STARTING-UP AND ADJUSTMENT WORKS ON CRYOGENIC AND VACUUM SYSTEM OF THE SUPERCONDUCTING RADIO-FREQUENCY SEPARATOR

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Abstract

The OKA experimental complex to produce a separated Kaon beam from U-70 proton accelerator is under construction at State Research Center IHEP. The Cryogenic and Vacuum System (CVS) to keep the radiofrequency separator at operating temperature of 1.8 K is now at the commissioning stage. Different modes of the CVS operation are investigated to determine the most efficient and reliable one. Measures for reaching of the CVS design parameters and increasing the reliability of its operation are described. The experimental values of heat leaks to the CVS elements are given. The modes of the CVS operation in the emergencies are examined. The technological parameters data acquisition and control system is described.

INTRODUCTION

The cryogenic-vacuum system (CVS) of the experimental complex OKA for obtaining the separated beam of K-mesons on the U-70 accelerator [1] - [5] has been built at IHEP. The CVS flow chart with the superconducting RF cavities as the cryogenic load is given in Fig.1.

The cryogenic helium plant KGU 500-4.5/140 serially produced by “Geliymash” company is the basic cold generating unit of the CVS. It produces both the cold at T=4.6 K and liquid helium at the same temperature.

This cryogenic production from KGU-500/4.5 with the aid of the condensation heat exchangers located in the liquid helium bath of intermediate cooling (LHB), large vacuum heat exchanger (HEX), heat exchangers at the entrances into RF1, RF2 and pumps of the pumping machine (PM) is transformed into cold at 1.8 K to cool the cavities RF1 and RF2.

Calculated refrigerating capacity of the entire CVS is 250 W at 1.8 [5]. The experimental value of refrigerating capacity is 240 W at 1.8 K, but the plant liquefies 3 g/s of helium at T=4.6 K, which represent the excess load for PM forced to derive it from the cycle. Several runs of the system made it possible to estimate the heat balance of the CVS in more details and to modify its elements.

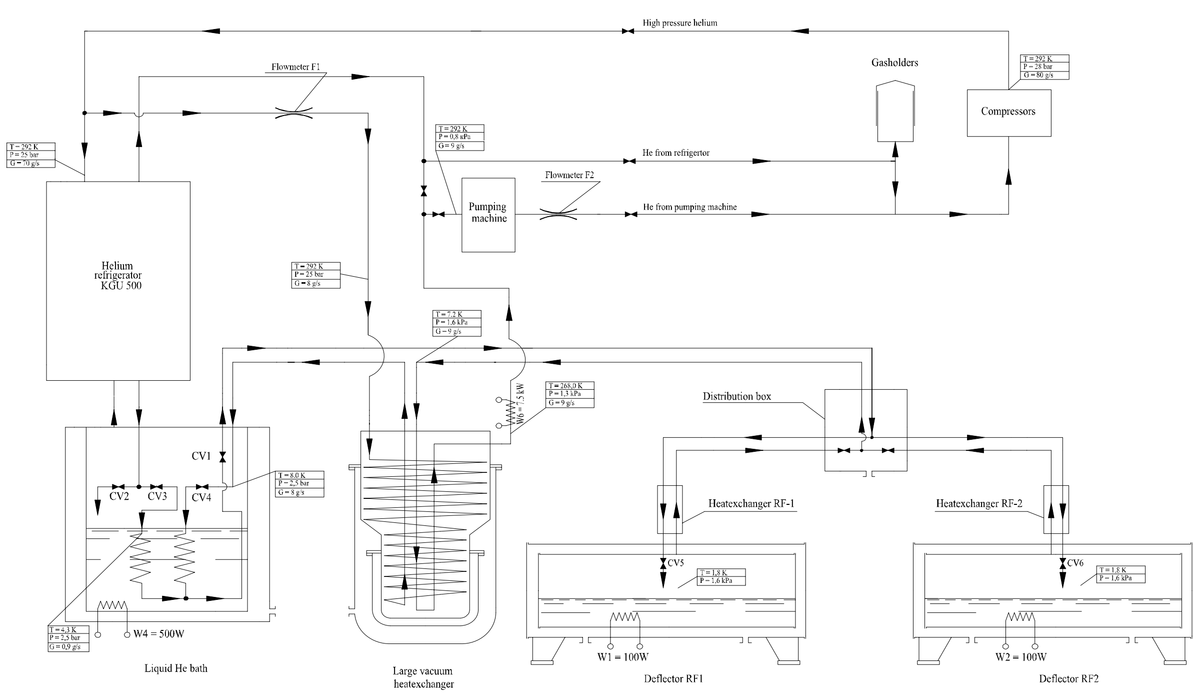

Figure 1. Flow chart of the cryogenic and vacuum plant cooling the superconducting RF deflectors

HEAT LEAKS AND HEAT RELEASES IN LOW TEMPERATURE PARTS OF CVS

Measured and calculated values of heat load in the main CVS units are given in Table 1.

Table 1. Heat loads to cryogenic units of CVS at He temperature.

CVS unit	Heat load [Watt]
Liquid He intermediate bath	5
(RF1 + RF2) deflectors	18
Large vacuum heat exchanger, cryogenic transfer lines from HEX to (RF1 + RF2) deflectors	150
Cryogenic tube from liquid He intermediate bath up to HEX (calculated value)	10
RF load in RF1 + RF2 (calculated value)	25
Total to CVS	208

It could be seen that 240 W of the CVS refrigeration capacity is enough for normal operation of the RF separator superconducting cavities.

COOLING CAVITIES DOWN TO OPERATING TEMPERATURE

Cooling down time is determined by a number of factors: by the tradeoff between the refrigerating capacity of the CVS units and the mass of the cooled components (Table 2) and by limitations to the rate of cooling, which are superimposed by the design features of the cooled cavities RF1 and RF2. The specified cooling rate of the cavities is as follows: in the temperature range 300-150 K not more than 10 K/hr; in the temperature range 150-90 K the rate must be close to 20 K/hr; from 90 K to 1,8 K not more than 10 K/hr. All the other CVS subunits tolerate any rate of cooling.

Time graph of the cavities cooling down by CVS is shown in Fig. 2. During first 12 hours the cryogenerating plant KGU 500-4.5/140, LHB and the transfer lines are cooled down (Fig. 1). Then liquid helium from LHB is fed to the cavities along the transfer lines. In about 35 hours the cavities are at 20 K, and HEX starts to operate which acts in the CVS as the satellite refrigerator.

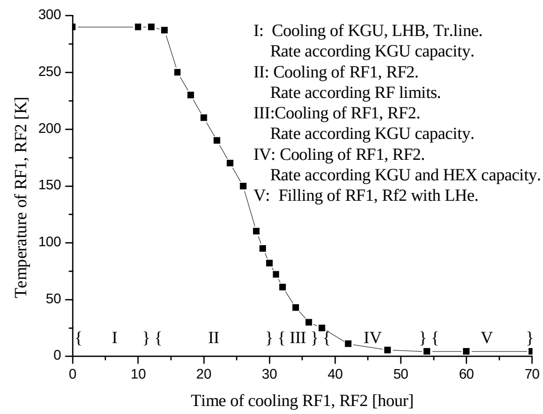

Figure 2. Cooling down of the RF separator superconducting cavities by CVS.

Cooling down to 1.8 K depends not only on the CVS capasity but on the necessity to train the cavities inner surface against the multipactor discharge as well, and it can take up to 60 hours. Training of the cavities is carried out at the intermediate temperatures of 3.0, 2.5 and 2.0 K. Three stage pumping machine starts sequentially, stage by stage. Initially to pump from the gasholder pressure 8 pumps of the AVZ-180 type are started and it is necessary to keep suction pressure not exceeding 20 kPa at the mass flow rate about 10-12 g/s. With reduction of temperature in the cavities cryostats down to 2.8 K the pumps reach their limit. For further pumping the helium gas the Roots type vacuum pumps 2DVN-500 are started, and then 2DVN-1500. Presence of the excessive 3 g/s of liquid helium inflow in the refrigeration mode overloads the pumping machine. In the future this problem is to be solved by withdrawal of helium from the system cycle bypassing the pumping machine. After reaching the operating mode separator is ready to work with the particles beam from the cryogenics point of view.

TRANSIENT MODES OF CVS OPERATION

During the work of the CVS different disturbances take place, both permitted by processing procedure and as a result of the more serious equipment failures, namely power-off, compressors cooling water-off, mortality of the CVS components and subsystems and so on..

Table 2. Cold mass and specific heat of the CVS components

Component name	Material	Mass [kg]	Specific heat [J/(g K)]				
			290 K	80 K	20 K	10 K	5 K
Transfer line	Stainless steel	1000	0.480	0.202	0.0113	0.005	0.001
Cavities cryostats	Stainless steel	356	0.480	0.202	0.0113	0.005	0.001
Cavities	Niobium	520	0.260	0.173	0.0113	0.0022	0.0006
Helium inventory in the cold units: KGU 500-4.5/140, LHB, HEX, transfer line, cavities cryostats		From 0.66 kg at 290 K up to 54.3 kg at 5 K	5.193	5.197	5.260	5.462	8.10

Situation analysis had shown that in case of failure it is essential to prevent the warming up of the cavities higher than 15 K. If not, after the cooling down a time consuming (3-5 days long) cavities surface training against multipactor discharge will be requiered.

In normal operation mode each cavity cryostat contains ~ 500 l of liquid helium. After the CVS stoppping this helium will vaporize at least for 30 hours due to the heat leaks (Table 1), and this time could be enough to recover the normal operation. But there is another critical component, that is the transfer line with high enough heat leaks (Table 1) to warm up to 20 K in 30 min after the high pressure helium flow is stopped. If then to feed the cryostats trough this transfer line even by “cold “ helium, in any case the “warm” temperature wave will heat part of the cavity surface over 15 K. Only one of all the possible failures results in such a situation, namely refrigerator turbine failure. It takes from 4 up to 10 hours to eliminate such a breakdown.

To solve the problem a special CVS operation mode was developed and implemented when with the refrigerator down the transfer line warms up to 14 K within 15-16 hours, and not all the transfer line has this temperature, but only part of it adjacent to the HEX. The idea is that when a turbine of the KGU 500-4.5/140 is broken down not to stop but to keep operation of HEX as a satellite refrigerator. In this case the imbalance, the extra cold helium flow rate is generated not by liquefier, but it comes from the cavities cryostats due to the liquid evaporation owing to the heat leaks (Table 1). This method has one more interesting feature, that is the satellite refrigerator operates at variable temperature level: from 1.8-4.3 K in the cavities cryostats up to 12-14 K in the transfer line. According our experience, 15 hours is quite enough to eliminate most complex emergency situation.

DATA AQUISITION AND CONTROL SYSTEM

The CVS data aquisition and control system developed at IHEP enables to display on the operator’s console main parameters of the system necessary for manual or remote control. After commissioning the system shall provide control of the following parameters:

- measurement of the temperature of cryogenic components, of nitrogen and helium flows in 72 points;
- measurement of the temperature of pumps of the pumping machine in 42 points;
- pumping machine interstage pressure measurement by differential pressure transducers in 3 points;
- medium and high insulation vacuum measurement by PMT-6-3 and PMT-4 sensors in 32 points;
- liquid helium level – in 3 vessels;
- helium and nitrogen pressure – in 11 points;
- helium mass flow rate – in 2 points;
- measurement of the phase currents of the pump motors of piping machine – 72 channels;
- discret signals – 48 reading channels (status).

The control system includes the sensors and equipment of multiple types, and it requires development of the variety of dedicated instrumentation.

Layout of the equipment, its location in different areas requires the distributed layout of the electronic control units and the arrangment of communication between electronics and between CVS operators.

At present the remote control of the main helium flows is realized. The work on CVS automation is in progress.

CONCLUSION

Operational modes of the unique cryogenic and vacuum system for cooling the superconducting cavities down to 1.8 K by superfluid helium with mass flow rate up to 10 g/s are being investigated. For the first time in Russia this installation provided filling of two RF cavities cryostats with 1000 litres of the superfluid liquid helium that enabled to separate the charged particles beam and concentrate the K-mesons. The satellite refrigerator operation mode was developed and implemented with variable temperature level and with low pressure flow imbalance due to the liquid helium evaporation by heat leak to the cavities cryostats.

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