and the width (in deg. K) of the superconducting transition of the films all have to be known. Then, after fabrication in a clean room by techniques such as lithography and etching, the quantum circuits themselves have to be tested at low temperature. A table-top Helium 3 cryostat has been created in order to perform these electrical characterizations quickly.

As shown in Fig. 1(a), this cryostat is very compact and can be placed on a laboratory work table. It is composed of a vacuum chamber (50 cm high and 20 cm diameter) containing two helium circuits interlocked with each other. The first helium circuit is an open circuit containing liquid Helium 4, which flows around the cryostat from the supply reservoir to the helium gas recovery exhaust. The second circuit is a closed Helium 3 circuit, containing a small quantity of this very rare and extremely expensive isotope. As the coldest part of the cryostat is at its top, the sample holder is very accessible, just below the two thermal screens and the cover, which makes loading the sample much easier than in conventional designs where the sample compartment is at the bottom of the cryostat.

The basic principle of a Helium 3 cryostat is to condense He³ gas to the liquid inside a reservoir by bringing the gas in contact with a pumped Helium 4 reservoir (the “1 K pot”, see Fig. 1(b); liquid He³ can be cooled to about 1 degree K by strong pumping). The temperature inside the Helium 3 reservoir can then be lowered to around 300 mK by reducing the vapour pressure on the liquid He³. This is achieved with an internal, sorption pumping system (activated charcoal, Fig. 1(b) "sorption"). When all the Helium 3 has been adsorbed (no liquid He³ left), the charcoal is reheated at 40 K in order to liberate the adsorbed gas. A new condensation cycle can then be initiated.

The sample holder is thermally connected to the Helium 3 reservoir via the cold finger shown in Fig 1(b). This connection allows us to cool the sample down from 1 K to 300 mK. But the initial cooling of the sample holder from 300 K to 4 K requires a thermal connection with the 1 K pot in order to be efficient and rapid. The setting-up of a thermal switch allows this connection for temperatures to 4 K. This “switch” is a small closed volume of Helium exchange gas which can be adsorbed using a dedicated small sorption pump. Below 4 K, the He gas is adsorbed and the switch is turned off.

The available cooling power is 100 µW at 390 mK. During the early phase of testing the performance of the cryostat, 300 mK was reached in a time of 3 hours. The lowest temperature achieved was 280 mK. The working time available before the need to regenerate He³ liquid is several hours. The regeneration phase requires half an hour.

Up to now, two kinds of superconducting thin films have been characterized: thin films of rhenium produced at SIMAP lab (Laboratory for Materials and Processes Science and Engineering, Grenoble) and thin films of niobium evaporated in the Néel Institute’s recently upgraded ultra-high vacuum system.

The cryostat was created by Pierre Brosse-Maron according to an idea of Bernard Pannetier and Philippe Gandit.