



**AUTOMATED CONTROL SYSTEM OF
MODERNIZED KYROPOULOS METHOD
MONOCRYSTAL GROWING FURNACE**

«OMEGA-PG350»

Program description





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2. ACCEPTED ABBREVIATIONS, TERMS AND DEFINITIONS

The following terms herein have the following designation:

Abbreviation	Denomination
AW	Automated workplace
ACS	Automatic control system
UPS	Uninterruptible power supply
IP	Indicator panel
PC	Personal computer
PLC	Programmable logic controller
IM	Instruction manual
MGF	Monocrystal growing furnace



3. INTRODUCTION

3.1. The Purpose of Software

Software of the automated control system (hereinafter referred to as software ACS) is designed for the operation of the modernized kyropoulos method monocrystal growing furnace (hereinafter MGF) and on-screen visualization at the operator automated workplace in real time of full and accurate information about the current process.

This software allows service personnel to monitor the status of current values of monitored parameters, the state of the main equipment, manage the process and alarm system for the operative control of devices and systems of the MGF, analysis of their work.

The program interface provides an efficient and comfortable work with the data, which in its turn minimizes errors and inaccuracies. For working with the software of MGF ACS it is necessary to have a basic level of training by the user.

The software provides full automation of the process of monocrystals growing by Kyropoulos except stage of seeding crystals.

The program is designed in accordance with the standards and recommendations for the development of modern software and runs on the operating system GNU / Linux.

3.2. The Software Features

The software of MGF ACS provides:

- enabling operators to select and fine tune the technological parameters of ACS;
- automatic maintenance of the process of monocrystals growing;
- configuring the parameters of automatic modes of technological process;
- displaying parameters of the current state of the systems and devices of MGF;
- registration and displaying the emergencies of ACS;
- formation and displaying the graphs of technological parameters;
- formation and displaying the log messages of technological actions of ACS and operator' actions;
- formation and storage of technological process parameters archives, action logs of ACS and the operator;
- differentiation of access rights to technological settings and data protection from unauthorized access;
- providing information to remote users;
- possibility of remote support service.

4. ACS MGF PROGRAM DESCRIPTION

4.1. The Window of the Current State

When enabled the software starts automatically, ACS switches to the window-displaying mode of the current state, which displays the status of the main technological parameters of the system (Fig. 3.1):

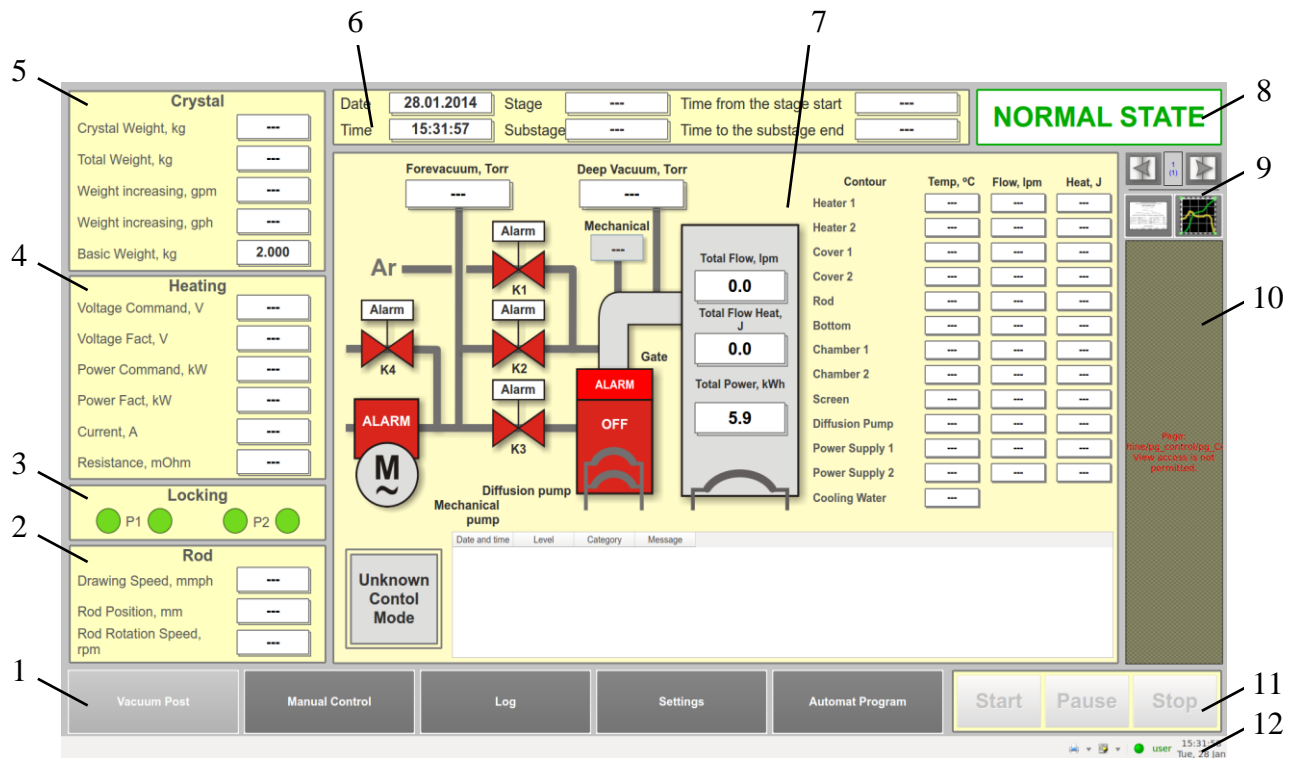


Fig. 3.1. A status window of main technological parameters of the system

In the window the following panels are shown:

1. Navigation bar between the pages of project (4.1.8);
2. The status infobar of rod (4.1.5);
3. The status infobar of vacuum blocking (4.1.4);
4. The infobar of energy parameters (4.1.3);
5. The infobar of weighting parameters (4.1.2);
6. The infobar of technological process stages (4.1.1);
7. Page of vacuum control (4.1.7) or page of parameter settings (4.2);
8. The status bar of system (4.1.6);
9. The switch of pages (4.1.9);
10. Context menu of control and configuration (4.1.10);
11. The control panel of the automatic program (4.7.3);
12. The panel of tools for OpenSCADA environment (4.1.11).

4.1.1. The Infobar of Technological Process Stages

Panel (Fig. 3.2) displays the current date and time, number of stage and section, which is performed at this time, the elapsed time from the beginning of the current stage, and time to completion of the current section:

Date	20.12.2013	Stage	---	Time from the stage start	---
Time	15:16:46	Substage	---	Time to the substage end	---

Fig. 3.2. The infobar of technological process stages

When switching the automatic program performance to state **Pause**, the time until the end of the section "freezes" and will resume when pressing **Start**.

4.1.2. The Infobar of Weighting Parameters

Panel (Fig. 3.3) displays the actual values of total mass of pulling mechanism, the mass of the crystal, as well as values mass increase per hour and minute.

Crystal	
Crystal Weight, kg	---
Total Weight, kg	---
Weight grein, gpm	---
Weight grein, gph	---
Basic Weight, kg	2.000

Fig. 3.3. The infobar of weighting parameters

In position **Basic Weight, kg** level corresponding to an initial value of the weight in kilograms is displayed, which is set by the operator on the mass settings page, as a rule, at the start of growth.

In the absence of communication with the controller following text is displayed .

When double click on the icon the limit values configuration panel appears (4.1.10.2). (Available only to the user with the **Kip** rights).

4.1.3. The Infobar of Energy Parameters

The infobar is shown on Fig. 3.4

Heating	
Voltage Command, V	---
Voltage Fact, V	---
Power Command, kW	---
Power Fact, kW	---
Current, A	---
Resistance, Om	---

Fig. 3.4. The infobar of energy parameters

In **Fact** position the current values of voltage and heater power are displayed.

The position **Command** displays the current setting, which is set by the operator or automatic program.



If the current control is done by the voltage, the **Voltage Command** field displays the current setting, and the field **Power Command** - value of 0.000. Conversely, if the control is done by the power, the **Power Command** field displays the current setting, and the field **Voltage Command** - 0.000.

The position **Current** displays the value of current.

The position **Resistance** displays calculated resistance value of the heater.

In the absence of communication with the controller following text is displayed .

When double click on the icon the limit values configuration panel appears (4.1.10.2). (Available only to the user with the **Kip** rights).

4.1.4. The Status Infobar of Vacuum Blocking

Alarm panel of blocking status (Fig. 3.5) is intended to indicate the loss of vacuum. On exit of the measured values of the vacuum beyond the preset critical values the indicator becomes red.

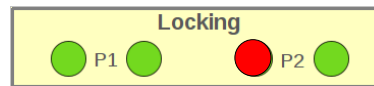


Fig. 3.5. The status infobar of vacuum blocking

Given two sets of blockings: 1) blockings of the vacuum gauge within forevacuum pump line; 2) blockings of the vacuum gauge in crystallizer chamber. Blockings have forbidden character.

There are three blocking statuses:

actions are not allowed	– gray indicator;
actions are allowed and the blocking is not active	– green indicator;
actions are allowed and blocking is active	– red indicator.

Detailed blocking management is described in [section 4.2.1](#).

4.1.5. The Status Infobar of Rod

The infobar is shown on [Fig. 3.6](#)

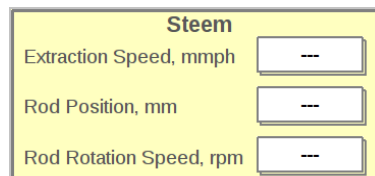


Fig. 3.6. The status infobar of rod

The field **Extraction Speed** displays the current value of the extraction speed.

The field **Steem Position** displays the calculated value of the stroke position by number of worked steps of the stepper motor.

The field **Steem Rotate Speed** displays the current rotation speed value.

In the absence of communication with the controller following text is displayed .

When double click on the icon the limit values configuration panel appears (4.1.10.2). (Available only to the user with the **Kip** rights).



4.1.6. The Status Bar of System

Alarm panel displays the status of the system. Clicking on it opens access to the page of the active alarms (see 4.6).

Message **NORMAL STATE** (Fig. 3.7) indicates that all the controlled parameters of the system are within the normal range and the data exchange with the measuring instruments on RS-485 network is executed.



NORMAL STATE

Fig. 3.7. System parameters are normal

ALARM message in red (Fig. 3.8) indicates that one or more parameters of the system has the alarm value and / or exchange with measuring devices is violated through digital interface RS-485. This activates the red light and audible alarm of the lighting column.



ALARM

Fig. 3.8. Alarm state

ALARM message in yellow (Fig. 3.9) indicates the presence of an emergency, but the alarm being turned off. The red indicator and audible alarms of the lighting column are off.



ALARM

Fig. 3.9. State of dropped alarm

4.1.7. Page “Control”

The page layout of control is shown in Fig. 3.10:

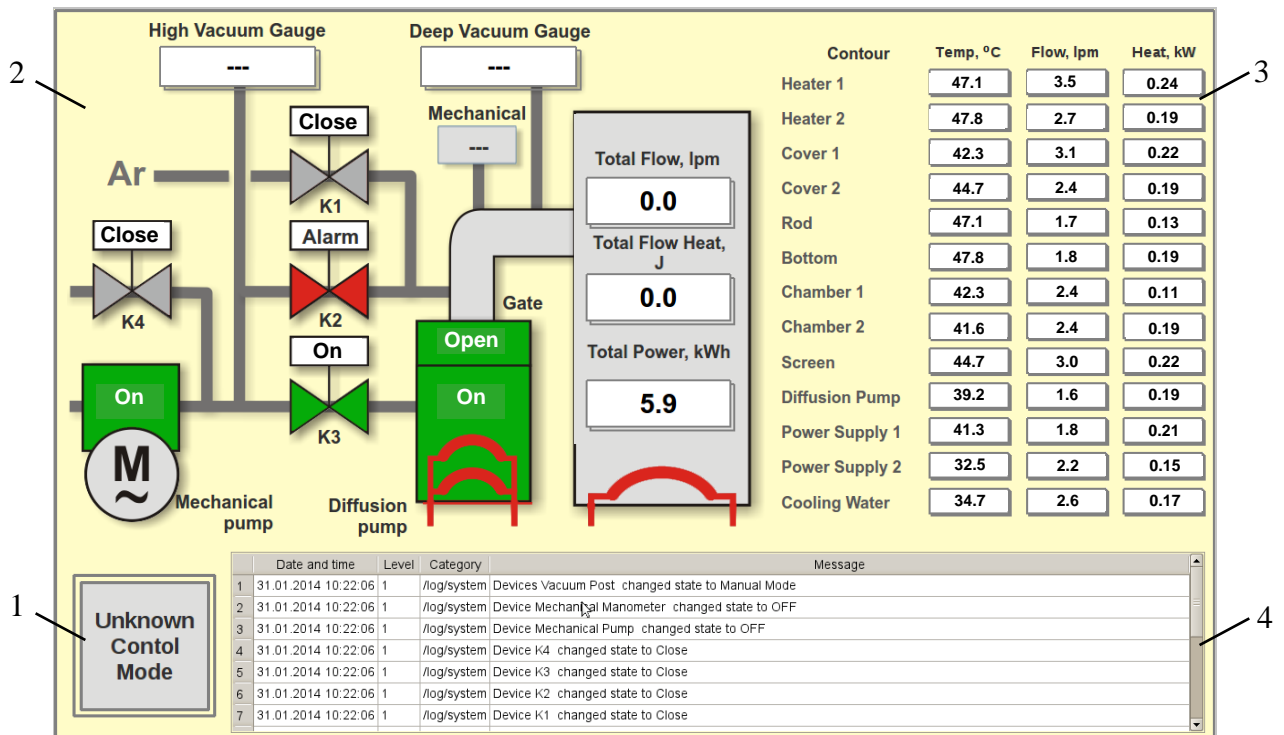


Fig. 3.10. Control page:

1. Indicator displaying the operation mode of equipment;
2. Mnemonic scheme of vacuum equipment (see 4.1.7.1)
3. The status bar of the cooling system (see 4.1.7.2)
4. Message log (see 4.1.7.3).

4.1.7.1. Mnemonic Scheme of the Vacuum Equipment

The mnemonic scheme displays the status of vacuum system equipment and pressure readings measured by vacuum gauges.

Control indicator informs about the current control mode of vacuum equipment. Indicator color is determined by the system's mode of operation:

- gray – communication error with the controller;
- green – automatic operation of the system;
- white – manual operation of the system;

In manual mode, the control of vacuum equipment is carried out only with the control keypad. In automatic mode, the control of vacuum equipment is carried out by the system in accordance with the program.

The operator is given the opportunity to control vacuum equipment by pressing the icon of the device. While the control panel will take the appearance corresponding to the selected equipment (see 4.1.10).

Color of the icons displaying the equipment is determined by its condition:

- gray – device is switched off;
- green – device is switched on;
- yellow – failure status of one of the helices of the diffusion pump;
- red – alarm state.



When double click on the icon of any of the devices the control panel and settings appear (see 4.1.10.1)

4.1.7.2. The Status Bar of the Cooling System

Panel (Fig. 3.11) shows the values of the temperature and flow, the calculated values of the thermal power carried away by the coolant in each of twelve circuits of the cooling system and the total values of flow and thermal power.

When data gets outside preset ranges the icons with data appear with yellow or red (above normal) or blue (below normal) color. How to set the limits described in section 4.2.4.

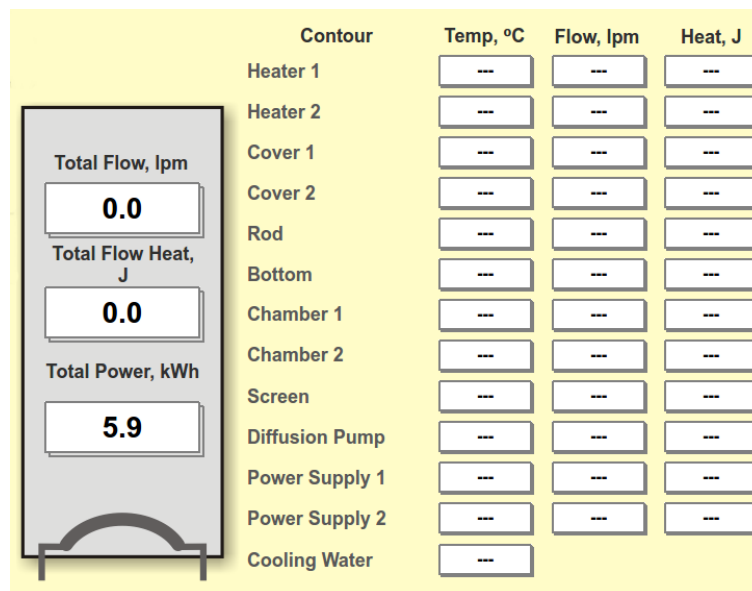


Fig. 3.11. The status bar of the cooling system

Furthermore, there is the indicator of total electrical power on the panel.

In the absence of communication with the controller following text is displayed .

When double click on the icon the limit values configuration panel appears (4.1.10.2). (Available only to the user with the **Kip** rights).

4.1.7.3. Message Log

Operator and system actions during the technological process logs messages (Fig. 3.12), indicating the date and time.

Date and time	Level	Category	Message
19.12.2013 16:03:44	1	/log/operator	Command to change state of the device Diffusion Pump to OFF
28.10.2013 16:36:19	1	/log/system/alarm	Registered disabled alarm "Alarm enabled"
28.10.2013 16:36:17	1	/log/operator	Command to reset alarm
28.10.2013 16:30:19	1	/log/system/alarm	Device connection alarm "Connection error with EInetLTE"
28.10.2013 16:30:18	1	/log/system/alarm	Device connection alarm "Connection error with TKU6"
28.10.2013 16:30:18	1	/log/system/alarm	Device connection alarm "Connection error with RRG12"
28.10.2013 16:30:17	1	/log/system/alarm	Device connection alarm "Connection error with Driver Rotaning Rod"
28.10.2013 16:30:15	1	/log/system/alarm	Device connection alarm "Connection error with Driver Working Movement"
28.10.2013 16:30:14	1	/log/system/alarm	Device connection alarm "Connection error with IP3"
28.10.2013 16:30:14	1	/log/system/alarm	Registered alarm "Devices connection alarm"

Fig. 3.12. Message log of operator actions

The log can be reviewed on a separate page of the log review (see 4.4).

4.1.8. The Navigation Panel

Navigation panel (Fig. 3.13) provides the ability to switch between the pages of the program interface.

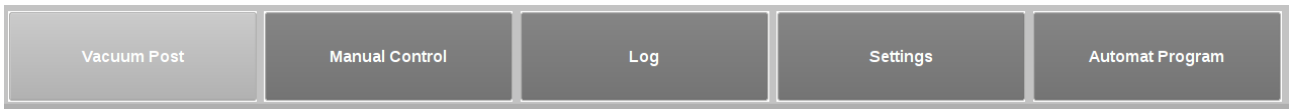


Fig. 3.13. Navigation panel

If the button is highlighted in yellow, it is active, if not - inactive.

Manual Control page is available in the states of the automatic **Stop** and **Pause**, in the state **Start** button to jump to page is inactive.

4.1.9. The Switch of Pages

The switch of pages (Fig. 3.14) enables fast navigating to the desired control functions.

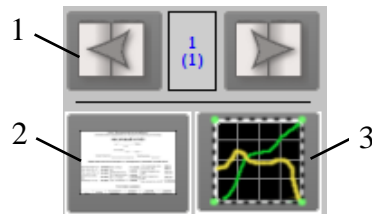




Fig. 3.14. switch of pages:

1. The icon of switching pages review;
2. The icon of jumping to the documents page;
3. The icon of jumping to the charts page.

Icon switching pages review provides the ability to switch pages, provided if the number of pages is greater than one. The number in parentheses indicates the total number of frames on a given page, the number that appears over the brackets indicates the number of active frame.

Pressing the  takes you to a page displaying the graphs (see 4.5).

Pressing the  takes you to a page displaying the documents (see 4.2.6)

In the current version of the program button is inactive.

4.1.10. The Control Panel and Configurations

The panel appears when selecting equipment. The content of panel depends on the type of equipment selected (Fig. 3.15).

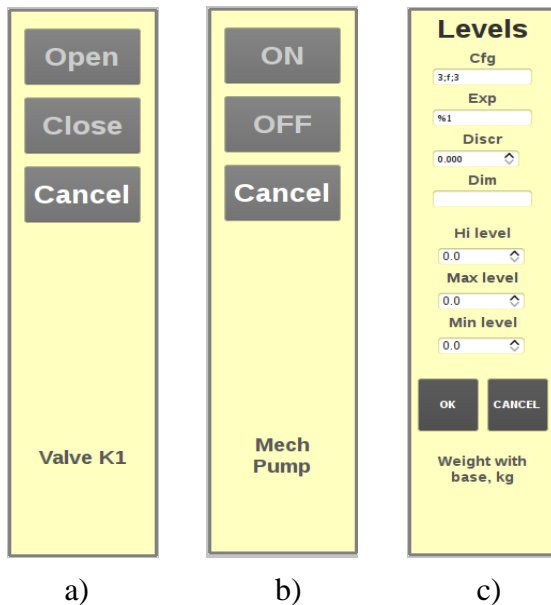


Fig. 3.15. The control panel and configurations:
a) and b) - the control panel of vacuum equipment;
c) - the limits configuration panel.

4.1.10.1. The Control Panel of Vacuum Equipment

Possible forms of the panel are shown in Fig. 3.15, a), b).

Open	On	– opening the valve or turning the device on;
Close	Off	– closing the valve or turning the device off;
Cancel		– cancellation of window opening, the device status is not changed.

4.1.10.2. The Limits Configuration Panel

The panel (Fig. 3.15 c) is intended to configure the alarm levels and only available to a user with **Kip** rights. The panel contains fields for setting the following parameters:

- Parameter **Cfg** - shows the configuration of displaying the value in the icon of equipment and is recorded as **[width]; [form]; [prec]**, where
 - width** - width value;
 - form** - form values:
 - 'g' - without displaying the unnecessary zeros after commas (*for example, 7, 7.02*);
 - 'e' - the exponential mapping (*for example, 7e10, 2e-11*);
 - 'f' - the usual displaying (*for example, 3.00, 7.45*).
 - prec** – the number of digits after the decimal point..
- Parameter **Exp** - selecting mode of displaying the values.
 - 1% - displays the value
 - 1 - displays the text "1"
 - % 2 - displays "0".


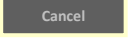
Recommended value "% 1".
- Parameter **Disc** - setting the value of multiplicity.



- Parameter **Dim** - setting the unit of measurement.
- Parameter **Hi level** - setting the limit above which an alarm message is displayed in red.
- Parameter **Max level** - set the maximum above which a message about possible emergency is displayed in yellow.
- Parameter **Min level** - setting the minimum value, while reducing the monitored value below which the message is displayed in blue.

Parameters *Min level* < Normal < Max level < Hi level.

To change field's value after entering data it is necessary to click on .

Button  - confirms the previous action, and the button  - cancels it

4.1.11. The Panel of Tools for OpenSCADA Environment

The panel is shown in [Fig. 3.16](#)

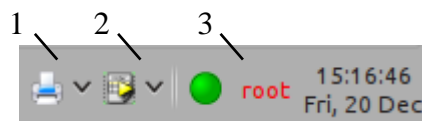




Fig. 3.16. The panel of tools for OpenSCADA environment:

1. Print button;
2. Export button;
3. Panel indicating the current user.

Print button  provides access to print the active frame, or exporting it to file. When clicking on printing of the active frame printer selection window appears.

When clicking on , window of selecting the file type to be saved appears. There are three types of files: page completely, graphics and tables. Selecting the type of graphics and tables is possible if they are present on this page.

Panel  displays the current user.

If it is necessary to change the user, you need to double-click on the indication panel of the current user; resulting in user selection menu appearance ([Fig. 3.17](#)).

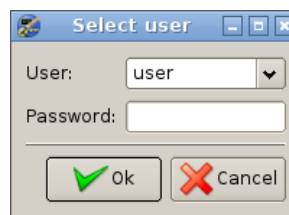


Fig. 3.17. User selection menu

In position **User** enter your user name; in the position **Password** enter the required password. Pressing **Accept** changes the system user.

There are three levels of user access:

Root – a system developer

Closed user with the rights to change program settings.

Kip – chief technologist

User with the rights of access to change technological system parameters.

User – system operator

User with the rights of conducting the technological process.

4.2. Page of Settings

Page is opened by pressing the **Setting** on the panel of navigation between the pages of the project (see 4.1.8). The page consists of:

- ✓ Page with controlling the parameters of blockings (see 4.2.1).
- ✓ Page with electrical settings (see 4.2.2).
- ✓ Page with parameter settings of stepper motors, rod and mass (see 4.2.3).
- ✓ Page with settings of cooling circuits (see 4.2.4).
- ✓ Page with system settings (see 4.2.5).
- ✓ Page with data export (see 4.2.6).

Page selection is done via the panel of page switching



4.2.1. Page of Controlling the Parameters of Blocking

Blockings are intended to ensure the safe operation of the unit during the loss of vacuum. There is the opportunity to choose the action while blocking by activating permission of actions and accordingly by selecting the required actions.

Blocking level determines the pressure at which the action is to block. Actions are performed at the end of a specified time.

Page with blockings parameter settings is shown in [Fig. 3.18](#)

The settings page of blockings displays:

- blocking parameters of two vacuum gauges;
- blocking levels, unlocking levels and actions delay time.

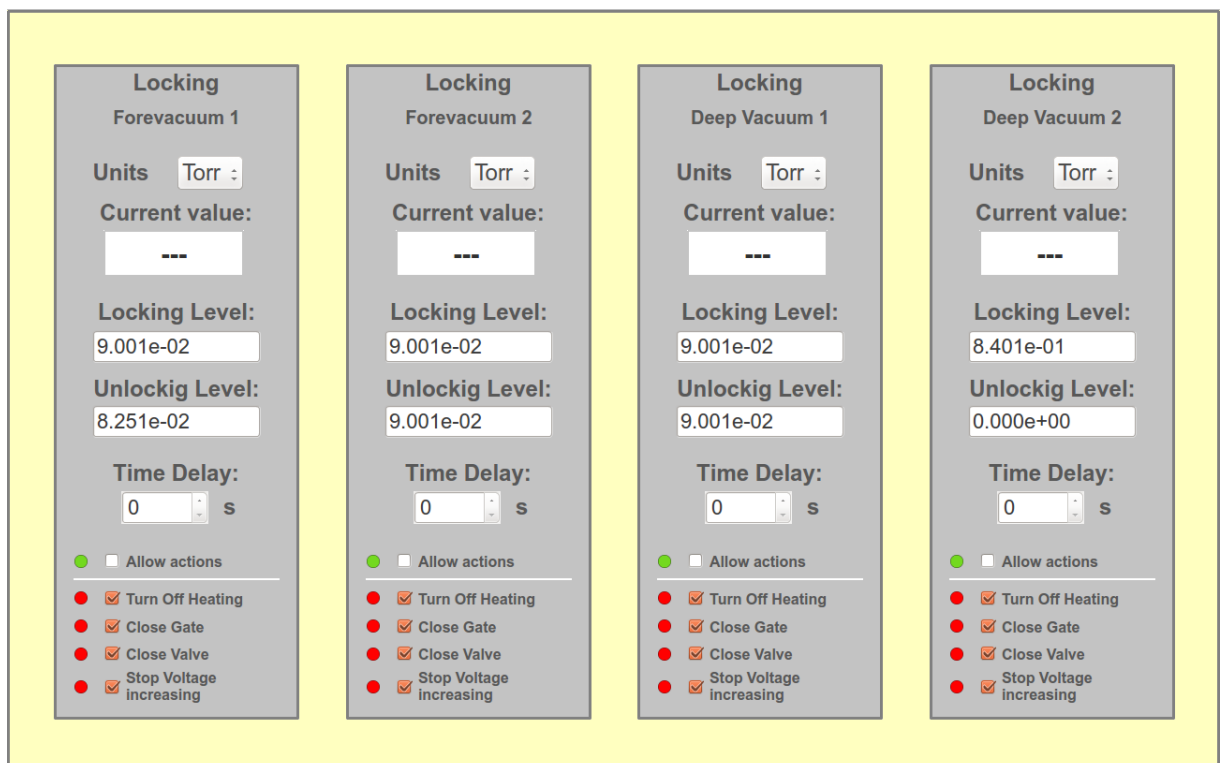


Fig. 3.18. Page of system blockings



Action **Gate close** envisages closing gate when activating the blocking, but after deactivating that blocking, gate will not open automatically, it is assumed that the operator will do it manually on the basis of analysis of the situation. Action **Valve close** closes the valve K3 when activating the blocking, and similarly to the gate, does not open it after deactivating the blocking.

Action **Voltage raise stop** transfers the automatic program execution into mode **Pause**, thereby fixing the power/voltage setup. Accordingly, the panel **Manual Control** becomes available and operator, if necessary, can change the setup or disable the heating. After deactivation of the blocking the automatic program execution continues (mode **Start** is automatically activated).

Two sets of blockings are provided upon two vacuum gauges. As both sets simultaneously, as each separately can be used. Each of them operate independently, and for example, if two blockings are on, both envisage closure of the valve (K3), but only the first blocking is triggered, then the valve will be closed.

Level values of blocking and unlocking can be set in Pa, Torr or in millivolts.

It is allowed to change the actions for blocking on condition that blocking has not occurred. If there is a need to change the blocking when they are active, then the previous unlocking must be performed manually.

Triggering of blockings is recorded in the log, which specifies at which level of pressure and voltage the blocking occurred.

4.2.2. Parameter Settings

Page of electrical parameter settings of devices is shown in [Fig. 3.19](#)

Electrical Settings

- Power Jump Value, W: 1
- Max Increase Power, Wps: 0.00
- Power Jumps Analyze Time, s: 10
- Max Increase Voltage, Vps: 0.00
- Electrical prm average points: 1
- IP3 Min Operating Voltage, V: 0.00
- Max calibration voltage, V: 0.00
- Calibration Accuracy Factor, V: 0.0000
- Reset Power Counter: Set
- Start Calibration IP3: Set
- Stop Calibration IP3: Set
- Factor proportional Level Voltage: 0.00
- Factor integral Level Voltage: 0.00
- Factor differential Level Voltage: 0.00
- Factor proportional Level of Power: 0.00
- Factor integral Level of Power: 0.00
- Factor differential Level of Power: 0.00
- Calibration state of IP3:

Fig. 3.19. Page of electrical parameter settings

Electrical settings:

1. Allowable power jump increase.
2. Maximum power increase.
3. Power jumps analyze time.
4. Maximum voltage increase.
5. Electrical prm average points.
9. Reset power counter.

Calibration parameters of the power meter IP-3:

6. Minimum operating voltage.
7. Maximum calibration voltage.
8. Calibration accuracy factor.
10. Command to start the calibration.
11. Command to stop the calibration.
18. Indicator of IP-3 calibration process.

The parameters of proportional-integral-derivative controllers:

12. Proportional term of voltage PID controller.
13. Integral term of voltage PID controller.
14. Derivative term of voltage PID controller.
15. Proportional term of power PID controller.
16. Integral term of power PID controller.
17. Derivative term of power PID controller.

Data input is recorded by the program after clicking on the icon .

IP-3 calibration mode is designed for synchronization of the IP-3 readings with the readings of an Flex Kraft DC Rectifier.

4.2.3. Page of Stepper Motors and Rod Parameters Settings

The page of stepper motors and rod parameters settings is shown in [Fig. 3.20](#).

Step Motors, Rod and Weight Settings

1	Max Crystal Weight for drowing stop, kg	0.00		11	Set Base Weight, kg	0.00	
2	Weight Averaging Points	0		12	Set current weight as base		Set
3	Weight Increase Analyzes Time Length, s	10		13	Weight ADC Value	---	
4	Alarm Weight Increase, g	1		14	Potentiometer Max Rotation Speed, rpm	0.00	
5	ADC code at 0 calibration tenzosensor	0.00		15	Number of pulses for drawing of 1 mm	0.00	
6	ADC code at 1 calibration tenzosensor	0.00		16	Number of pulses for 1 revolution	0.00	
7	Weight value at point 0 tenzosensor, kg	0.00		17	Reset rod position		Set
8	Weight value at point 1 tenzosensor, kg	0.00		18	ADC code at 0 calibration potentiometer		Set
9	Set current ADC code at 0 calibration tenzosensor		Set	19	ADC code at 1 calibration potentiometer		Set
10	Set current ADC code at 1 calibration tenzosensor		Set				

Fig. 3.20. Page of stepper motors and rod parameters settings

Mass analysis parameters:

1. Maximum mass of the crystal, which stops the extraction.
2. Time of averaging the mass of the crystal (parameter affects only displaying of the weight on the graphs (value range 0 - 60s).
3. Interval of mass increase analysis (value range 10 ... 65535s (~ 18 h)).
4. Maximum value of mass increase at which the alarm is activated (value range 1 ... 65535).

The strain gauge calibration parameters:

5. ADC code value at the calibration point 0.
6. ADC code value at the calibration point 1.
7. Mass in the calibration point 0.
8. Mass in the calibration point 1.
9. Setting the value of the current ADC code in the calibration point 0.
10. Setting the value of the current ADC code in the calibration point 1.
11. Setting the base weight of the crystal.
12. Assigning to the current weight of the crystal the base value.
13. Indicator of current value of ADC code.

Settings of movement and rotation drives of rod:

14. Maximum speed of the rod rotation.
15. Number of encoder pulses of drive movement that corresponds to the displacement of rod by 1 mm.
16. The number of pulses that corresponds to one revolution of the engine.
17. Position reset.
18. ADC potentiometer code value of rotation in the calibration point 0.
19. ADC potentiometer code value of rotation in the calibration point 1.

Data input is recorded by the program after clicking on the icon .

To install the command, you must click **Set**.



Calibration of strain gauge ADC readings may be performed either by entering the ADC digital code values in fields 5 and 6 or according to data of the indicator 13 using the commands in fields 9 – 10.

4.2.4. Page of the Cooling System Control Settings

Page of cooling system control (Fig. 3.21) provides the ability to set the temperature measurement in circuits and flow values at which the emergency notification will appear. The numbering of temperature circuits corresponds to the numbering of temperature and flow sensors.

Field Number	Parameter	Unit	Value
1	Temperature Gisteresis	°C	0.0
2	Max temperature 1	°C	0.0
3	Max temperature 2	°C	0.0
4	Max temperature 3	°C	0.0
5	Max temperature 4	°C	0.0
6	Max temperature 5	°C	0.0
7	Max temperature 6	°C	0.0
8	Max temperature 7	°C	0.0
9	Max temperature 8	°C	0.0
10	Max temperature 9	°C	0.0
11	Max temperature 10	°C	0.0
12	Max temperature 11	°C	0.0
13	Max temperature 12	°C	0.0
14	Max temperature 13	°C	0.0
15	Max temperature 14	°C	0.0
16	Max temperature 15	°C	0.0
17	Max temperature 16	°C	0.0
18	Water Consumption Coefficient	ipl	0.00
19	Min Water Flow 1	lph	0
20	Min Water Flow 2	lph	0
21	Min Water Flow 3	lph	0
22	Min Water Flow 4	lph	0
23	Min Water Flow 5	lph	0
24	Min Water Flow 6	lph	0
25	Min Water Flow 7	lph	0
26	Min Water Flow 8	lph	0
27	Min Water Flow 9	lph	0
28	Min Water Flow 10	lph	0
29	Min Water Flow 11	lph	0
30	Min Water Flow 12	lph	0

Fig. 3.21. Page of cooling system control

Right of the editing field, there is the current value of a parameter.

The hysteresis value to enable / disable the alarm is given in the field 1.

For example: if the level of the maximum allowable temperature is set equal 55 °C then when setting the hysteresis of 2 °C, audible and visual alarm switching on will be made with temperature rising up to 55 °C and switching off at temperature reduction up to 53 °C.

In the fields 2 – 17, the maximum temperature values in 16 cooling circuits are to be entered; at those values, the alarm will turn on.

In the field 18, the pulses quantity of flow sensors, which corresponds to the liquid flow of 1 liter, is to be entered.

In the fields 19 - 30, maximum flow rate values in 12 cooling circuits are to be entered; at those values, the alarm will turn on.

Data input is recorded by the program after clicking on the icon .

4.2.5. System Settings Page

System settings page (Fig. 3.22) consists of three panels:

GROUP	NAME	VALUE	PATH
Electrical	iElectricParamAvrgPoints	40	/sub_DAQ/mod_ModBus/cntr_PLC/prm_ElectricalSettings/%2fval%2fiElectricParamAvrgPoints
Electrical	rIP3MinOperatingVoltage	1	/sub_DAQ/mod_ModBus/cntr_PLC/prm_ElectricalSettings/%2fval%2friP3MinOperatingVoltage
Electrical	rMaxCalibrationVoltage	15	/sub_DAQ/mod_ModBus/cntr_PLC/prm_ElectricalSettings/%2fval%2frMaxCalibrationVoltage
Electrical	rPIncreaseForSec	15	/sub_DAQ/mod_ModBus/cntr_PLC/prm_ElectricalSettings/%2fval%2frPIncreaseForSec
Electrical	rUIncreaseForSec	0.1	/sub_DAQ/mod_ModBus/cntr_PLC/prm_ElectricalSettings/%2fval%2frUIncreaseForSec
Electrical	wPowerJumpTime	0	/sub_DAQ/mod_ModBus/cntr_PLC/prm_ElectricalSettings/%2fval%2fwPowerJumpTime
Electrical	wPowerJumpValue	1000	/sub_DAQ/mod_ModBus/cntr_PLC/prm_ElectricalSettings/%2fval%2fwPowerJumpValue
PID	rKDP	0	/sub_DAQ/mod_ModBus/cntr_PLC/prm_PIDSettings/%2fval%2frKDP
PID	rKDU	0	/sub_DAQ/mod_ModBus/cntr_PLC/prm_PIDSettings/%2fval%2frKDU
PID	rKIP	0.2	/sub_DAQ/mod_ModBus/cntr_PLC/prm_PIDSettings/%2fval%2frKIP
PID	rKIU	0.2	/sub_DAQ/mod_ModBus/cntr_PLC/prm_PIDSettings/%2fval%2frKIU
PID	rKPP	0.3	/sub_DAQ/mod_ModBus/cntr_PLC/prm_PIDSettings/%2fval%2frKPP
PID	rKPU	0.3	/sub_DAQ/mod_ModBus/cntr_PLC/prm_PIDSettings/%2fval%2frKPU

Fig. 3.22. System settings page

1. The infobar shows the current version, the assembly and the table of current parameters values.

Locale Chooser

Language select button.

2. PLC settings panel displays controller status, its current network address and allows to set a new network address. To set a new network address it is necessary to enter the address in field and press the **Set** button.

Data input is recorded by the program after clicking on the icon .

3. Table allows to view the current values of all current parameters and settings:

Group – a group of elements;
Name – name of the parameter, setting;
Value – value of the parameter, setting;
Path – storage of the parameter, setting in the database.

Save

– Saving the current parameters.

Load

– Loading the archive parameters.

4.2.6. Page of Data Export

Page of data export (Fig. 3.23) consists of the start and end dates input panel, the period input panel, export data button and status indicator.

Fig. 3.23. Page of data export

Using the date input panel, you can specify the start and end dates, the time of data export. The period input panel sets period of data export.

Data export is done by pressing the button **Start Export**. Export status is displayed on the indicator. 100% filled progress bar corresponds to the completion of the data export process.

Data input is recorded by the program after clicking on the icon .

4.3. Page of Manual Control

Page of manual control (Fig. 3.24) provides the ability to control the parameters of current process manually in real time.

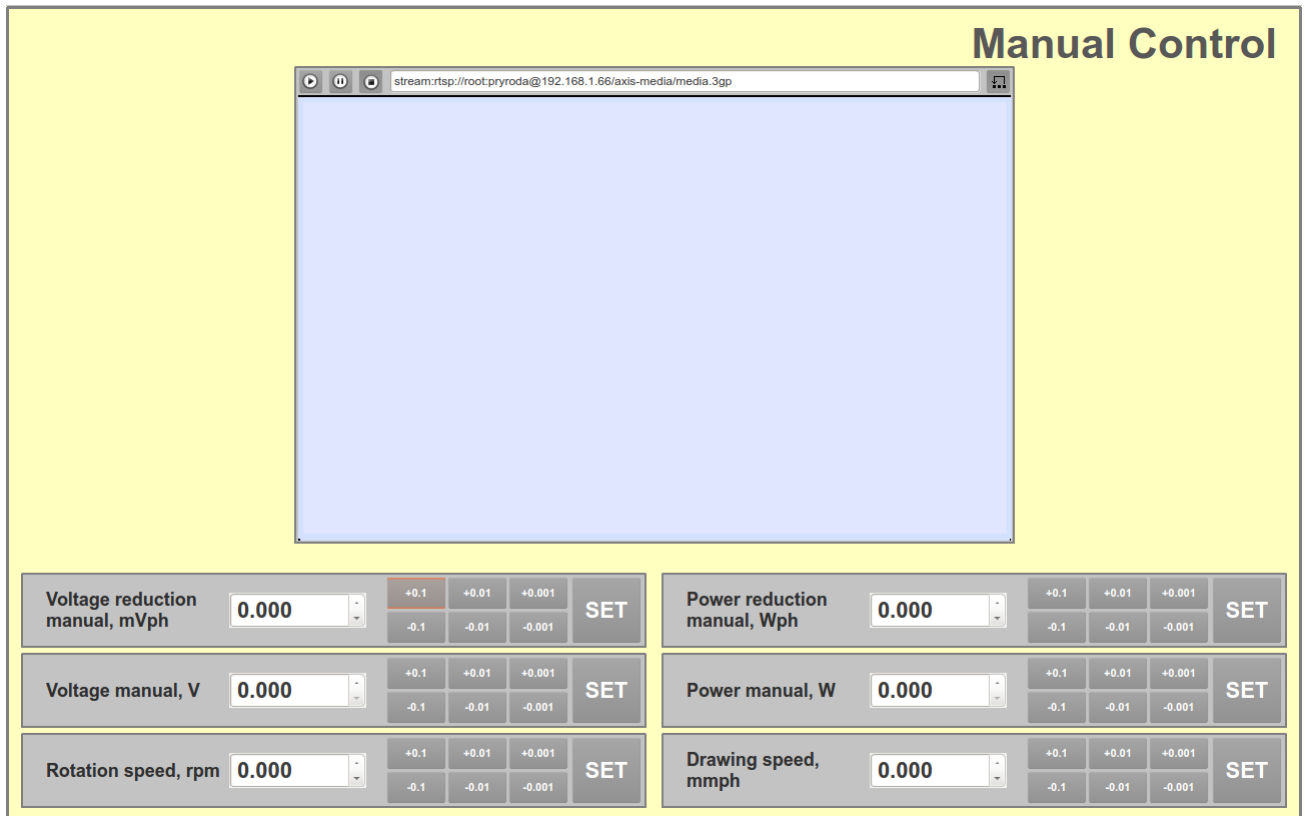



Fig. 3.24. Page of manual control

Within the lower panels, such parameters can be set: voltage increase, voltage, rotational speed, power and extraction speed. Depending on the configuration of manual control process, the parameters of installation commands may be changed.

When you press the **+0.1**, **+0.01** **+0.001** or **-0.1**, **-0.01**, **-0.001** the value in the input panel will change by selected value.

Data input is recorded by the program after clicking on the icon  .

The page also displays the video of the camera.

4.4. The Operator's Message Log

All events occurring during the technological process, including accident and operator's actions are logged (Fig. 3.25). Log can be viewed in a separate window.

	Date and time	Level	Category	Message
1	31.01.2014 10:22:06	1	/log/system	Devices Vacuum Post changed state to Manual Mode
2	31.01.2014 10:22:06	1	/log/system	Device Mechanical Manometer changed state to OFF
3	31.01.2014 10:22:06	1	/log/system	Device Mechanical Pump changed state to OFF
4	31.01.2014 10:22:06	1	/log/system	Device K4 changed state to Close
5	31.01.2014 10:22:06	1	/log/system	Device K3 changed state to Close
6	31.01.2014 10:22:06	1	/log/system	Device K2 changed state to Close
7	31.01.2014 10:22:06	1	/log/system	Device K1 changed state to Close

Fig. 3.25. Page of message log

All log messages are divided into categories, which show the date and time of the message, as well as in a simple and understandable form describe the essence of the event.

The settings panel helps to set the viewing period of required messages, also to filter them by category: messages caused by the actions of the operator; messages arising out of the system; all messages.

Structure of the log:

1. Date and time of the event.
2. Message level (1 - normal level, 3 - error 4 - remark).
3. Category of the messages (system or operator).
4. Text of the message.

4.4.1. The Panel of Log Settings

When displaying the message log settings panel takes the form shown in Fig. 3.26. The panel is designed to customize the displaying of log data.

To view any portion of the current archive on the settings control panel, the upper limit of time and displaying depth are to be set.

Fig. 3.26. The panel of log settings.

Upper displaying limit of the archive is set in the **Time**. The upper limit can be set by choosing the date and time in the input field or by using the keys:

- < – back 5 hours;
- > – forward 5 hours;
- << – back 10 hours;
- >> – forward 10 hours;
- Current Time – current time.




Displaying depth of the archive, appearing on the view, is selected in the field **Size**.

The interval can be changed and data of the interval will be loaded on the graph. While viewing the archive, newly arriving data is added to the beginning.

The field **Filter** defines the category of displaying protocol:

- log / * - displaying all messages;
- log / operator - displaying only operator messages;
- log / system - displaying only system messages;
- log / system / alarm - displaying only error messages.

| *Data input is recorded by the program after clicking on the icon  .*

4.5. Displaying the Graphs

4.5.1. Page of Summary Graphs

Page of displaying the summary graphs is called out by a switch of summary graphs frames on the panel of page switching (see 4.1.9). Page of summary graphs with active configuration panel is shown in Fig. 3.27:

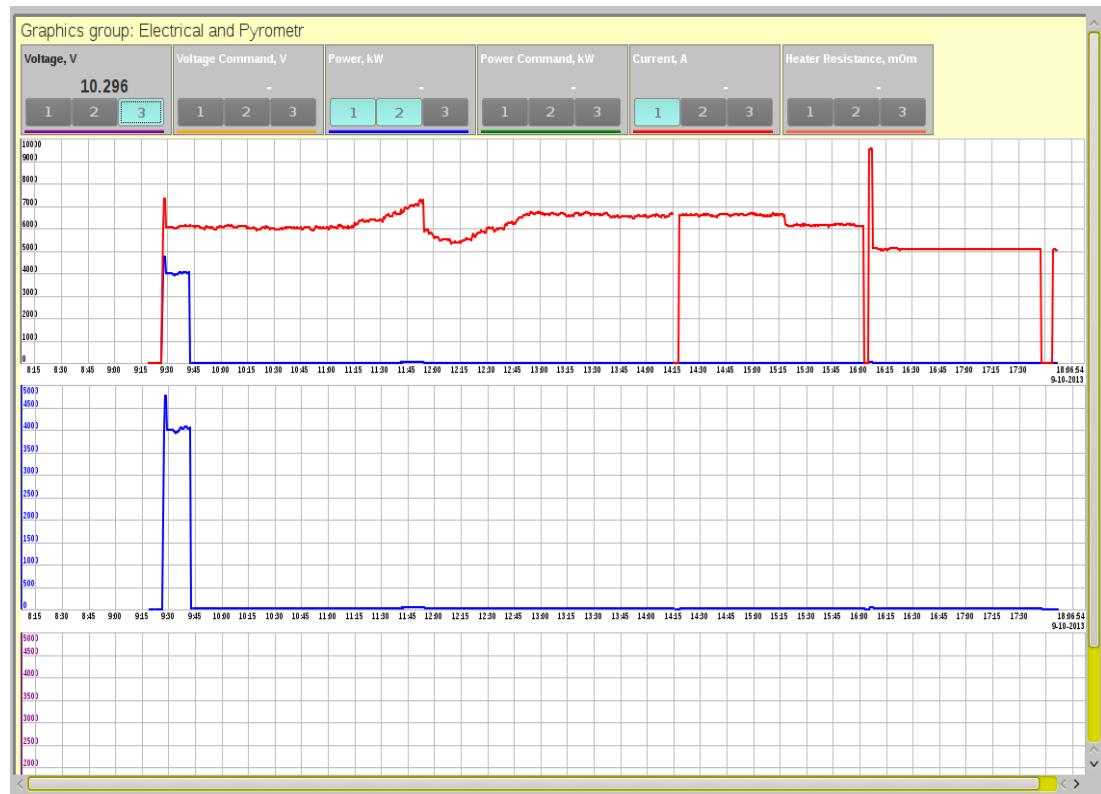


Fig. 3.27. Page of summary graphs

When opening a page values of the controlled technological parameters are displayed on the graphs with the possibility of comparing necessary parameters simultaneously in different fields of graphs, which are set using the display panel of selected parameters. Settings panel is activated when clicking on the graph field.

It is intended for displaying settings. Updated data is added to the end of the graph, and the graph itself when being filled moves to the left.

Such blocks (groups) of summary graphs are envisaged:

Electrical parameters: voltage, setting voltage, power, power setting, current, heater resistance;

Weight and extraction: mass of the crystal, total mass of the mechanism, mass increase per minute and per hour, rod position, the extraction speed.

Pressure: pressure measured by vacuum gauges of preliminary and deep vacuum;

Temperature (2blocks): the coolant temperature;

Water (2 blocks): consumption of the cooling fluid.

Page selection is done via the panel of page switching



4.5.2. The Panel of Parameters Selection

With panel (Fig. 3.28) trends of parameters necessary to compare are displayed on graphs, or in the same field of graph, or separately.

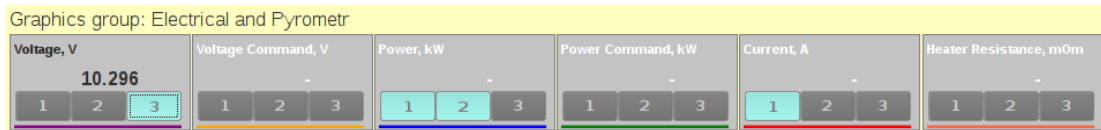


Fig. 3.28. The panel of parameters selection

On each element of viewing the parameter values graphs field selection buttons are displayed and values at the intersection of the cursor and the trend indicating the unit of measurement. The number of highlighted button indicates a field that displays the trend. The same parameter can be displayed simultaneously on several fields of graph.

The graph shows every trend of controlled parameter in the color, which is marked on the element of viewing the values for each parameter.

The arbitrary setting of displaying the required parameters is allowed in the fields of graphs. If in the same field parameters with the same dimension will be displayed, the vertical scale of this graph will have absolute values, otherwise the scale will have relative values.

4.5.3. The Panel of Graphs Settings

When displaying the page of graphs settings panel takes the form shown in Fig. 3.29. The panel is designed to customize the displaying of graphs.

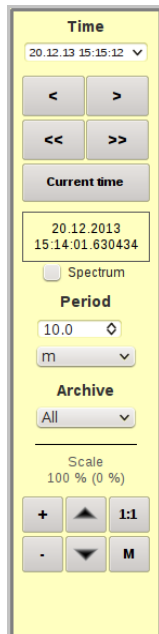


Fig. 3.29. Graphs settings panel

To view any portion of the current archive on the settings control panel, the upper limit of time and displaying depth are to be set.

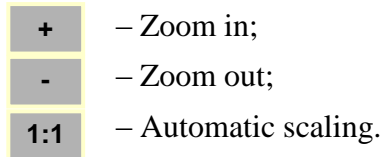
Upper displaying limit of the archive is set in the **Time**. It can be set by choosing the date and time in the input field or by using the keys:

- back 5 hours;
- forward 5 hours;
- back 10 hours;
- forward 10 hours;
- current time.


The interval can be changed and data of the interval will be loaded on the graph. While reviewing, newly arriving data is added to the beginning.

The field **Archive** helps to select the archive for viewing.

To change the zoom such buttons are provided:



Automatic scaling is performed every minute.

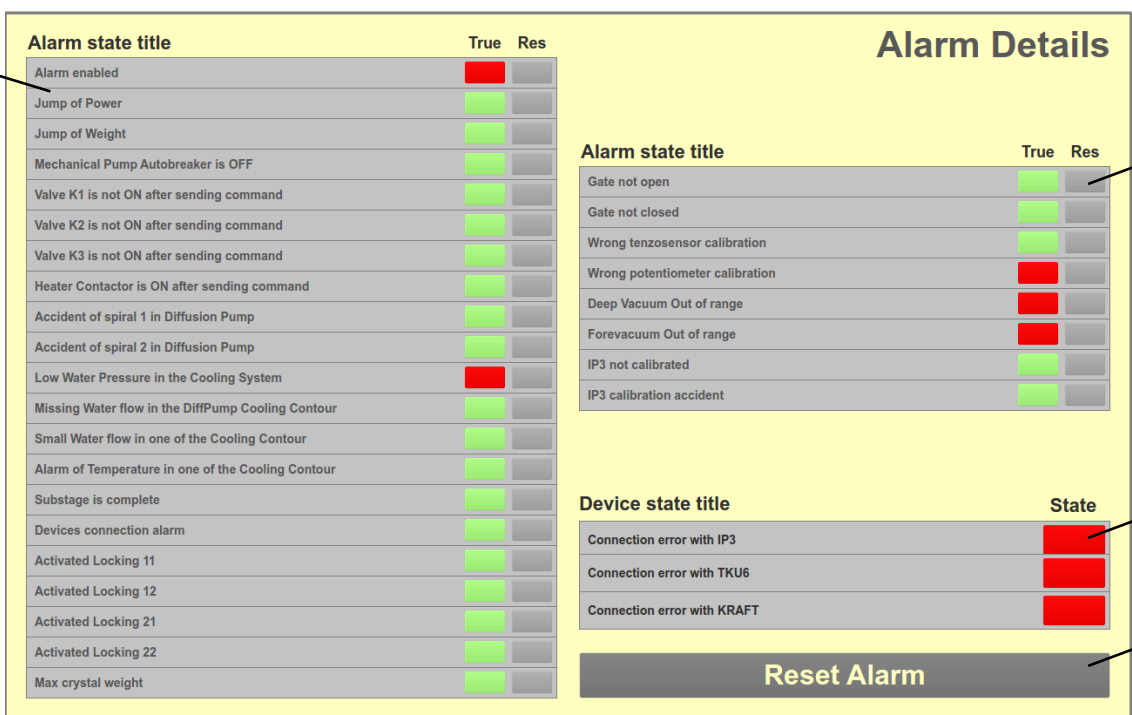
To move along the graph up and down keys  are used.

When the cursor is in an arbitrary position of the graph - value of the parameter corresponding to the cursor position will be displayed next to the graph name.

In the mode **Spectrum** graphs are displayed as a spectrum.

4.6. Page of Active Alarms

Clicking on the status icon of the system ([Fig. 3.7](#), [Fig. 3.8](#), [Fig. 3.9](#)) displays the page of active alarms ([Fig. 3.30](#)), which provides possibility of a timely decision on an emergency arose.



Alarm state title	True	Res
Alarm enabled	■	<input type="button" value="Res"/>
Jump of Power	■	<input type="button" value="Res"/>
Jump of Weight	■	<input type="button" value="Res"/>
Mechanical Pump Autobreaker is OFF	■	<input type="button" value="Res"/>
Valve K1 is not ON after sending command	■	<input type="button" value="Res"/>
Valve K2 is not ON after sending command	■	<input type="button" value="Res"/>
Valve K3 is not ON after sending command	■	<input type="button" value="Res"/>
Heater Contactor is ON after sending command	■	<input type="button" value="Res"/>
Accident of spiral 1 in Diffusion Pump	■	<input type="button" value="Res"/>
Accident of spiral 2 in Diffusion Pump	■	<input type="button" value="Res"/>
Low Water Pressure in the Cooling System	■	<input type="button" value="Res"/>
Missing Water flow in the DiffPump Cooling Contour	■	<input type="button" value="Res"/>
Small Water flow in one of the Cooling Contour	■	<input type="button" value="Res"/>
Alarm of Temperature in one of the Cooling Contour	■	<input type="button" value="Res"/>
Substage is complete	■	<input type="button" value="Res"/>
Devices connection alarm	■	<input type="button" value="Res"/>
Activated Locking 11	■	<input type="button" value="Res"/>
Activated Locking 12	■	<input type="button" value="Res"/>
Activated Locking 21	■	<input type="button" value="Res"/>
Activated Locking 22	■	<input type="button" value="Res"/>
Max crystal weight	■	<input type="button" value="Res"/>

Alarm state title	True	Res
Gate not open	■	<input type="button" value="Res"/>
Gate not closed	■	<input type="button" value="Res"/>
Wrong tenzosensor calibration	■	<input type="button" value="Res"/>
Wrong potentiometer calibration	■	<input type="button" value="Res"/>
Deep Vacuum Out of range	■	<input type="button" value="Res"/>
Forevacuum Out of range	■	<input type="button" value="Res"/>
IP3 not calibrated	■	<input type="button" value="Res"/>
IP3 calibration accident	■	<input type="button" value="Res"/>

Device state title	State
Connection error with IP3	■
Connection error with TKU6	■
Connection error with KRAFT	■

Reset Alarm


Fig. 3.30. Page of active alarms:

1. Panel displaying active alarms;
2. Status bar of communication with devices;
3. Emergencies reset button.



4.6.1. The Panel of Active Emergencies Displaying

In case of emergency during the technological process, sound and light alarm is triggered. The work area displaying active alarms submits the most authentic major emergencies. In turn, in the column **True** opposite the emergencies that arose, red marker is activated.

To disable the sound and light alarm operator must click . In this case, the marker in column **Res** will change from gray to green.

4.6.2. The Status Bar of Communication With the Devices

When communication errors occur with the measuring devices and power inverter KRAFT via digital interface RS-485, marker will change its color to red, and an alarm will be generated.

Devices connected via digital interface RS-48:

- parameters meter SP-3;
- cooling system controller TAS-6;
- power inverter KRAFT.

4.7. Page of Process Automation Settings

Page of process automation settings is shown in [Fig. 3.31](#).

This page displays the stages of the technological process of growing a monocrystal in the form of tables, each of which corresponds to a certain stage of the technological process and provides control of process stages:




1.	Starting Vacuum Equipment
2.	Heating
3.	Seeding
4.	Growing
5.	Detachment, Holding in Vacuum
6.	Cooling
7.	Holding in Vacuum
8.	Holding in Argon
9.	Atmosphere Overlap



STAGE # 1 — Vacuum Equipment						
Substage	Time interval, m	Target Value			Enable	
		P3, Torr	P2, Torr	P1, Torr		
1	1	0	1	1	Y	
STAGE # 2 — Heating						
Substage	Time Interval, h	Target Value		Drawing Speed, mmph	Enable	
		Voltage, V	Power, kW			
1	8	Y	10.5	40	0.1	Y
STAGE # 3 — Seeding						
Substage	Time Interval, h	Target Value		Enable		
		Voltage, V	Power, kW			
1	2	Y	10	0.1	Y	
STAGE # 4 — Growing						
Substage	Time Interval, h	Reduction Value		Drawing Speed, mmph	Enable	
		Voltage, mVph	Power, Wph			
1	10	Y	800	0	0	Y
2	20	Y	10	0	0.5	Y
3	120	Y	6	0	0.1	Y
4	3	Y	0.1	0	0	Y
5	3	Y	0.1	0	0	Y
6	3	Y	0.1	0	0	Y
7	3	Y	0.1	0	0	Y
8	4	Y	1	0	0	Y
STAGE # 5 - Detachment, Holding In Vacuum						
Substage	Time Interval, h	Reduction Value		Drawing Speed, mmph	Enable	
		Voltage, mVph	Power, Wph			
1	10	Y	1	45600	0	Y
2	10	Y	1	45600	0	Y
STAGE # 6 — Cooling						
Substage	Time Interval, h	Reduction Value		Drawing Speed, mmph	Enable	
		Voltage, mVph	Power, Wph			
1	30	Y	125	23000	0	Y
2	20	Y	100	23000	0	Y
3	40	Y	75	23000	0	Y
4	41	Y	100	23000	0	Y
STAGE # 7 — Holding in Vacuum						
Substage	Time Interval, h				Enable	
1	12				Y	
STAGE # 8 — Holding in Argon						
Substage	Time Interval, h				Enable	
1	12				Y	
STAGE # 9 — Atmosphere Overlap						
Substage	Time Interval, h				Enable	
1	11				Y	

Fig. 3.31. Page of the technological process automation settings

The indicator button of section control:

-  – stage is inactive;
-  – stage is active;
-  – stage is prohibited.



4.7.1. The Characteristics of Technological Process Stages

Tables allow to form sets of programs. Set selection is performed at program startup via setting the sections.

Stages **2 (Heating)**, **4 (Growth)**, **6 (Cooling)** are divided into sections. (See [4.7.2](#)).

The operator sets number of sections. Maximum number of sections - 30. Each section corresponds to the line in the table. The content of section is changed depending on the stage.

Each section defines a finite value of the technological parameter to be achieved within the predetermined time. Minimum time of the section is 0,001 hours. When editing the section the edit menu appears, and after making changes corresponding entry in the log listing the parameters of the section is created.

Stages **2 (Heating)**, **3 (Seeding)**, **5 (Detachment, holding in vacuum)**, **6 (Cooling)** prescribe the final value of voltage or power (volts, kW). After launching the section voltage / power varies linearly from the current (at the time of launch) to the specified final value over the specified time. The initial value of the voltage / power of the next section will be the final value of the previous one.

Stage **4 (Growth)** specifies rate of the voltage or power reduction (mV / h, kW / h), and the change in the extraction speed of the rod. At the beginning of stage the initial the extraction speed is set, and in each section - the final value of the extraction speed. Command of the extraction rate varies linearly from an initial value to the final. The initial value of the voltage / power and speed of extraction of the next section will be the final value of the previous.

On sections where the voltage or heater power values are specified, control mode selection (voltage or power) is done by pressing the button next to the corresponding mode. Confirmation of the chosen mode is button's color change from gray to green, and the appearance of a "tick".

All parameters allow fractional setting and the dot character is used as the decimal separator. Setting an empty value corresponds to an unaltered state of the parameter.

Stage 1 Launching the Vacuum Equipment

Used for automatic launch of the MGF vacuum equipment.

Before the launch of this stage turn the control of the vacuum equipment to manual mode and turn off forevacuum, diffusion pumps, close valves and the vacuum gate.

When setting parameters of this stage, enter the following data:

- pressure setting P1 (K3 valve opening condition);
- pressure setting P2 (gate opening condition);
- pressure setting P3 (stage completion condition);
- time T1 (the time from switching on the diffusion pump until the shutter is opened).

Pressure level P1 is fixed according to vacuum gauge of the forevacuum pump line, pressure levels P2 and P3 - according to vacuum gauge in the crystallizer chamber.

The stage is performed in the automatic mode.



Order of automatic switching on the vacuum equipment:

1. Launching the forevacuum pump;
2. At reaching the pressure level on forevacuum pump line below the P1 setting level, but not earlier than 10 s, K3 is opened;
4. After 10 s, under condition that the pressure level of forevacuum pump line is maintained below P1 setting level, K3 is closed;
5. After 1 s K2 is opened;
6. After 10 s, under condition that the pressure level of forevacuum pump line is maintained below P1 setting level, K2 is closed, K3 is opened, diffusion pump is switched on, timer T1 is launched;
7. After time T1, under condition that the pressure level of forevacuum pump line is below P1 setting level and the pressure level in the crystallizer chamber is below P2 setting level, the vacuum valve is opened;
8. Upon reaching the pressure level in the crystallizer chamber below P3 setting level, the stage is finished.

More detailed algorithm of switching on the vacuum equipment is given in [Appendix 1](#): Algorithm of switching on the vacuum equipment.

Stage 2 Heating

Intended for smooth increase of chamber temperature to obtain the melt.

It is recommended during the execution of this stage to activate blocking with the action of **Voltage raise stop** (see [Fig. 3.18](#)), to ensure the released from the insulating materials or batch gas does not damage the heater or crucible.

When setting parameters of this stage you must enter the time, the final value of voltage (power) and stock pulling speed for each site.

Stage 3 Seeding (non-automated stage)

Intended for the selection of the thermal mode of the MGF and seeding crystal.

It is recommended during performing this stage to choose such the value of the final voltage (power), at which the melt guaranteed solidifies.

***For example:** The melt is formed at a power of 72 kW. The final value of the power in stage 2 was set 72.5 kW. In Stage 3, it is recommended to set the final value of 71 kW. The program gradually will reduce power on the heater. Operator constantly monitors the process and at the completion of seeding presses a button of early stage termination.*

Stage is performed in the PAUSE mode manually. Allowed to change the setting values of voltage (power) in the manual control page (see 4.3). During operation of this stage

Finish stage

button is displayed, by pressing which the program proceeds to the next stage.

Stage 4 Growth

Designed for practicing the prescribed growth program.

At the stage speed of voltage (power) on the heater and change of the extraction rate of the rod are set.



Stage 5 Detachment and Holding in Vacuum

Intended to accelerate, with no signs of crystal sticking, the crystal increase to the specified height and holding in vacuum.

The voltage (power) at the heater varies smoothly from an initial value at the time of launching to the final stage, indicated in the section.

Stage 6 Cooling

Designed for practicing prescribed program power reset.

The final value of the voltage (power) at this stage should be set 0, because when launching the next stage of the heating will turn off instantly.

Stage 7 Holding in the Vacuum

Intended for holding during preset time after the shutdown of the heater.

Stage 8 Holding in Argon

Intended for automatic argon inlet and holding during the specified time.

Necessary condition for launch of a stage is the automatic control mode of the vacuum equipment. When launching the stage, the shutter closes and the diffusion pump switches off. After five seconds, once shutter was closed, K1 valve opens and argon is let into the chamber. This condition persists until the activation of the lower end switch of the signaling vacuum gauge. After that K1 closes and timer for the specified time in section starts. If this time is more than 3 hours, then at the expiration of this time, the forevacuum pump automatically turns off and the K3 valve closes, if less, it is necessary to close the pump and the valve manually.

Stage 9 Holding in the Atmosphere

Intended for holding during the predetermined time in chamber, filled with atmospheric air.

Necessary condition for launch of the stage is the switched off heating, closed shutter and automatic control mode of the vacuum equipment. If were switched on, the forevacuum and diffusion pumps are switched off. After triggering of the top limit switch of the signaling vacuum gauge (assuming that the operator manually opens the valve allowing air to leak into the chamber), a timer is started for a specified in the section time. After time elapsed, stage is complete.

4.7.2. The Editing Panel of Technological Process

Editing panel of the stages is shown in [Fig. 3.32](#).

This panel provides the ability to create, edit and delete sections, as well as edit the parameters of sections:

- ❖ runtime;
- ❖ voltage, power and control type;
- ❖ the extraction speed;
- ❖ permission to perform this section.

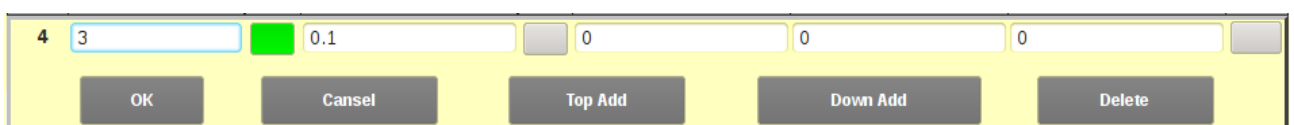


Fig. 3.32. Menu of editing the stages

OK	– confirmation of changes;
Cancel	– cancellation of changes;
Top Add	– creating a new section before the current one;
Down Add	– creating a new section after the current one;
Delete	– removal of the section;
	– section is inactive;
	– section is active;
	– section is prohibited.

To start the automatic crystal growing, you must click **START**. After clicking **START** there is a sending of data on sections in the PLC (up to 5 sec.). The process will be launched at the end of data transmission.

In **START** mode sections, that are after the currently active and allocated in green, can be edited. To edit the active section it is needed to transfer the automatic technological process into mode **PAUSE** (press **PAUSE**). Also in the **PAUSE** mode the access to the manual control panel is allowed.

4.7.3. The Control Panel of the Automatic Program

When clicking on **Start** (Fig. 3.33, a)) a confirmation panel is displayed (Fig. 3.34, a)) and sequential execution of beforehand entered the program will start - sections and the stages with working off parameters defined by the operator. With this the access to the page of **Manual Control** (see 4.3) is blocked and parameters of voltage / power, extraction rate settings will not be available for correction.



Fig. 3.33. The control panel of the automatic program -

a) **Start** button is active;

b) **Stop** button is active.

Pressing the **Pause** button during the execution of the stages **2 – 6** executable program saves all current parameters of the system, settings of the power / voltage does not change its value, the drive of the extraction of rod is switched off (if it was on), time until the end of the section "freezes." After having switched to mode **Start** section will last exactly as long as it had remained before the transition into a state of **Pause**.

In this mode, the page of manual control **Manual Control** (see 4.3) becomes available and the operator can manually adjust the settings of power / voltage. In addition, if the current stage is **2 – 3** or **5 – 6**, then after resumption of the execution program recalculation of setting values increase will happen in order to enter the specified final value by the end of the section.



In stage **4**, after the resumption of the program the recalculation of setting increase is not performed because it is rigidly set in a program.

Stages **1, 7 – 9** ignore **Pause** command.

To resume it is needed to click **Start**, and then the execution of the current section will continue, the drive of the extraction of rod will switch on (if listed in the program).

When clicking on **Stop** (Fig. 3.33, b)) and confirmation on the panel (Fig. 3.34 b)) software control of technological process stops and the drive of rod movement is switched off, the vacuum equipment saves its state.

If at this point Stages **2 – 6** were active, then the setting value of voltage / power will remain the same as it was before clicking **Stop**. Further, the ability to adjust the setting value manually is given, or, by editing the program, to launch it again. Program execution starts with the first allowed stage.

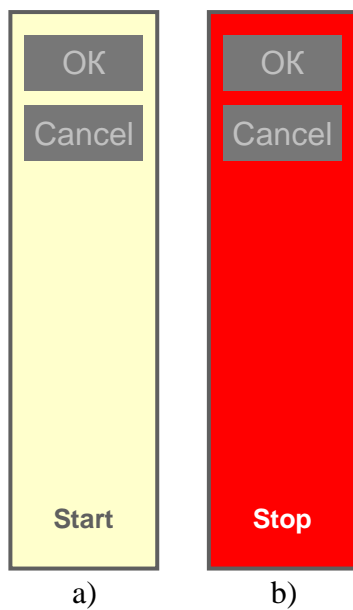
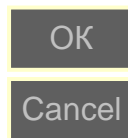


Fig. 3.34. Panel of button pressing acknowledgment:

a) Start; b) Stop.



– confirmation of the action;

– cancellation of action.



Appendix 1: Algorithm of switching on the vacuum equipment.

