

# **MODERNIZATION OF THE MANAGEMENT AND CONTROL SYSTEM FOR THE COLD NEUTRON MODERATOR AT THE FAST PULSED REACTOR**

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The management and control system of the cold neutron moderator allows the engineering staff to monitor, in the process of its operation, the main parameters of the moderator, including the gas blower rotation speed, the consumption and temperature of helium, the vacuum in the jacket and the passage of pellets in the transport pipe. Today, complex upgrading of the cold neutron moderator at the fast pulsed reactor "IBR-2M" is underway. The paper presents the current version of the structure of the management and control system for the cold moderator. Interface convertors are used to connect the management and control equipment of the cold moderator to the computer. The main interface of the data acquisition and control system of the executive devices is RS-485. Specialized software has been created to operate the management and control system of the cold neutron moderator.

**Keywords:** IBR-2, cold neutron moderator, modernization

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## 1. History of the moderator

In the 80s of the last century, the idea of a bulk neutron moderator using ice and methane was first proposed, but it could not be realized because of the low radiation resistance of these materials.

Later, at the end of the last century, while studying the radiation properties of hydrogen-containing materials, it was found that mesitylene is destroyed 20 times slower than methane and absorbs neutrons three times less than methane. So, the idea of creating a neutron moderator with the use of mesitylene in a helium medium appeared [1]. In 2005 project work on the pelletized cold neutron moderator started. Research on specific features of the pneumatic transport of mesitylene pellets in helium was carried out parallelly. Specialists of the Central Aerohydrodynamic Institute were involved in choosing the optimal mode. They selected an optimal mode for transport of pellets in the system allowing them to overcome the rises. The cryogenic system and the optimal size of the pellets were developed.

In 2011 development of the project was completed, and in 2012 the moderator was firstly launched. In 2013 the moderator was put into operation [2].

## 2. Control system

The moderator control system consists of the following main subsystems:

- Control and management system of the dosing machine;
- Temperature control system for individual units;
- Pressure monitoring system in the moderator circuit.

The main areas of modernization of the moderator control system are:

- Improving the reliability of the control system;
- Increasing the level of automation of the control system;
- Integration of new elements into the control system.

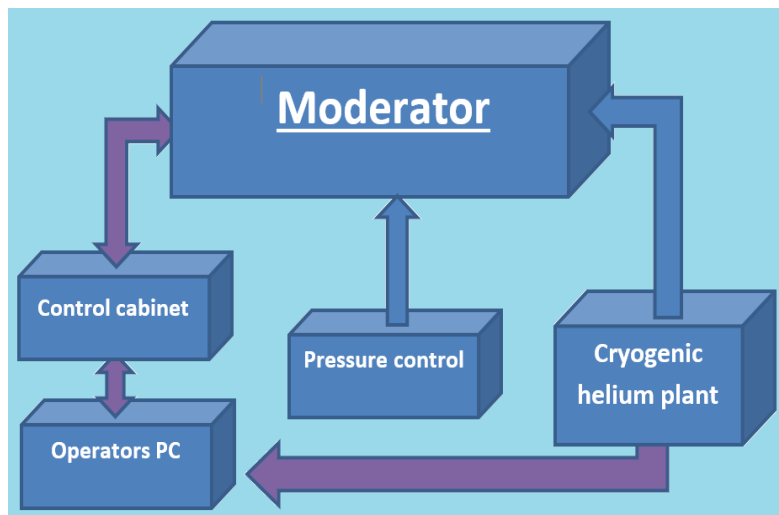


Figure 1. The moderator control system

### 2.1 Control and management system of the dosing machine

The control system of pellets' transport is based on the pressure difference during the passage of pellets between two points in the pipeline. The DXLdp differential pressure measuring device records the difference in pressure before and after the passing pellet. This allows to register the pellet,

to determine the speed of its movement. There are three differential pressure sensors in the system. The first measures the gas flow during the operation of the facility. The gas flow rate is averaged per second, to get rid of the high-frequency noise. Other sensors record the passage of pellets: the first registers the passage of pellets into the system immediately after the dosing machine; the second registers the passage of pellets on the rise and the lack of congestion control before the rise.

Differential pressure sensors, in the process of modernization, are replaced by optical span sensors *Smart Fiber Amplifier Unit E3NX-FA11* allowing to record the passage of pellets at a high rate.

Data from pressure sensors are received by LA-20USB ADC (LA-20USB is multifunction board analog-to-digital conversion for IBM PC) in real time, buffered and sent in packets via a USB connector to a PC. In this case, the frequency of measurements on pressure sensors is 1 ms, the control program survey is at a maximum rate of 1 s.

The dosing machine is driven by stepper motors. About three hundred pellets are loaded at a time. The stepper motor control system includes: a USB-CAN2 adapter with galvanic isolation to form a CAN communication interface link for connecting a PC to stepper motor controllers, a KSMC-8 stepper motor main controller with galvanic isolation on the CAN link and optical isolation on the limit switch monitoring circuits mounted in control cabinet.

For work with KSMC-8 the standard MidStepTest software module is used to set the following parameters of the engine operation:

- Velocity and direction of rotation;
- Current control modes in coils;
- Magnitude of the operating current and retaining current;
- Minimum and maximum velocity;
- Acceleration (in rotation mode for a given number of steps);
- Processing modes of limit switches.

## 2.2 Temperature control system for individual units

The complex system of sensors includes 6 K-type thermocouples, a platinum resistance thermometer for measuring the temperature of the cold junction and a silicon diode for high-precision measurement of cryogenic temperature.

Measurements are carried out using Keithley 2000 high-precision multivoltmeter with a twenty-channel scanning card. Thermocouples are connected via a 2-wire circuit, the thermodiode and the platinum thermometer - via a 4-wire circuit (a current of 10  $\mu\text{A}$  for a Keithley resistance thermometer and 50  $\mu\text{A}$  for a thermodiode from an additional LakeShore 102 Current Source are supplied through two wires). Voltage and resistance are measured differentially over two wires; the other pair of wires (with a four-wire circuit) serves as power for the sensor current.

Temperature is displayed in real time on the front panel of the display Keithley and is also transmitted via the RS232 interface (again using the MOXA UPort1400 interface converter) to the PC. During operation, we had to abandon the previously used multi-channel interface converter MOXA Uport due to regular problems with the numbering of COM ports on the operator's PC. Instead, a multi-channel USB hub is used.

The measurement accuracy is 0.002% for DC voltage and 0.008% for resistance.

Software processing of the received data (with high-precision measurement of the reference junction temperature) allows to get an error of not more than  $\pm 1\text{K}$ .

All information on the temperature is displayed both in numerical and graphical forms in PC and is saved to a text file at the request of the user. The operating temperature in the moderator circuit is about 30 K.

## 2.3 Pressure monitoring system in the moderator circuit

The vacuum control system in the moderator circuit includes eight MKS925 pressure sensors and one MKS901 sensor.

Also, during modernization of the moderator, 16 valves of the vacuum system were changed from manual ones to electromagnetic. The valve solenoid is controlled via the 24 V line through the OWEN relay block from the operator's PC. When the moderator is operating, the system pressure is controlled programmatically and a ban is issued on changes in the state of the sensors, which can lead to an emergency.

The vacuum sensors MKS925 and MKS901 are designed for measuring pressure in the range from  $1 \times 10^{-8}$  to 3000 Torr, at normal atmospheric pressure. The MKS925 sensors measure pressure in the moderator circuit in the range of  $1 \times 10^{-4}$  Torr in the operating mode of the vacuum control system. MKS901 sensors measure pressure close to normal atmospheric pressure, being reference sensors for amending the readings of the MKS925 vacuum sensors.

During operation and modernization of the cold moderator, the MKS925 sensors were replaced with sensors of the same type of the later series with an improved electronic base and an enlarged display, which reduced the number of failures.

### 3. Software

The SCP software package has been developed for the use of the moderator [3]. It includes six modules:

- database server – *VarmanServer*;
- driver of the vacuum sensors MKS-901 and MKS-925 - *d\_press*;
- temperature sensor driver - *d\_termo*;
- gas holder driver - *d\_gasholder*;
- driver of the frequency drive of the gas blower control system - *d\_freq*;
- LA20-USB ADC driver - *d\_LA20*;

as well as two main user interfaces:

- **BMC** to control the loading and movement of mesitylene pellets and gas flow;
- **CM\_Viewer** to obtain information on the operation of cryogenic moderator systems.

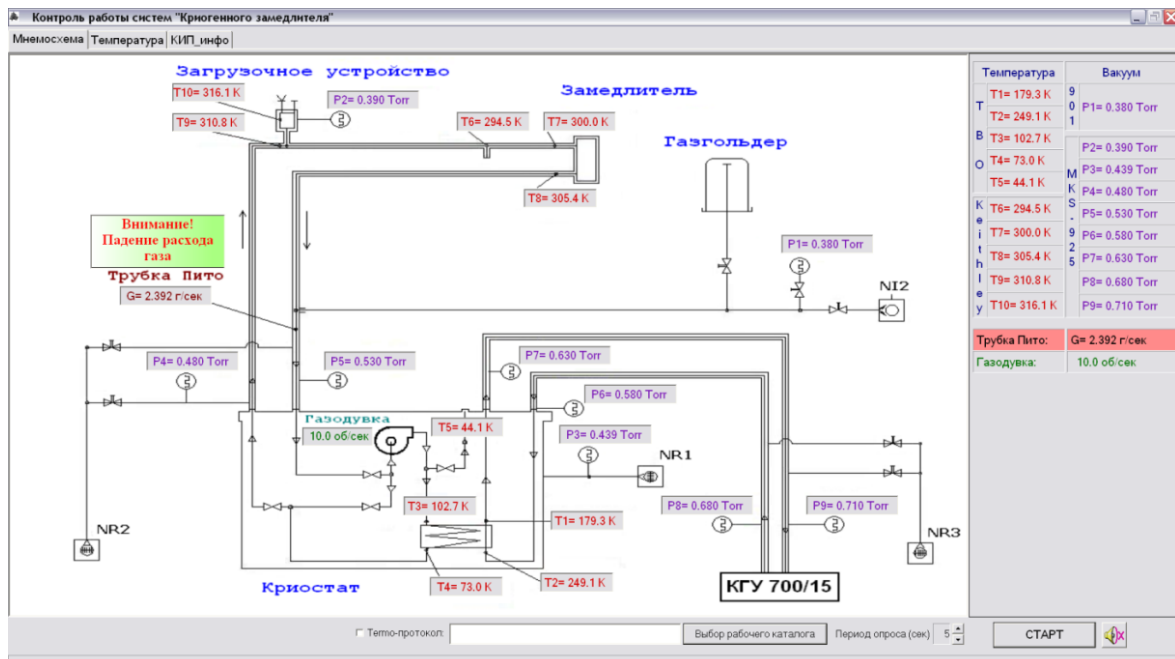


Figure 2. CM\_Viewer screen

The software package is designed for the automation of the following functions:

- Measurement of vacuum in the space between pipes with MKS-925 sensors;
- Measurement of vacuum or overpressure in the inner (mesitylene) pipe by the MKS-901 sensor;
- Display of data from thermocouples for temperature control;
- Graphic image of temperature change;
- Control of changes in gas blower speed;
- Helium level control in a gas tank;
- Monitoring of the passage of mesitylene pellets;
- Gas flow control;
- Periodic display on the screen of measuring and control devices;
- Sound and text alarm in case of emergency.

The user can set a measurement interval (from 2 to 5 seconds) and parameters for saving data to a file.

## **4. Results**

According to the results of operation and modernization of the cold moderator, the number of hardware failures in the operation of the moderator is planned to be reduced by 50% and software failures - by 80%.

At present, work is underway to integrate the FANUC robot-repackler and a video control system for its manipulations into the six-axis robot control system. The operator only needs to click on the program button on the robot control tab and study the robot operating.

## **5. Perspectives**

The main promising area of modernization of the cold moderator control system is the refusal of using a PC as a means of control in favor of the Programmable Logic Controllers (PLC). The operator's PC will carry out only the function of an external user interface and a server for remote control of the moderator parameters. This will increase the reliability of the system and its security against unauthorized interference and exposure.

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