# REFRIGERATOR $^3$He BASED ON CLOSED CYCLE CRYOCOOLER COOLING

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FLNP JINR is developing gas-filled thermal neutron detectors [1]. One of the components of the mixture of gases filling such detectors is $^3$He. The detector assembly technology involves the addition of pure $^3$He to a pre-prepared mixture of other gases. At the end of the service life, the detectors require refilling with a mixture of gases. The use of factory-made $^3$He for these purposes is an expensive solution due to the high price of $^3$He. It seems more rational to extract $^3$He from the previously used gas mixture in the detector by a cryogenic means. To do this, it is necessary to have temperatures below 3.3 K, corresponding to the liquid state of $^3$He.These temperatures can be obtained in helium cryostats or using closed-cycle cryocoolers, for example, Gifford-McMahon (GM), and combining with them a $^3$He refrigerator - a device in which $^3$He is liquefied and its vapors are pumped out.

This paper describes the design of a $^3$He refrigerator specialized for the task of purifying $^3$He from impurities based on a GM cryocooler (Fig. 1).

Refrigerator $^3$He is a column of heat exchangers located on the regenerative part of the cold head. Here 1 is the main flange, on which container 2 is mounted from below, a pipe with a diameter of 150 mm made of thin-walled stainless steel and a length of 390 mm. 3 - cryostat manifold, on which a cold head 4 is installed coaxially with the container. The length of the container was determined by the requirement to accommodate the entire cold head and heat exchangers in it.

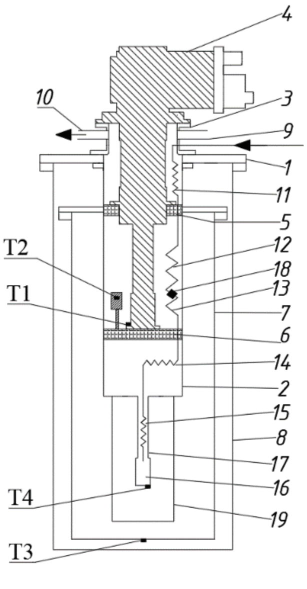


*Fig.1. Scheme of the $^3$He refrigerator and cryostat*

The first and second stages are equipped with heat exchangers 5 and 6, respectively, which provide thermal connection of helium with the cryocooler stages. The thermal connection of these heat exchangers with the container wall is carried out due to the thermal conductivity of helium. 7 – thermal screen mechanically connected to the container wall at the level of the first stage of the cryocooler; 8 – vacuum housing of the cryostat.

$^3He$ is fed into the container through tube 9, and is pumped out through pipe 10. Tube 9 passes into a tubular heat exchanger consisting of several sections connected in series (11, 12, 13 and 14) wound around the regenerator part of the cold head.
The heat exchanger ends with a throttle 15, which provides the necessary condensation pressure $^3He$. Liquid $^3He$ accumulates in the evaporator 16, which is connected to the container by means of a thin-walled stainless steel tube 17 12 mm in diameter and 60 mm long.
To separate $^3He$ from impurities, a pump with activated carbon 18 is installed between the sections of the heat exchangers.
Helium vapor $^3He$ from the evaporator enters the container and then is pumped out through pipe 10.
An important element of the refrigerator is the heat shield 19, which takes a temperature close to the temperature of the second stage of the cold head, about 2.5 K.
The temperature was measured by temperature sensors - silicon diodes - T1, T2, T3 and thermistor T4. Figure 2 shows a photograph of the refrigerator heat exchangers, the numbering corresponds to Figure 1.

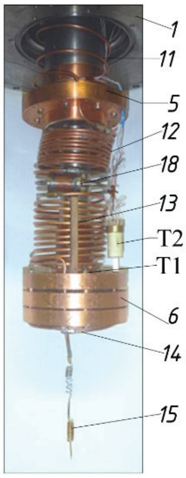


*Fig.2. Refrigerator heat exchanger system*

In the mode of evacuation of $^3He$ vapors through pipe 10 with a pump with a capacity of 35 $m^3/h$ and replenishment of liquid $^3He$ in the evaporator by continuous condensation through throttle 15, a temperature of 0.78 K was obtained (thermistor T4).
In the mode of pumping out vapors of pre-condensed $^3He$ without replenishing it, a temperature of 0.52 K is reached in the evaporator (thermistor T4).

[1] A. V. Belushkin et al. (2010). Development of gas-filled position-sensitive detectors of thermal neutrons at the Frank Laboratory of Neutron Physics of the Joint Institute for Nuclear Research. Phys. of the S. St., 52, 1025–1028