CONTROLLER OF THE PISTON-TYPE EXPANDER MACHINE FOR CRYOGENIC SYSTEM OF THE KEDR DETECTOR

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Abstract

Due to a piston-type expander machine of the helium refrigerator with cooling power of 600 W the total consumption of liquid helium by the superconducting magnet system of the KEDR universal electromagnetic detector for general purpose created for experiments with e+e- collider VEPP-4M (BINP, Novosibirsk, Russia) could be decreased in two times. For exploiting the expander machine, an electronics controlling its valves and allowing adjust a mode of its work is necessary. Developed system consists of the controller and program for PC interacting with it.

INTRODUCTION

For research of particle physics in the energy range of 2E=12 GeV, the KEDR detector for general purpose at the e^+e^--collider VEPP-4M (BINP,Novosibirsk,Russia) have been operated since 2002.

The constant homogenous magnetic field in the KEDR detector is provided by superconductive (NbTi/Cu) solenoids: the central (0.6 T) and two compensating (6.55 T). Liquid helium passed through pipes of 20 m length is used to stabilize the coil temperatures. The helium refrigerator of the cold power 600 W at the temperature level of 4.5 K provides the liquid helium consumption of 1100 litres per day in mode of throttling. The expander machine of the piston type decreases it down to 600 litres per day. Thus, high reliability of the expander machine is necessary for a long time and continuous run of experiments with the KEDR detector.

DESCRIPTION OF THE PISTON-TYPE EXPANDER MACHINE

Design

The expander machine has a pair of components: a cylinder and a piston of 40 mm in diameter. The gap between its work surfaces is a few micrometers. The teflon skin coats them for decreasing the force of resistance in the range of cryogenic temperatures of 6-11 K. The helium flew through the machine is up to 80 kg/h.

Two cryogenic valves are used to control a helium flow through the expander machine. The electromagnetic coils are used to lock the valves in an open state in a desired time. The piston passes the pressure (24 bar) of the helium flow to the flywheel by metallic pipe, which connects it with a cranked shaft. The electric engine is stabilized by the belt-drive pass the rotating speed of the flywheel on the one of three desired velocities. Three-phase AC of 380V supplies the electric engine.

Principle of Operation

Figure shows a diagram of the cryogenic cycle of the expander machine.

The pressure of 25 bar of the helium flow pushes the piston up, and the helium fulfilled the cylinder. The valve remains opened (see Fig.1, piece 1-2), if its electromagnet has been powered beforehand. If current in the magnet is interrupted, the valve is closed by returnable force of a spring. The event named as interrupt of admission occurs: (Fig.1, point 2) some volume of helium remains locked in the cylinder and will be expanded while the piston arrives at top of the cylinder (Fig.1, piece 2-3). The losses of energy by pushes and the piston are cools of the gas. Near the top of the cylinder the piston passes a hole in walls of the cylinder (Fig.1, point 3). Pressure of the gas passes through the hole to the release valve, and it is opened pneumatically (Fig.1, point 4). The piston pushes out helium cooled down to 6 K through the release valve (Fig.1, pieces 4-5). If electric current is supplied in electromagnet of the valve, it remains to be opened while the current interrupts. Then the event called as interrupt of releases occurs, and the release valve is closed. The rest of gas is pressurized by the piston in the cylinder to soften an impact of the piston about the drive of the admission valve and the end cap of the cylinder.

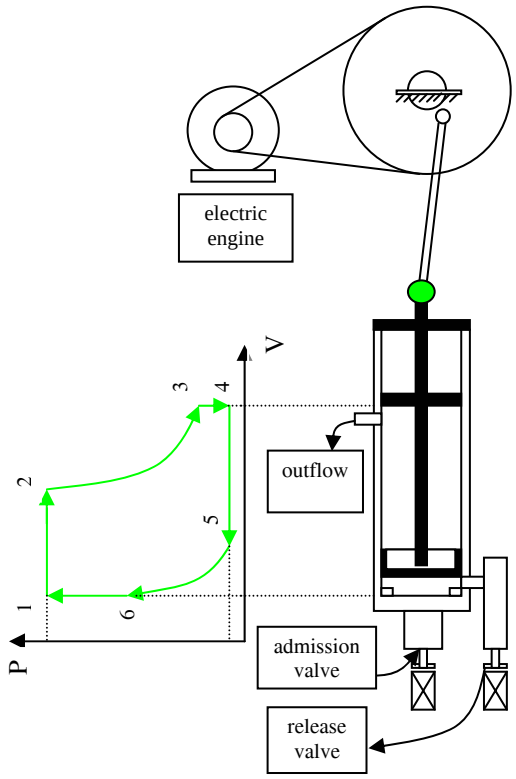

Figure 1: The simplified block diagram of expander machine

DESCRIPTION OF THE CONTROL SYSTEM

Figure 2 shows the block diagram of the controller. The kernel of the device is a microcontroller that integrates a 8-channel ADC, flash and RAM memory and an optimizied single-cycle 20 MHz 8-bit MCU on a single chip.

To control over an operating modes of the expander machine, the P-V-diagram (pressure - volume) of a refrigerating cycle is used, usually. The P-V - diagram is formed on the screen of PC. For this purpose the signal from a gas pressure gauge, powered by preamplifier, acts on input of ADC. The coordinate gauge issues the strobe-signal for ADC after each of 1 grade turn of the flywheel. Saved up for a full turn of a flywheel the controller transfers a file of the information on a command of inquiry in the PC. Besides a pressure, the measured values of currents in electromagnets of both valves are sent to PC. PC composes a PV-diagram, as well as a time diagram of currents in electromagnets.

The coordinate gauge (called "DC-90", developed in IHEP, Protvino) is fixed on the case of the expander machine, separately from the controller, it gives out single an TTL-impulse corresponding opening of the valve of an admission (zero readout), and also two displaced on a phase on a quarter of the period of sequence the TTL-impulses corresponding readout of each degree of turn of a flywheel, allowing to define a direction and speed of rotation of a flywheel.

There are two separated source current (1,2) with programmed diagram of pulses of the different pole, amplitude and duration to control the current in coils of valves. Power cascades of sources works in a pulse - mode that is the reason of electromagnetic noise. For decrease in a level of radiated noises the opportunity of inclusion of smoothing filters is stipulated.

Controller also has a power supplier to serve the coordinate gauge and the preamplifier of the gauge of pressure. To *serve* the controller need the power supply of 20-30 V.

To save the expander machine from destroy in case of the power supply on the stabilising engine will be off, the controller shuts down the power supply for the electromagnets of valves if rotating speed will be over programmed limit value. This function activated as well, if the flywheel will rotate in wrong direction.

Two galvanic outcome switches are used here to control the engines power supply. One of three rotating speeds could be selected for that.

Communication with the personal computer can be carried out through RS232, or through interface Ethernet - at the choice of the operator.

There is a program showing to an opportunity of the controller. The program works under control of OS Windows and allows to operate the controller and to display on the monitor all information necessary for the user.

The controller described above was successfully tested in operating installation of the KEDR cryogenic helium system in 2006.

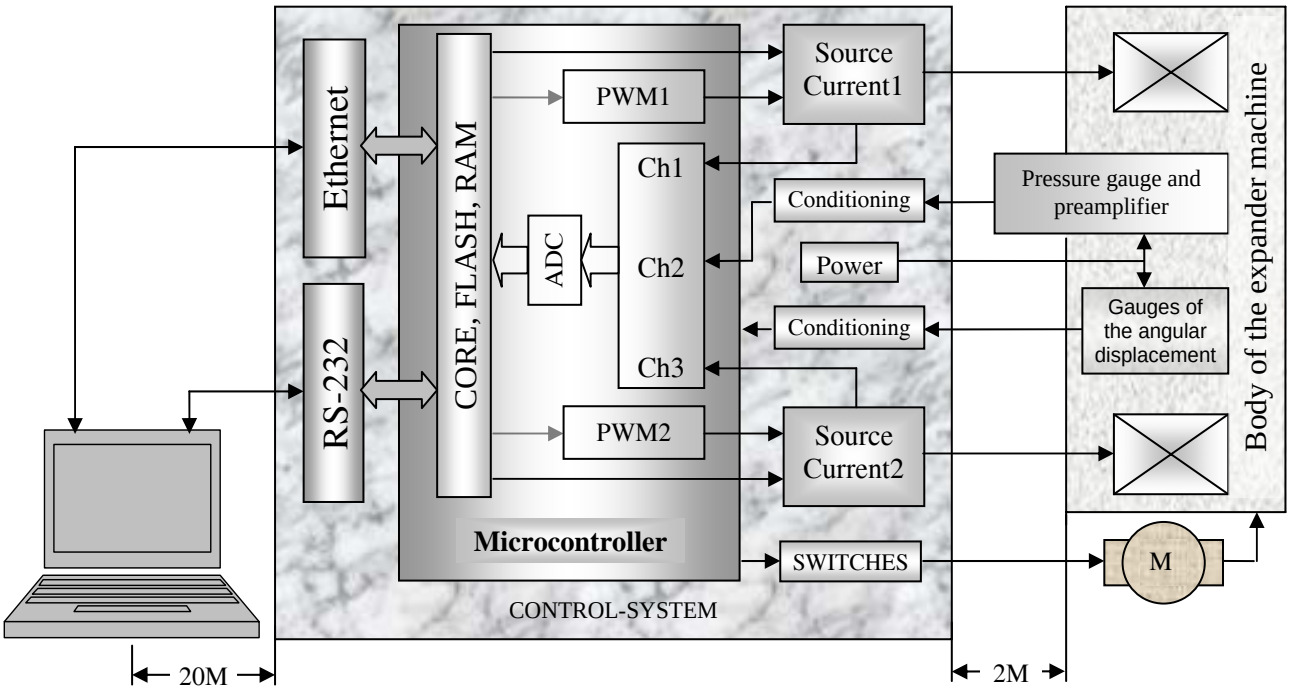

Figure 2: Block-diagram of the control-system for the expander machine