JOINT INSTITUTE FOR NUCLEAR RESEACH
Frank Laboratory of Neutron Physics

FINAL REPORT ON THE

SUMMER STUDENT PROGRAM

Study of operating modes of the 3He refrigerator on the basis of the 150 mm diameter shaft cryostat with cooling by the close-cycled cryocooler

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Participation period:

July 07 – August 18

Dubna, 2019

Abstract

In this work we study 3He refrigerator on the basis of the 150mm diameter shaft cryostat with precooling by close-cycled cryocooler SRDK415D to obtain temperatures below 1 K.

We have measured cooling power of the refrigerator in the temperature range 0.52 – 1.1 K in a single mode. We have got curves of temperatures of 3He still on time in process of cooling. It has been revealed, that the temperature level of 0.55K can be keep up to 20 hours in the single mode. In continuous mode the refrigerator reach temperature 0.8 K with evacuating by 30 m^3/hour vacuum pump. The obtained results can be used to create cryostats with 3He refrigerator for neutron beams of IBR-2, as well as for purification of 3He for neutron detectors. Also we obtained isothermal mode without outer pumping. This mode can be used for calorimetric measurements by studying of a derivation of temperature in dependence on time.

The refrigerator was created in the Department of Spectrometers Complex.

Introduction

The studying of condensed matter usually carry out with temperature above 4.2K by using liquid 4He, and above 3K by using close-cycled cryocooler. Usually temperatures of 1.5 K can be obtained by pumping saturated vapor above the liquid 4He. Working on neutron spectrometers with using liquid helium with saturated vapor pumping is a time-consuming and expensive method for obtaining a temperature level of 1.5 K. Facilities with temperatures below 1 K at the IBR-2 reactor have not been presented and researches at these temperatures are not carried out at the moment. In this work for obtaining temperatures below 1 K we study 3He refrigerator [1] on the basis of the 150mm diameter shaft cryostat with precooling by close-cycled cryocooler, which was created in the Department of Spectrometers Complex [2].

For advanced researches on the IBR-2 spectrometers the development of 3He refrigerators is underway [3,4,5].

Studies of heat flow to the sample by heat exchange gas along the shaft [6] as well as data of the paper [2] indicate that the cold head of the cryocooler can be placed in a vertical thin-walled stainless steel pipe with a diameter of 150 mm without significant loss of cooling power.

The obtained results motivated to create cryostats with 3He refrigerators for neutron spectrometers as well as for purification of 3He for secondary use in neutron detectors.

Experimental facility

Figure 1 shows a diagram of the cryostat on which the experiments were performed. Here 1 is the main flange on which the shaft with a diameter of 150 mm (2) is mounted from below, 3 is the head of the cryostat on which the cold head of the cryocooler SRDK415 D (SUMITOMO) (4) is located, shaft 2 has thermal contacts 5 and 6 to the first and second stage of the cold head. The still with liquid 3He (7) on the pumping tube 8 is hermetically suspended from the bottom to the pipe 2. 3He enters into the shaft 2 through the capillary 9 from the storage system, passes the heat exchanger system 10 and 11 and enters the chamber 7 through the throttle 12. This throttle has the hydraulic resistance for providing the condensation of 3He. 13, 14 – thermal screens. 14 – the sealed housing of the cryostat. 3He is pumped through the pipe 15 by hermetic scroll pump XDS35(EDWARDS). 3He goes back into the storage system or enters to the capillary after pumping. The pressure on the capillary was controlled by a model vacuum gauge. The temperature was measured by LAKESHORE 336 controller and DT670 thermometers (Input A, Input B, Input C) and Cernox one (Input D). The thermometers are located on the second stage of the cold head of the cryocooler- Input A, in thermal insulation - Input B, on the still with liquid 3He - Input D, and at the bottom of the thermal screen of the first stage of the cryocooler - Input C.

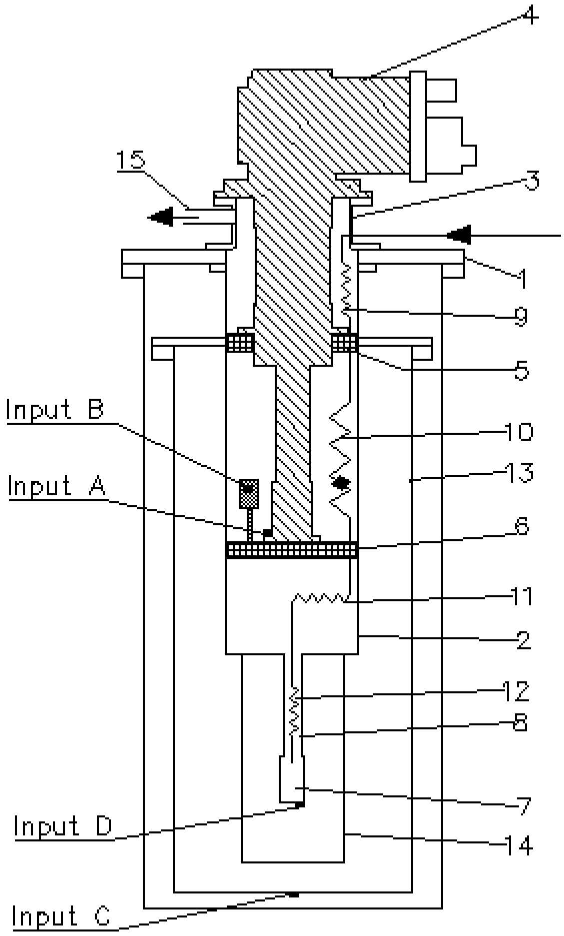

Figure 1

Figure 2 shows a photo of the cryostat, figure 3 shows a photo of the still where 3He is condensed, figure 4 shows a photo of the heat exchangers.

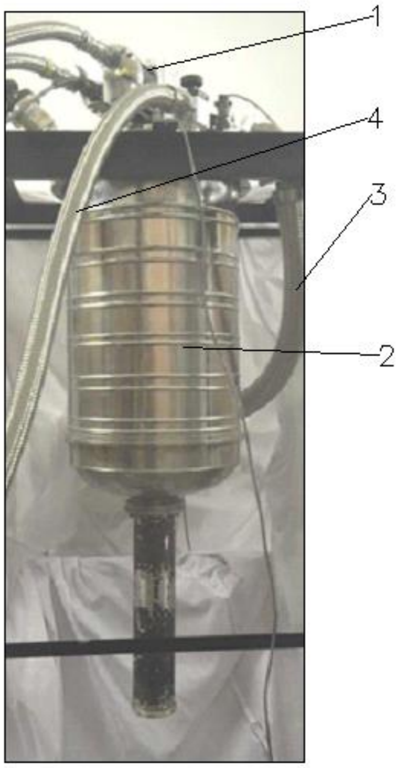

Figure 2. 1 – cold head of cryocooler, 2 – vacuum housing of cryostat, 3 – flexible hose for pumping of 3He, 4 – flexible hose of vacuum pumping of cryostat.

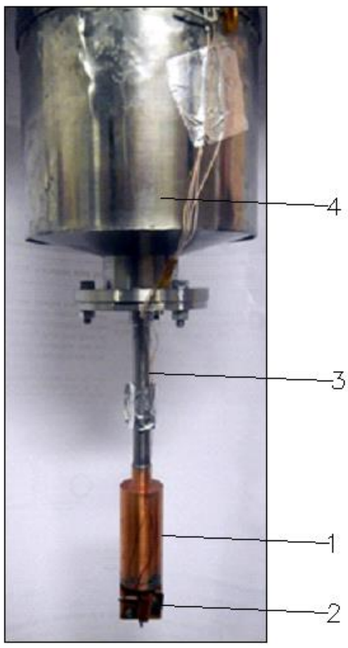

Figure 3. 1 - still with liquid 3He, 2 – thermometer (Input D), 3 – pumping tube, 4 – stainless steel shaft with 150 mm diameter.

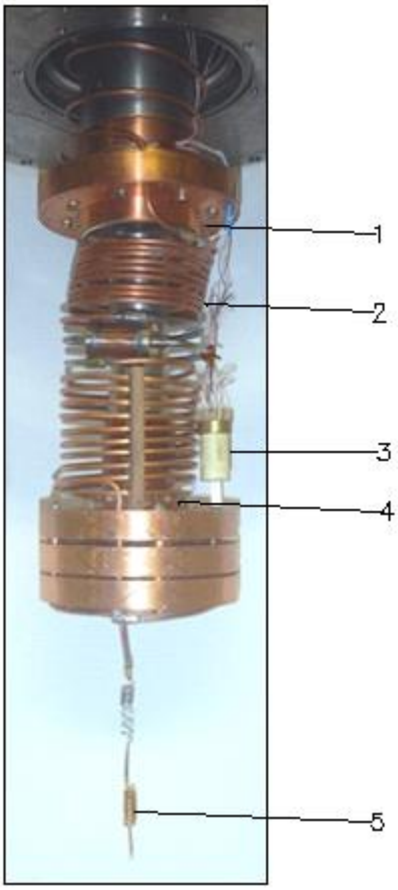

Figure 4. 1- the first stage of the cold head of the cryocooler, 2 – heat exchangers, 3 – insulated thermometer (Input B), 4 – thermometer on the second stage of the cryocooler (Input A), 5 – throttle.

Results and discussion

The processes which obtain low temperatures by using this system are shown in the figures below. The most interesting are observations of the cooling process, the duration of the isothermal mode at 0.82 K, obtaining a cooling power dependence on temperature, and also studying the cooling process with 3He circulation and reaching a temperature of 0.52 K in a single mode (with zero circulation score).

Initially the working of the facility begins with cooling the system from room temperatures to temperature level 2.5 K (Fig. 5 и 6). Next when 3He added through the capillary to the cryostat, there is a condensation of liquid 3He in the still (Fig. 7, time interval from 24 to 33 minutes). The process of reaching temperatures about 0.52 K in a single mode (Fig. 7, time interval 33-70 minutes) is obtained by closing a valve at the system input. Single mode can run about 20 hours at this temperature. Figure 8 shows the transition from continuous mode, the time interval 1.4-1.8 hours (with 3He circulation) to a single mode, the time interval 1.8 – 2.3 hours, and 2.3-3 hours and 3-3.9 hours respectively.

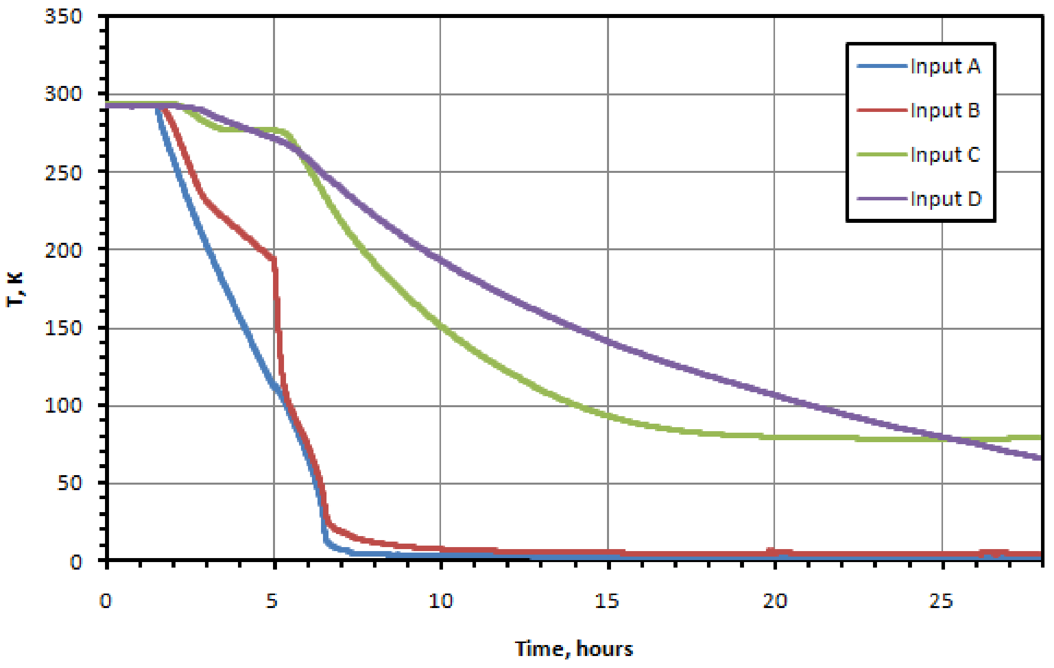

Figure 5. The beginning of the work of the cryostat

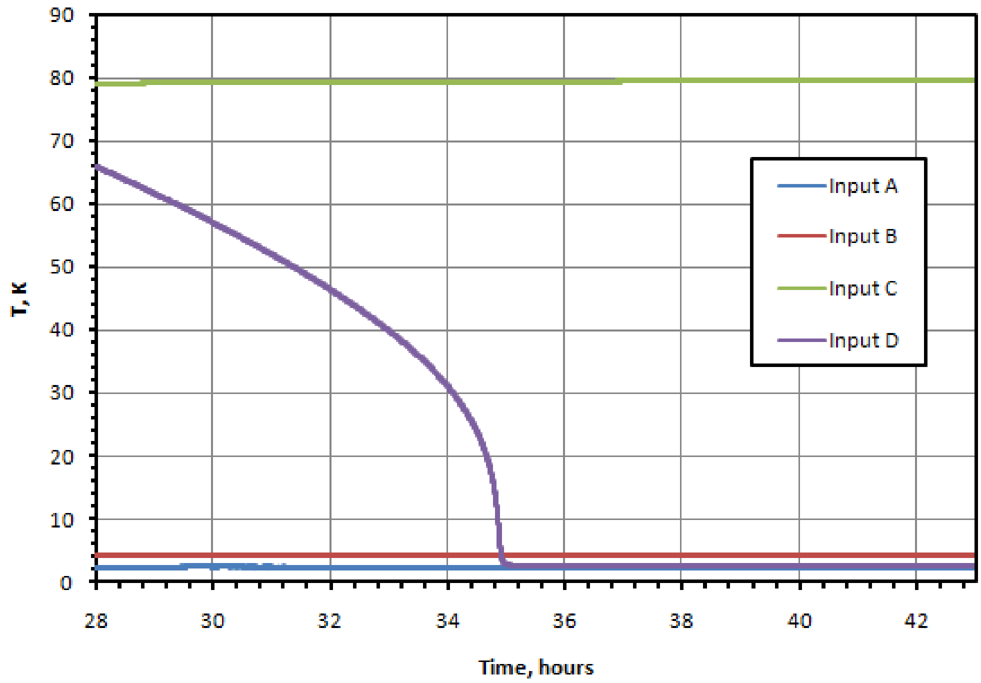

Figure 6. Reaching temperature 2.5K. The cryostat allows us to cool up 100 liters of 3He gas with purification of 3He to freeze impurities.

During operation with the facility there was obtained a dependence of cooling power on temperature by mean of electrical heater, which was connected to the still (Fig.9). Also we can obtain a dependence of temperature on time while increasing the current on the heater (Fig. 10).

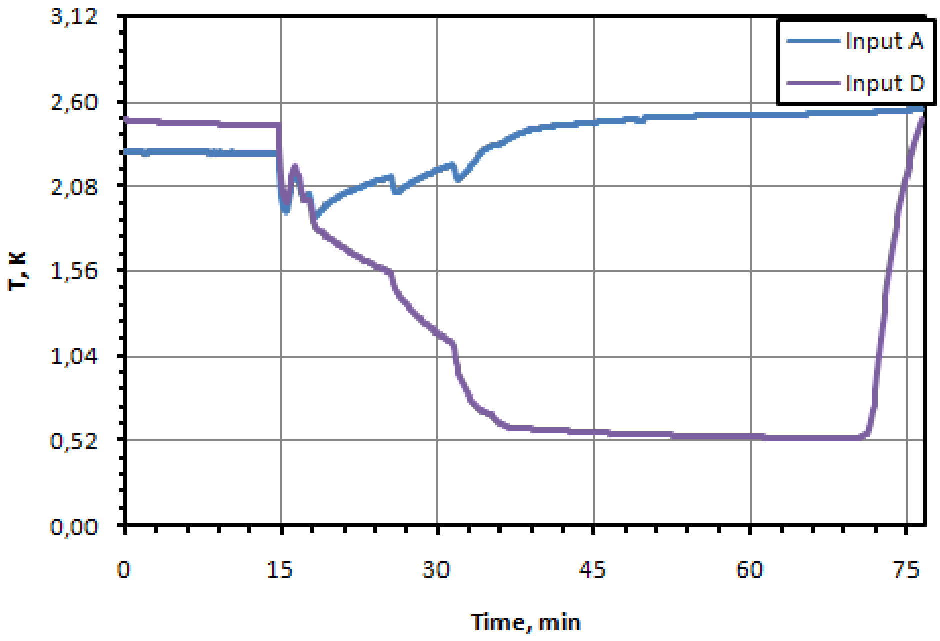

Figure 7. Reaching temperature 0.52K

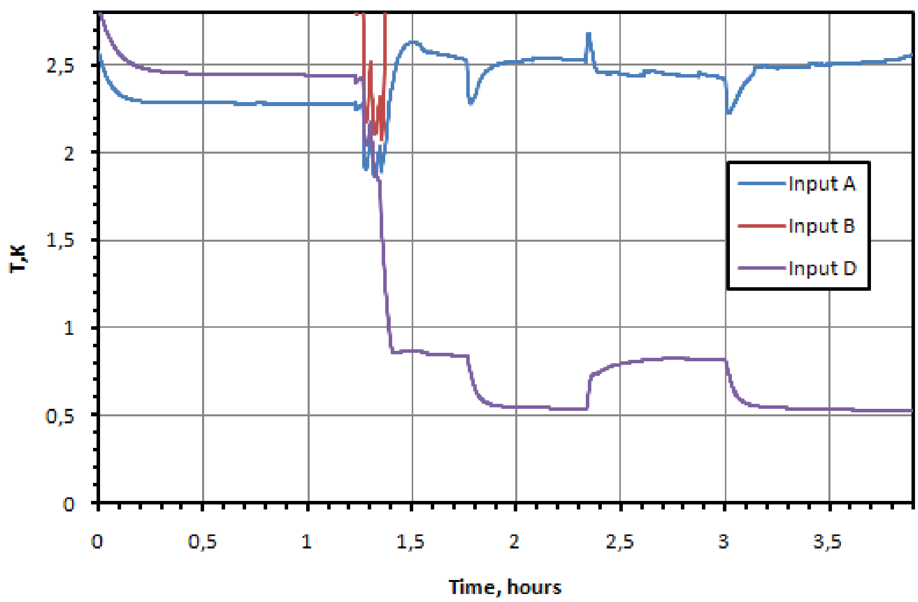

Figure 8. Changing of the temperature of the still in process of opening and shutting valve of capillary

An important stage of the experiment is obtaining an isothermal mode (Fig.11), which is carried out by closing the pumping valve after receiving the final temperature (0.76 K) in a single mode with pumping through a thin tube.

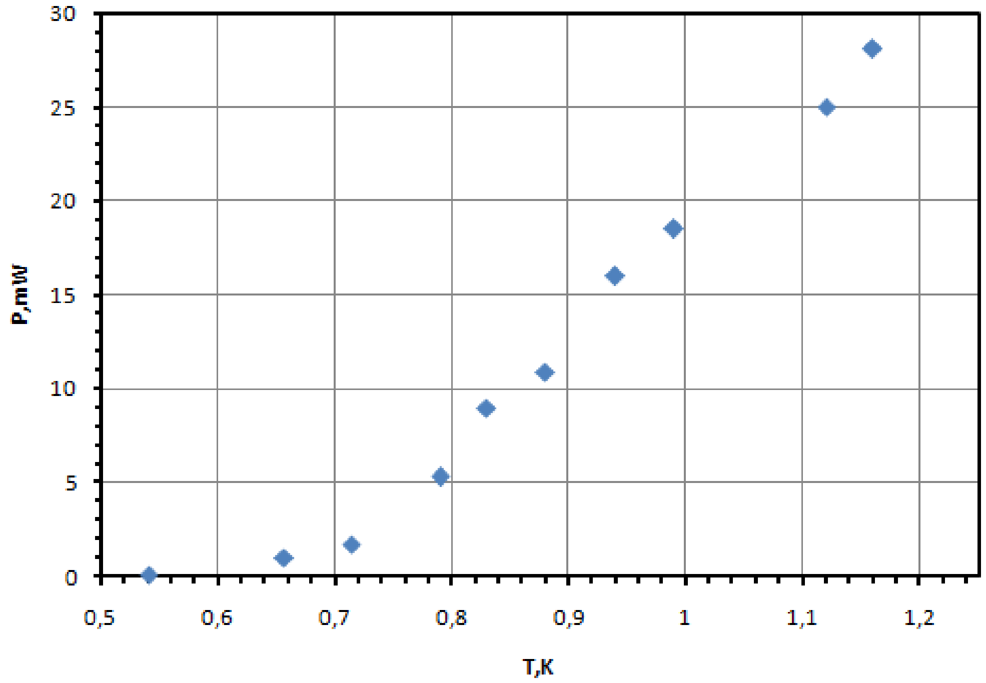

Figure 9. Cooling power

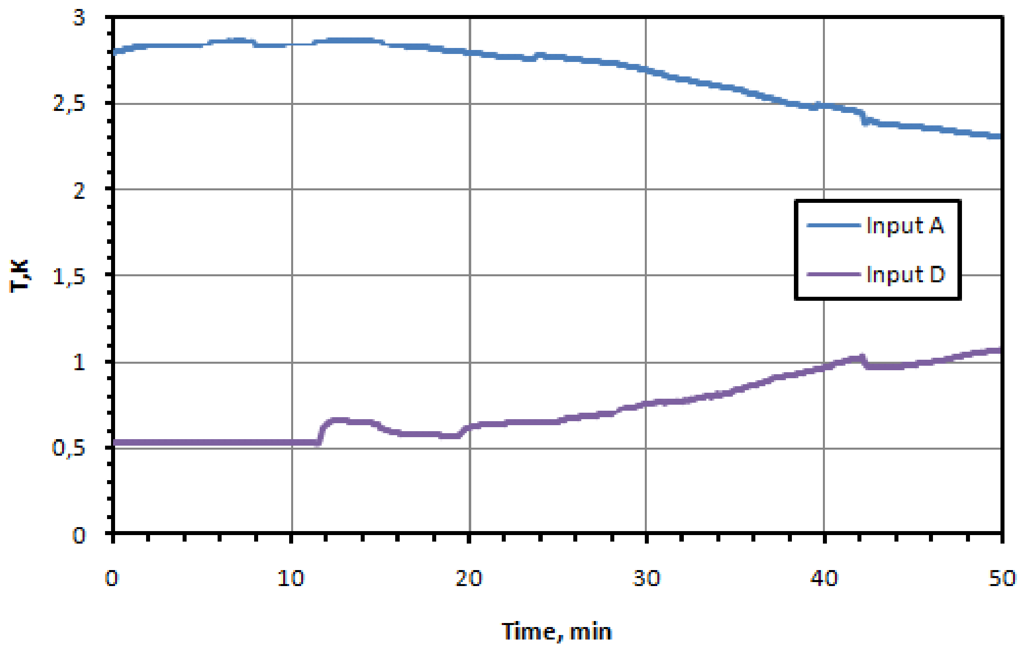

Figure 10. Changing of temperature while increasing the current on the heater

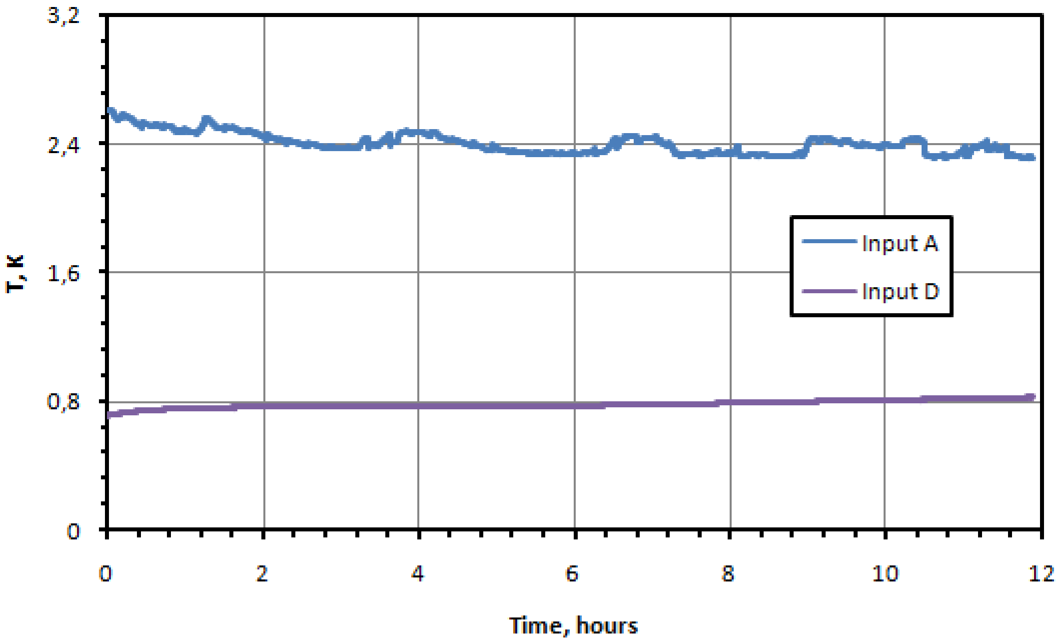

Figure 11. Isothermal mode. Temperature of the still reaches the value about 0.8K. The value of derivative of temperature on time (input D) allows us to define the value of heat dissipation of a sample in the still

The most interesting process is a cooling with the circulation of 3He in the cryostat. This mode can be continued for a long time and allows us to obtain temperatures about 0.8 K (Fig.12).

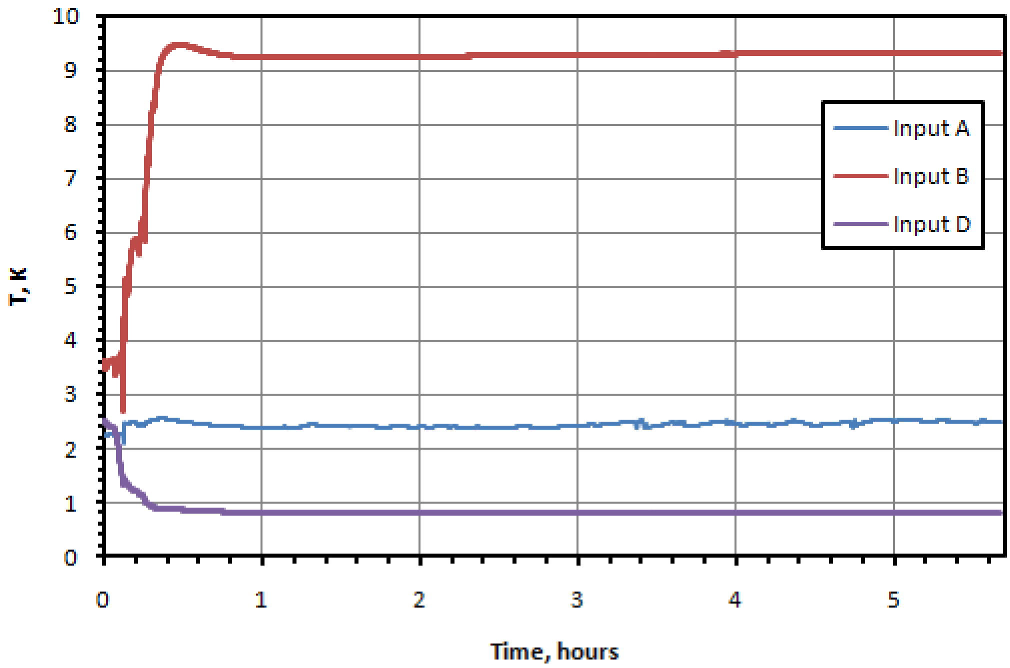

Figure 12. Temperature (input D) of the still with the circulation of 3He

Conclusions

1. We showed the efficiency of the cryostat with the 3He refrigerator with cooling by close-cycled cryocooler where cold head and heat exchangers placed inside the 150 mm diameter shaft.
2. Temperature of the cryostat reached 0.8 K in the continuous mode.
3. Temperature of the cryostat reached 0.52 K and was kept for 20 hours in the single mode.
4. Isothermal mode can be used for calorimetric measurements by studying the derivative of temperature on time.
5. The refrigerator can be used to purify 3He from impurities by cooling the gas with helium temperatures and freezing any impurities at low temperatures, which is necessary to maintain the production cycle and operation of neutron detectors.
6. The simplicity of the design and the obvious understanding of the operation will allow us to use cryostat on the neutron spectrometers with reaching temperature level of 0.5 K by the close-cycled cryocooler.

Acknowledgments

I take this opportunity to express my profound gratitude and deep regards to my supervisor A. N. Chernikov for his exemplary guidance, major competence, monitoring and providing an opportunity to obtain a great experience in such ambitious project.

Also I would like to thank a committee of Summer Student Program for opportunity to visit Joint Institute for Nuclear Research and for financial support.

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