AUTOMATED CONTROL SYSTEM OF MODERNIZED KYROPOULOS METHOD MONOCRYSTAL GROWING FURNACE

«OMEGA-PG350»

Equipment description

Vinnytsia, Ukraine, 2014

ABEC.008.00.00.000 PO

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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
PC	Personal computer
PLC	Programmable logic controller
IM	Instruction manual
MGF	Monocrystal growing furnace

1. GENERAL INFORMATION

Manual controls are intended for non-automatic control of ACS. The use of manual control is recommended for the prevention and exit out of emergency situations, as well as inspection and testing of the vacuum equipment.

Section **2** of the document describes manual controls provided to the operator of MGF, Section **3** – devices and bodies configuration used in the diagnosis, adjustment and maintenance of the ACS.

2. CONTROLS OF ACS

The ACS exterior view and control layout are shown in Fig. 2.1:

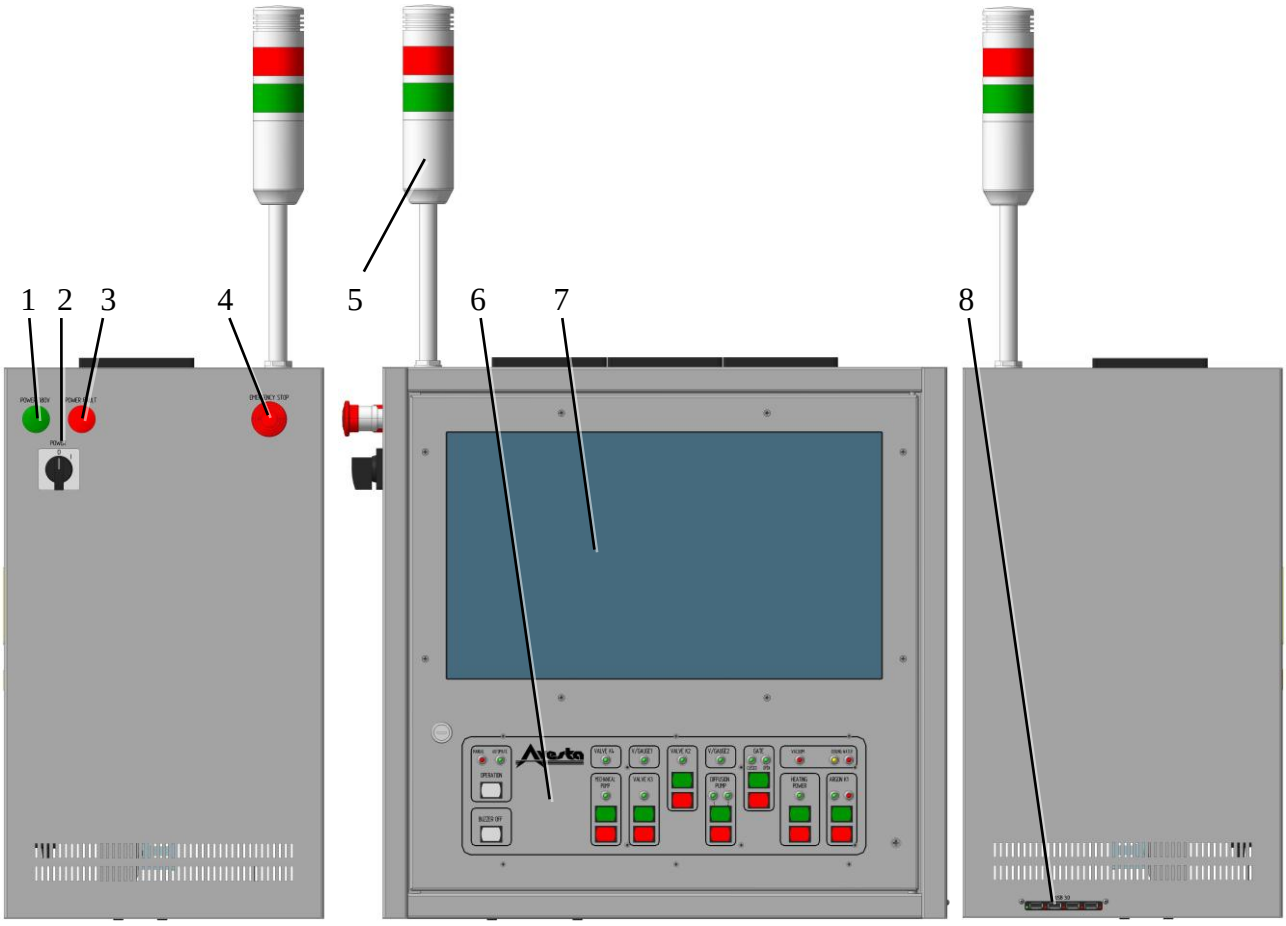


Fig. 2.1. The rack exterior view and control layout:
a) left side view;
b) front view;
c) right side view.

1. «POWER ~ 380V» status LED (2.1).
2. Power switch (2.2).
3. «POWER FAULT» status LED (2.3).
4. «EMERGENCY STOP» button (2.5).
5. Indicator bank with integrated buzzer (2.6).
6. Hardware control panel of vacuum equipment (2.4).
7. Touchscreen monitor (2.7).
8. Four-port USB 3.0 hub (2.8).

2.1 «POWER ~ 380V» Status LED

Status LED On when:

- ~ 380V three-phase electric power is correct;
- phase sequence is correct.

2.2 Power Switch

Designed to connect ~ 380V three-phase electric power for the MGF equipment.

2.3 «POWER FAULT» Status LED

Status LED On when:

- there is an asymmetry of three-phase electric power;
- phase failure is detected;
- phase sequence is incorrect.

2.4 Hardware Control Panel of a Vacuum Equipment

The panel is designed for non-automatic control of a vacuum equipment.

The panel exterior view and control layout are shown in Fig. 2.2:

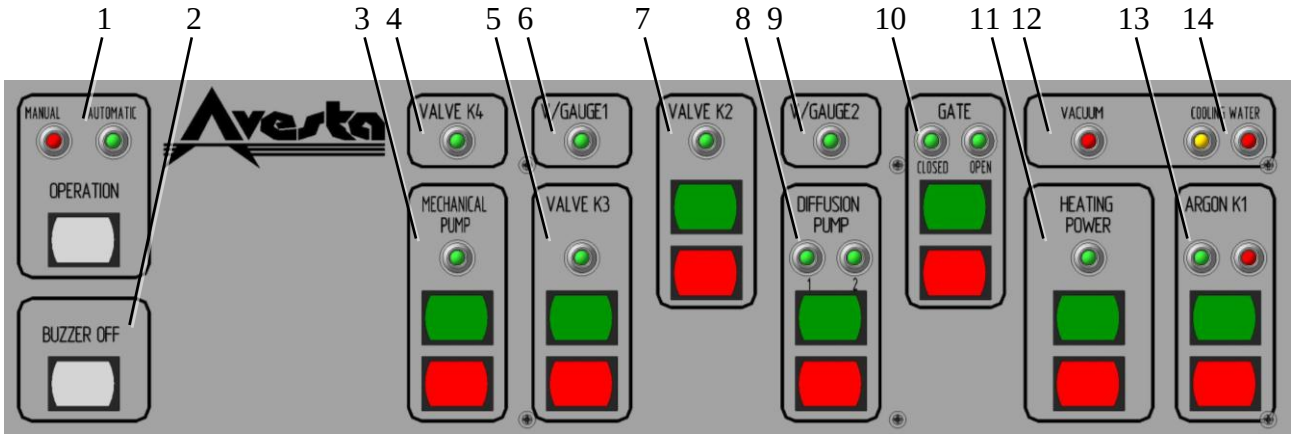


Fig. 2.2. Status window of the main technological parameters of system

1. Control mode selection panel (2.4.1).
2. Sound alarm shutdown panel (2.4.2).
3. Forevacuum pump control panel (2.4.3).
4. K4 vacuum valve switching ON status LED (2.4.4).
5. K3 vacuum valve control panel (2.4.5).
6. Forevacuum pump line vacuum gauge switching ON status LED (2.4.6).
7. K2 vacuum valve control panel (2.4.7).
8. Diffusion vacuum pump control panel (2.4.8).
9. Crystallizer chamber vacuum gauge switching ON status LED (2.4.9).
10. Vacuum gate control panel (2.4.10).
11. Heater control panel (2.4.11).
12. Crystallizer chamber vacuum status LED (2.4.12).
13. Argon supplying K1 vacuum valve control panel (2.4.13).
14. Coolant pressure control panel (2.4.14).

2.4.1 Control Mode Selection Panel

The panel has status LEDs of manual (red) and automatic (green) modes and selection mode button.

Automatic operation status LED lights ON when mode selection button is released and the launch of technological program is in mode "Automatic". In this mode, the vacuum equipment control buttons are disabled and the program solely performs control.

2.4.2 Sound Alarm Shutdown Panel

The panel has a sound alarm shutdown button.

When pressed the button becomes highlighted; sound alarm is disabled.

2.4.3 Forevacuum Pump Control Panel

The panel has status LED and ON / OFF buttons.

When pressed the green button is highlighted, but forevacuum pump power status LED ON only with the actuation of launch contactor and the absence of emergency shutdown of QF2 motor (Fig. 3.9) circuit breaker.

Red button is used to switch OFF the forevacuum pump.

Switching ON the forevacuum pump is possible only with available and correct phase sequence of the ~ 380V three-phase electric power.

2.4.4 K4 Vacuum Valve Switching ON Status LED

Green status LED ON with K4 vacuum valve opening. K4 vacuum valve opens automatically during a time defined by the KT1 time relay (Fig. 3.3) after switching OFF the forevacuum pump.

2.4.5 K3 Vacuum Valve Control Panel

The panel has status LED and opening/closing buttons.

Opening the K3 vacuum valve is only possible under the conditions:

- available and correct phase sequence of the ~ 380V three-phase electric power;
- delay after switching ON the forevacuum pump is expired; it is defined by the KT2 time relay (Fig. 3.3).

When pressed the green button is highlighted, but the opened status LED of the K3 vacuum valve lights up only on the condition that the FU26 fuse (Fig. 3.9) is serviceable and if the K3 valve opening limit switch has triggered.

Red button is used to close the K3 vacuum valve.

The K3 vacuum valve is closed automatically in case of:

- absence or violation of phase sequence of the ~ 380V three-phase electric power;
- forevacuum pump being switched OFF.

2.4.6 Forevacuum Pump Line Vacuum Gauge Switching ON Status LED

Forevacuum pump line vacuum gauge switching ON status LED lights up if the power is ON and the FU13 fuse (Fig. 3.3) is serviceable.

2.4.7 K2 Vacuum Valve Control Panel.

The panel has status LED and opening/closing buttons.

Opening the K2 vacuum valve is only possible under the conditions:

- available and correct phase sequence of the ~ 380V three-phase electric power;
- delay after switching ON the forevacuum pump is expired (it is defined by the KT2 time relay) (Fig. 3.3).
- vacuum gate is closed.

When pressed the green button is highlighted, but the opened status LED of the K3 vacuum valve lights up only under the condition that the FU25 fuse (Fig. 3.9) is serviceable and if the K2 valve opening limit switch has triggered.

Red button is used to close the K2 vacuum valve.

The K2 vacuum valve is closed automatically in case of:

- absence or violation of phase sequence of the ~ 380V three-phase electric power;
- forevacuum pump being switched OFF.

2.4.8 Diffusion Vacuum Pump Control Panel

The panel has status LED and ON / OFF buttons.

Switching ON the diffusion vacuum pump is only possible under the conditions:

- available and correct phase sequence of the ~ 380V three-phase electric power;
- delay after switching ON the forevacuum pump is expired (it is defined by the KT2 time relay) (Fig. 3.3).

When pressed the green button is highlighted, but diffusion pump power status LED lights up only with the actuation of launch contactor and the absence of emergency shutdown of current control relay in QF3 and QF4 heaters (Fig. 3.9).

Red button is used to switch OFF the diffusion pump.

Diffusion pump is switched OFF automatically in case of:

- absence or violation of phase sequence of the ~ 380V three-phase electric power;
- forevacuum pump being switched OFF.

2.4.9 Crystallizer Chamber Vacuum Gauge Switching ON Status LED

The crystallizer chamber vacuum gauge switching ON status LED lights up if the power is ON and the FU14 fuse (Fig. 3.3) is serviceable.

2.4.10 Vacuum Gate Control Panel

The panel has opened/closed status LEDs and opening/closing buttons.

Opening the vacuum gate is only possible under the conditions:

- available and correct phase sequence of the ~ 380V three-phase electric power;
- delay after switching ON the forevacuum pump is expired (it is defined by the KT2 time relay) (Fig. 3.3).

When pressed the green button is highlighted, but the opened status LED of the gate lights up only with the absence of emergency shutdown of QF5 motor (Fig. 3.9) circuit breaker and if the opening limit switch has triggered.

Red button is used to close the vacuum gate. The closed status LED of the gate lights up only if the closing limit switch has triggered.

Vacuum gate is closed automatically in case of:

- absence or violation of phase sequence of the ~ 380V three-phase electric power;
- forevacuum pump being switched OFF.

2.4.11 Heater Control Panel.

The panel has status LED and ON / OFF buttons.

When pressed the green button is highlighted, but the heater turns on only when the emergency stop button is released and fluid pressure in the cooling system is normal. When switching ON the heater, the power status LED lights up.

Red button is used to switch OFF the heater.

2.4.12 Crystallizer Chamber Vacuum Status LED

The vacuum status LED lights up if the upper contact of signaling vacuum pressure gauge is triggered, evidencing deterioration of vacuum in the crystallizer chamber.

2.4.13 Argon Supplying K1 Vacuum Valve Control Panel

The panel has status LED and opening/closing buttons.

Opening the K1 vacuum valve is only possible under the conditions:

- K2 valve is closed;
- vacuum gate is closed;
- heater is switched OFF.

When pressed the green button is highlighted. When switching ON the K1 vacuum valve, the green color status LED lights up.

The red status LED lights up if the lower contact of signaling vacuum pressure gauge is triggered, evidencing absence of argon in the crystallizer chamber.

2.4.14 Coolant Pressure Control Panel

The panel has two status LEDs – yellow and red. The yellow one is designed to inform about the pressure drop of fluid in the cooling system, the red one – to inform about the critical pressure drop of fluid in the cooling system.

In the case of critical pressure drop of the fluid in the cooling system after the time defined by the KT3 relay (Fig. 3.3) the heater shuts down automatically.

2.5 «EMERGENCY STOP» button

Designed for immediate powering off the heater. When pressing the button, its cap self-locks; and can be released with a turn.

2.6 Indicator bank with integrated buzzer

Designed for visual and audible alert of an emergency during the technological process. Loudness of the siren - 85 dB.

2.7 Touchscreen Monitor

Designed for visual display of technological information and data entry.

2.8 Four-Port USB 3.0 Hub

Four-port USB 3.0 hub is designed for the connection, if necessary, of keyboard, mouse, and external flash drives.

3. INTERNAL EQUIPMENT OF ACS

3.1 Front Door

The arrangement of equipment on the rack door is shown in Fig. 3.1:

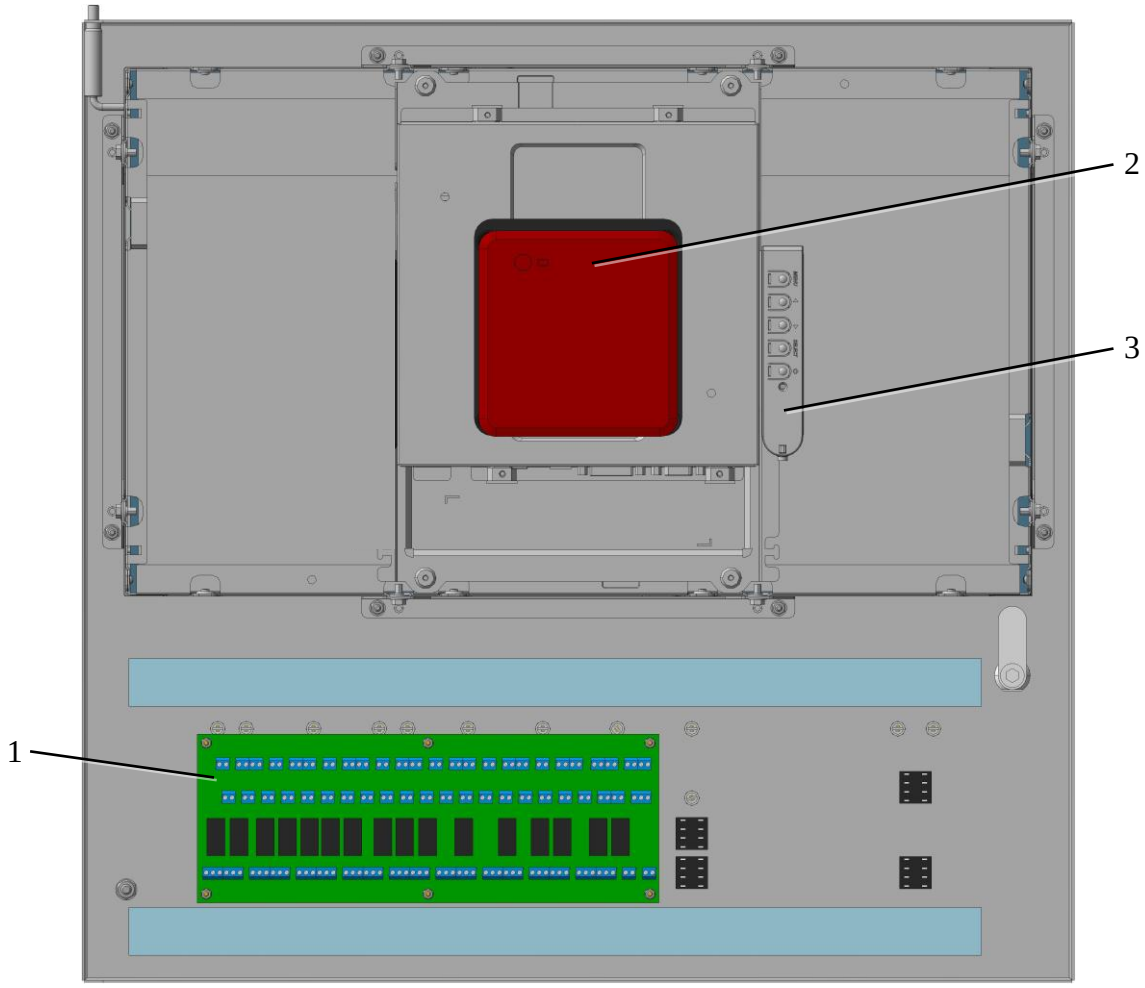


Fig. 3.1. The arrangement of equipment on the door:

1. Relay cross-plugging board (3.1.1).
2. Industrial computer (3.1.2).
3. Monitor settings control panel (3.1.3).

3.1.1 Relay Cross-plugging Board

Designed to provide the operation of control panel keypad, to control the executive equipment and to provide hardware blockings of vacuum equipment control.

Exterior view of relay cross-plugging board is shown in Fig. 3.2.:

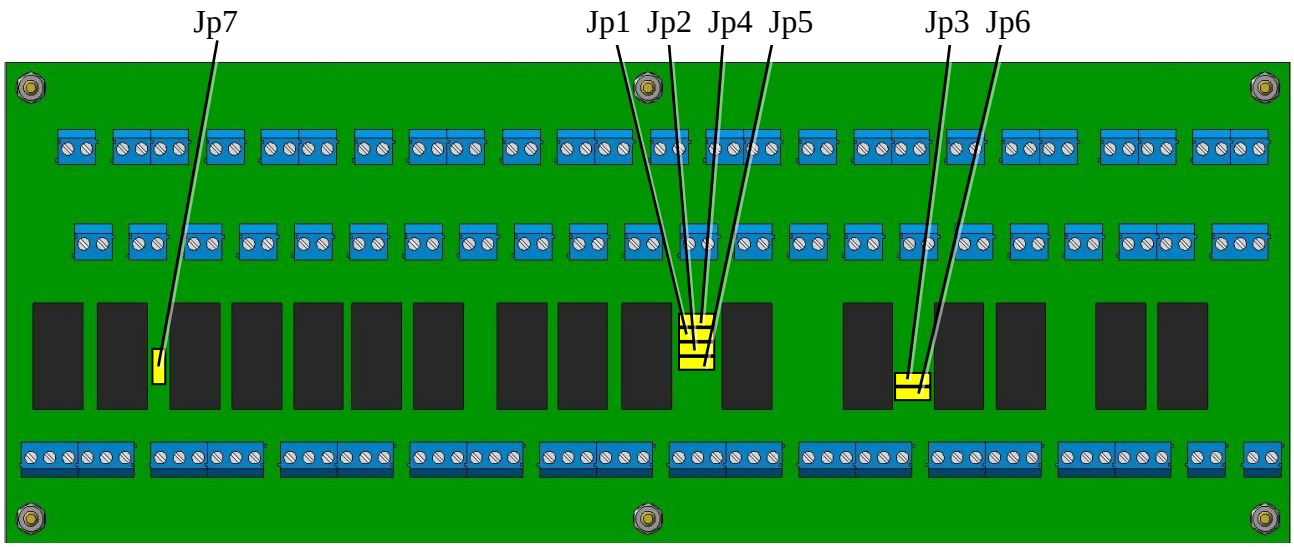


Fig. 3.2. Exterior view of relay cross-plugging board:

Jp1. Jumper switching OFF the blocking of opening the K1 vacuum valve when K2 vacuum valve is opened;

Jp2. Jumper switching OFF the blocking of opening the K1 vacuum valve when vacuum gate is opened;

Jp3. Jumper switching OFF the blocking of switching ON the forevacuum pump with absence or violation of phase sequence of the ~ 380V three-phase electric power;

Jp4. Jumper switching OFF the blocking of opening the K2 vacuum valve when vacuum gate is opened;

Jp5. Jumper switching OFF the blocking of opening the K1 vacuum valve when the heater is switched ON;

Jp6. Jumper switching OFF the blocking of control panel buttons of the vacuum equipment in automatic mode (2.4);

Jp7. Jumper switching OFF the blocking of closing the K1 vacuum valve with presence of argon pressure in crystallizer chamber (the upper contact of signaling vacuum pressure gauge is triggered).

3.1.2 Industrial Computer

Description according to the documentation shipped with the computer.

3.1.3 Monitor Settings Control Panel

Description according to the documentation shipped with the monitor.

3.2 Front Mounting Plate

The front mounting plate of the rack has a controller, measuring equipment, and low-voltage automation equipment. The arrangement of equipment on the front mounting plate is shown in Fig. 3.3:

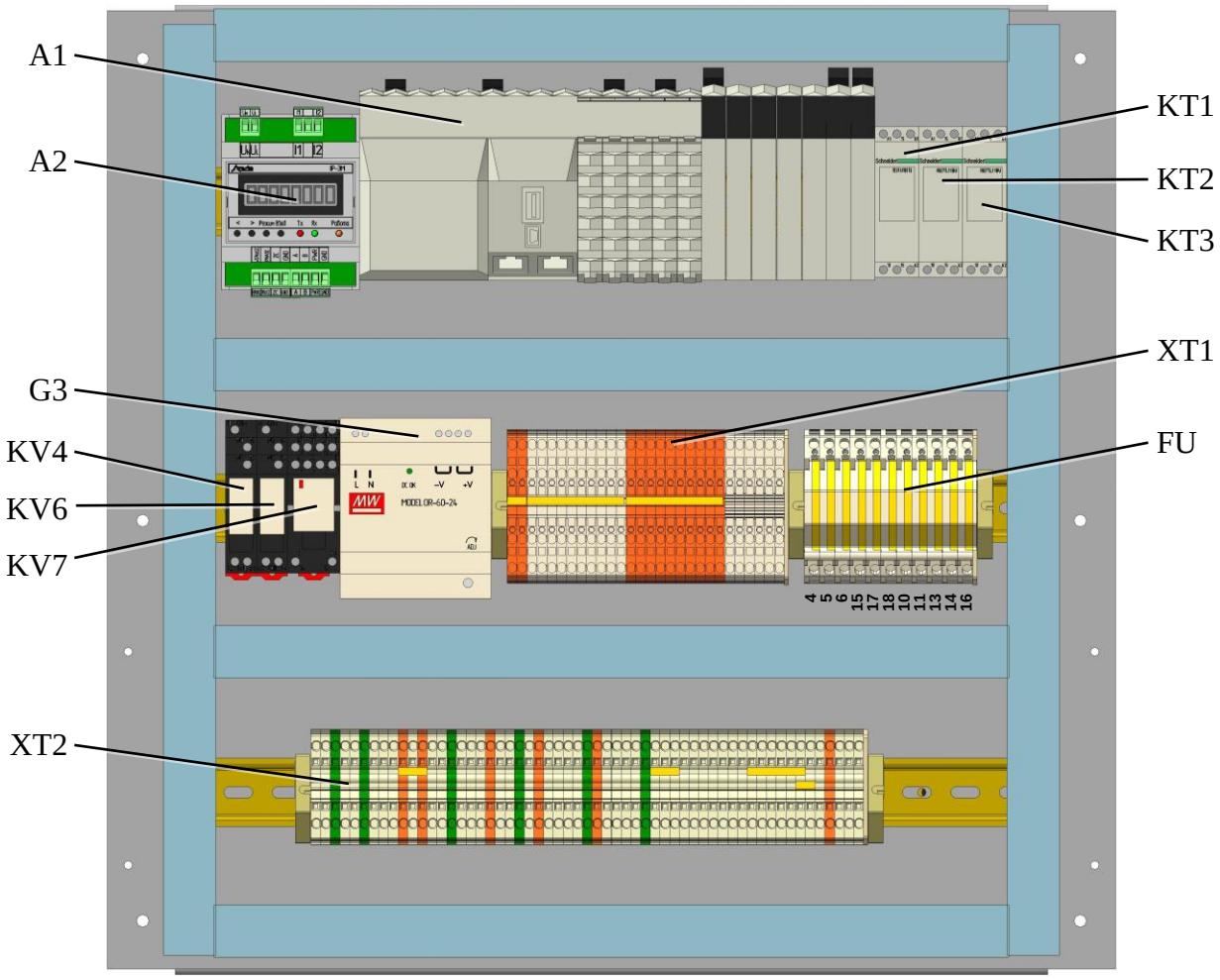


Fig. 3.3. The arrangement of equipment on the front mounting plate:

A1 – Programmable logic controller Schneider TM258LD42DT with interface modules (3.2.1);
A2 – Parameters meter ИП-3М-FK (3.2.2):
measures the voltage across the current leads of the crystallizer chamber;
G3 – Power source MDR-60-24 of the measuring devices;
KV4, KV6, KV7 – interface relays;
XT2 – Terminal block of external devices connection;
KT1 – Time Relay Schneider RE8TA11BUTQ (3.2.3):
defines duration of opening the K4 after switching OFF the forevacuum pump;
KT2 – Time relay Schneider RE7TL11BU (3.2.4):
defines the time of permission to open the K2, K3, vacuum gate after switching ON the forevacuum pump;
KT3 – Time relay Schneider RE7TL11BU (3.2.4):
defines the time of switching OFF the heater after the pressure drop of fluid in the cooling system below the critical level;
XT1 – terminal block of internal connections;
FU – the fuses package (3.2.5).

3.2.1 Programmable Logic Controller Schneider TM258LD42DT

The state of three power connections is indicated by a set of LEDs on the controller power distribution module (CPDM) (A1.1.1), Fig. 3.4.

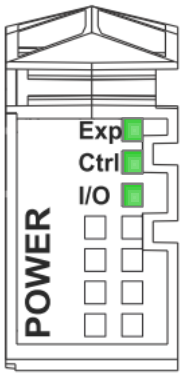


Fig. 3.4. PLC power control LEDs:

«Exp» – The Expert I/O power serves the Expert I/O module inputs and outputs, the power for the embedded Encoder port, and power for the Expert I/O module electronics (fuse FU5);

«Ctrl» – The Main power serves the TM5 power bus, the Serial Line port, the USB port, any PCI modules that may be installed, and power for the controller electronics (fuse FU4);

«I/O» – The 24 Vdc I/O power segment power serves the Regular I/O modules inputs and outputs, as well as providing power to the first segment of the 24 Vdc I/O Power segment for any optional I/O slices of the local configuration (fuse FU6).

The figure Fig. 3.5.shows the LEDs on the front panel display:

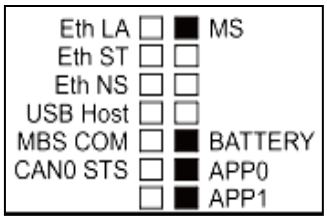


Fig. 3.5. PLC operating modes Status LEDs:

«Eth LA», **«Eth ST»**, **«Eth NS»** – Ethernet-ports Status LEDs;

«USB Host» – USB host port status LED;

«MBS COM» – serial line port status LED;

«CAN0 STS» – CAN port status LED;

«MS» – module status LED;

«BATTERY» – battery status LED:
ON when RTC battery needs to be replaced.

«APP0», **«APP1»** – Application LEDs.

The following table describes the MS status LED:

Flashing green / red	BOOTING
Flashing red	INVALID OS
Single flash green	EMPTY
Green ON	RUNNING
3 flash green	RUNNING with Breakpoint
Flashing green	STOPPED
Single flash red	HALT
Rapid flashing red	REBOOT after a hardware error has been detection
Red ON	HALT after system error detected
OFF	No power
Green / with single flash red	RUNNING with external error detected Or different Boot Project Or no Boot Project
Flashing green / with single flash red	STOPPED with external error detected

NOTE: For further details on controller states, refer to the Operating Mode discussion in the Programming Guide for your particular controller.

3.2.2 Power Meter A-Vesta IP-3M-FK

Power meter is designed to measure the voltage across the current leads of the crystallizer chamber.

Due to the fact that the built-in voltmeter in power inverter Flex Kraft has a resolution of 0,1 V, which is insufficient for heating control, IP-3M-FK is used to accurate measurement of (0,01 V) voltage in Flex Kraft meter dead zones between measured points. Therefore, for binding readings of the first time switching ON and, in case of divergence of data measured by the instrument and measured by Flex Kraft, the calibration procedure should be performed. The procedure is initialized from the MGF control program and is performed automatically. During performance of this procedure, the instrument operates in standalone mode, exchanging data with the PLC.

Exterior view and controls of the device are shown in Fig. 3.6

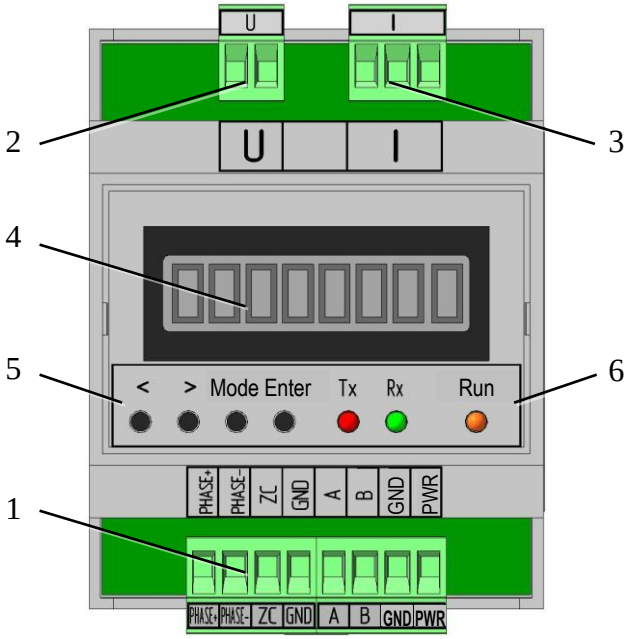


Fig. 3.6. Power meter IP-3M-FK:

1. Plug-and-sockets of control, connection of the interface lines and power supply;
2. Input plug-and-socket of the measured voltage;
3. Input plug-and-socket of the measured current (in the modification ИП-3М-FK not used);
4. LCD display. Backlight indicates that the device is powered;
5. Navigation panel:
   ◄► - navigation menu buttons;
   Mode - mode selection button;
   Enter - login button;
6. Indication panel:
   Tx - receiving data status LED via interface RS485;
   Rx - data transfer status LED via interface RS485;
   Run - mode status LED: alternating flashes with a period of 2s indicate the serviceability of the device.

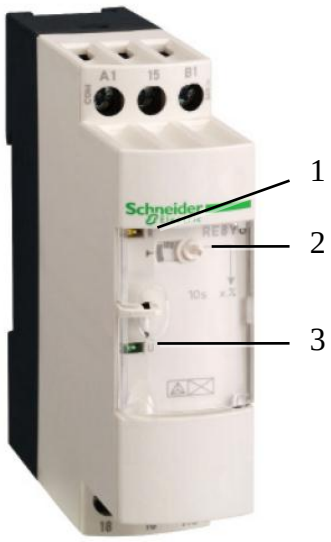
The device is equipped with audible sounder of button pressing acknowledgment and notification of mode efficiency - periodic sound signal (2s) indicates that all device parameters are normal.

Instrument menu has a hierarchical structure. If the level of menu has more than one item, the navigation buttons provide moving from item to item back and forth along this level. If the item is attached to the lower level of the menu, then moving to this level is made with the «**Enter**». Button «**Mode**» will return to a higher level. The name of the menu item is displayed on the LCD display.

Device menu:

Menu Item	Submenu Item	Action
Measure	**U mV**	Indication of input voltage in mV. If the device is not calibrated, LCD display shows the message: **«? Calibr».**
ValueADC	**U un.ADC**	Indication of input voltage in units of ADC code.
	I un.ADC	Indication of input current in units of ADC code.
Set Zero	**xxx***	Zeroing mode. The LCD display shows the voltage in ADC units minus the offset and the symbol "*". If the device is not calibrated, the displayed value ≥ 30,000. *Order of zeroing:* *- bring the input current and voltage signals to zero;* *- Pause for at least 10 seconds;* - *Fix a value of zero by pressing «Enter».* With proper offset fixation its value should vary symmetrically about 0 to ± 200. *To save the configuration data, it is needed to make a record to in the device memory (menu subitem toEEPROM).*
Calibrat	**CU Show**	Displaying the device calibration mode: - **«non-act»** – calibration is not active; - **«CU Start»** – start of calibration; - **«XXXXXsNN»** (XXXXX – point calibration voltage in mV, s – direction of the last executed transaction (◄►), NN – point number code; - **«End: XXX»** – the calibration is completed, where XXX – number of calibration points.
	U Points	Displaying values of ADC code by numbers of points in the calibration table in the format: **«XXXXX#NN»**, where XXXXX – ADC code, NN - calibration point number code.
Setup	**toEEPROM**	Saving settings in device memory. On entering the submenu **«to Write»** appears. To save the calibration and zeroing coefficients, simultaneously press both navigation buttons (◄ and ►) until you see **«Writing».** Upon successful completion **«is Done»** appears.
	Sound	Activation / deactivation mode of the audible sounder. Selection is made by navigation buttons (◄ ►): **«Enabled»** - sound enabled; **«Disabled»** - muted.
	Op. Time	Indication of device operating time counter readings in seconds.

3.2.3 Time Relay Schneider RE8TA11BUTQ



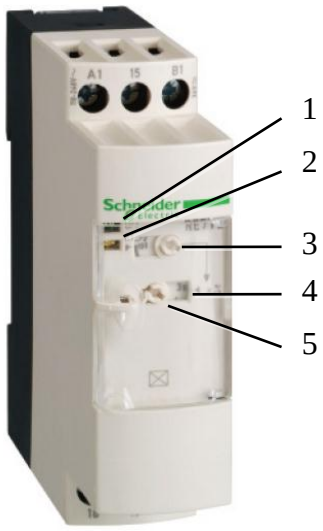
KT1 time relay is intended to set the duration of the K4 vacuum valve opening after switching OFF the forevacuum pump.

Exterior view and controls of time relay Schneider RE8TA11BUTQ are shown in figure Fig. 3.7

Fig. 3.7. Time relay Schneider RE8TA11BUTQ:

1. Relay actuation status LED;
2. Delay time controller;
3. Power status LED.

3.2.4 Time Relay Schneider RE8TA11BUTQ



Time relay KT2 is designed to set the delay time for the opening of K2, K3 vacuum valves and vacuum gate after switching ON the forevacuum pump, KT3 - set the time delay of switching OFF the heater after the pressure drop of fluid in the cooling system below the critical level

Exterior view and controls of time relay Schneider RE7TL11BU are shown in figure Fig. 3.8

Fig. 3.8. Time relay Schneider RE8TA11BUTQ:

1. Power status LED;
2. Relay actuation status LED;
3. Delay time controller;
4. Range status LED;
5. Range changer.

3.2.5 FU Fuses Package

FU4 – 3A fuse of main power (Ctrl) PLC Schneider TM258LD42DT;
FU5 – 1A fuse of expert inputs / outputs power (Exp.) PLC Schneider TM258LD42DT;
FU6 – 6A fuse of input/output power segment 24 VDC (I/O) PLC Schneider TM258LD42DT;
FU15 – 1A fuse of YC1 electromagnetic clutch power;
FU17 – 4A fuse of CW230 (A7) stepper motor driver power;
FU18 – 4A fuse of CW230 (A8) stepper motor driver power;
FU10 – 1A fuse of TKU-6 (A9) cooling system +5 V controller power;
FU11 – 1A fuse of TKU-6 (A9) cooling system +24 V power controller;
FU13 – 0.5A fuse of +24 V VG1 vacuum gauge power;
FU14 – 0.5A fuse of +24 V VG2 vacuum gauge power;
FU16 – 0.5A fuse of +24 V SG1 strain gauge power, CM2.1 strain gauge signal converter power, R2 rotation speed controller power.

3.3 Rear Mounting Plate

The rear mounting plate of the rack has power supply units and high voltage automation equipment. The arrangement of equipment on the rear mounting plate of the rack is shown in Fig. 3.9:

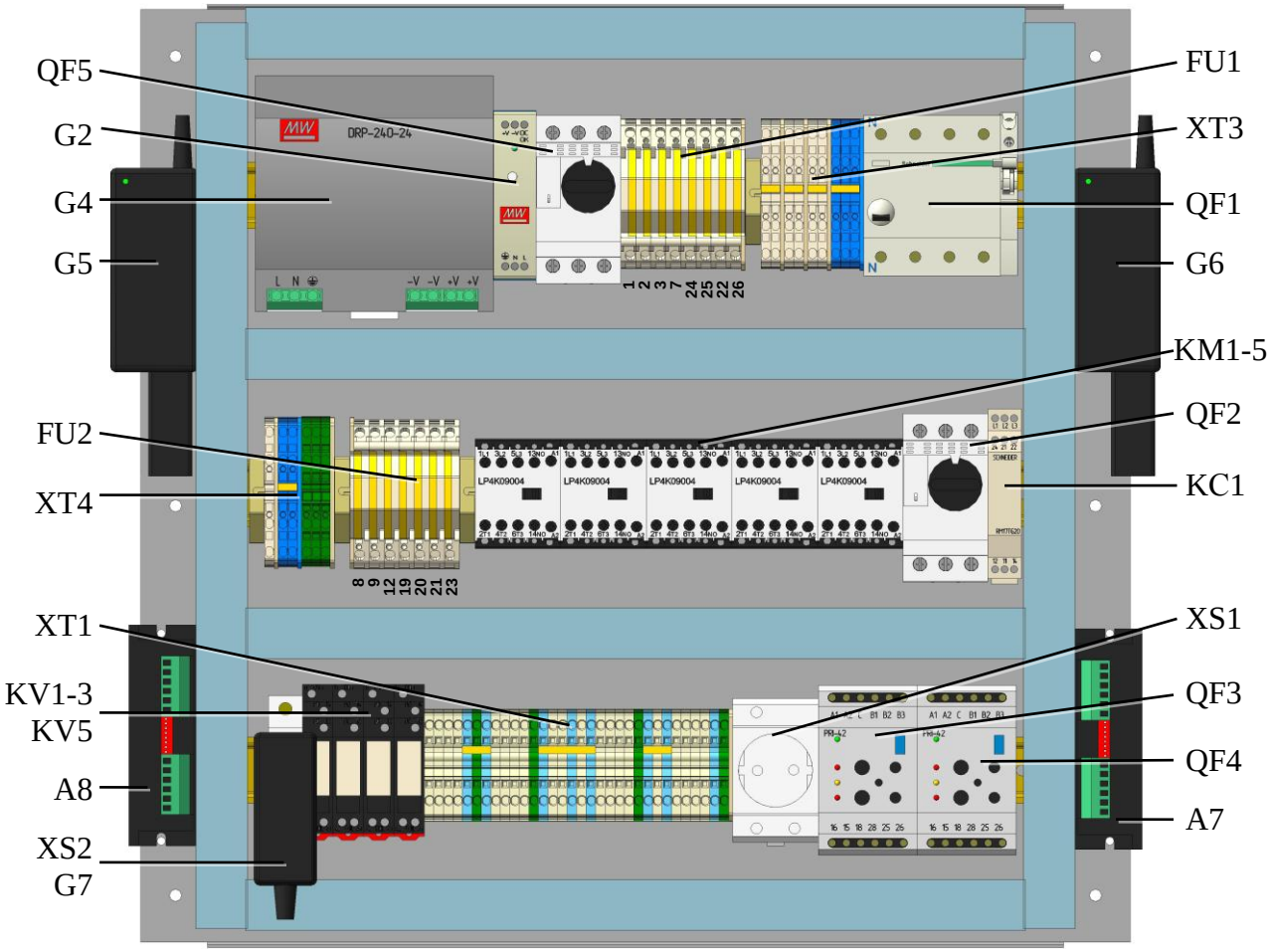


Fig. 3.9. The arrangement of equipment on the rear mounting plate:

QF5 – GV2L10 motor circuit breaker of the VV1 vacuum gate (3.3.2);
G2 – MDR-20-5 power source;
G3 – MDR-240-24 power source of automation power;
G5 – PC power source;
FU2 – fuses package (3.3.7);
XT4 – terminal block of internal connections;
XT1 – Terminal block of connecting the external devices;
KV1 – opening the K4 vacuum valve relay;
KV2 – opening the K2 vacuum valve relay;
KV3 – opening the K3 vacuum valve relay;
KV5 – opening the K1 vacuum valve relay;
A8 – stepper motor driver of vertical rod movement drive (3.3.5);
G5 – power source of the PoE DES-1005P switch;
FU1 – fuses package (3.3.6);
XT3 – terminal block of internal connections;
QF5 – residual current circuit breakers A9R41425 iID (3.3.3);
G6 – monitor power source;
KM1 – contactor of switching ON the forevacuum pump MP1 ;
KM2 – contactor of switching ON the diffusion pump DP1;
KM3 – contactor of opening the VV1 vacuum gate;

KM4 – contactor of closing the VV1 vacuum gate;
KM5 – Contactor of switching ON the heater;
QF5 – GV2L04 motor circuit breaker of the MP1 forevacuum pump (3.3.2);
KC1 – phase control relay RM17TG20 (3.3.4);
XS1 – socket connection of the G1 uninterruptible power supply;
QF3, QF4 – current monitoring relays PRI-42 control of currents in the coils of the DP1 diffusion pump (3.3.1);
A7 – CW230 stepper motor driver of rod rotary drive (3.3.5).

3.3.1 Current Monitoring Relay ELKO PRI-42

Current monitoring relays ELKO PRI-42 (QF3, QF4) are designed to control the current flowing through the diffusion pump spirals.

Controls of PRI-42 are shown in Fig. 3.10:

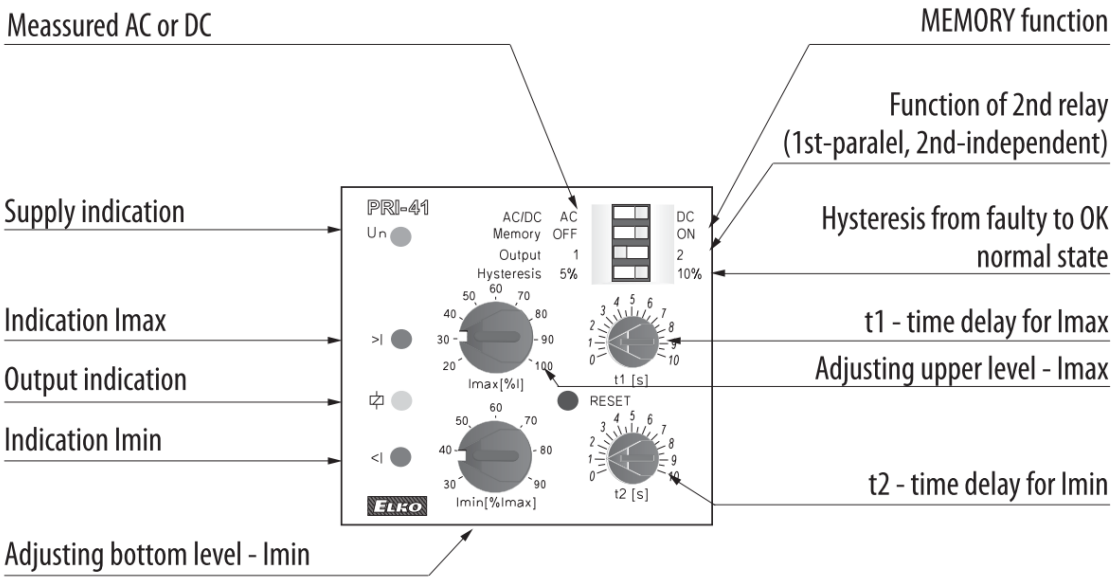


Fig. 3.10. Controls of current monitoring relay ELKO PRI-42

PRI-42 has function «WINDOW», which means that you set upper level (Imax) and lower level (Imin) individually in % of rated monitored range.

PRI-42 has selectable function «MEMORY». In case the relay gets to faulty state, this function leaves relay in this state until it is reseted by «RESET» button.

DIP switch No. 3 can be used to choose if output relay should switch for each level separately, or in parallel in case any current level is exceeded.

DIP switch No. 4 serves to set hysteresis of changing from faulty to normal state. Relay is protected against re-poling of DC current, or wrong AC/DC current (this fault is indicated by LED <I a LED >I common flashing).

3.3.2 Motor Circuit Breaker Schneider GV2L

GV2L10 QF2 motor circuit breaker is designed for current protection of the forevacuum pump motor, GV2L04 QF5 - vacuum gate motor.

Exterior view of motor circuit breaker is shown in Fig. 3.11:

Fig. 3.11. Circuit breaker Schneider GV2L

In operating mode it is necessary to turn the contact closure lever to the vertical position. In case of circuit breaker emergency activation, before restarting, you must first remove the cause of actuation and only after make contact.

3.3.3 iID Residual Current Circuit Breakers (AC type) Schneider A9R41425 iID

iID residual current circuit breakers is designed to protect of persons against electric shock by direct contact (≤ 30 mA).

Exterior view of current circuit breakers is shown in Fig. 3.12.

Fig. 3.12. Residual Current Circuit Breakers Schneider A9R41425 iID.

In operating mode it is necessary to cock the contact closure lever to the vertical position.

Before switching ON the MGF it is recommended to perform the efficiency test of residual current circuit breakers - press the «T» («Test»).

3.3.4 Phase Control Relay Schneider RM17TG20

Phase control relay monitored parameters of the ~ 380V 3-phase supply:

- asymmetry;
- phase failure detection;
- phase sequence.

Relay operation mode is controlled via the «POWER ~ 380V» status LED (2.1) of three-phase electric power ~ 380V availability and serviceability and the «POWER FAULT» status LED (2.3) of three-phase electric power ~ 380V failure.

Fig. 3.13. Phase control relay Schneider RM17TG20

3.3.5 Stepper Motor Driver CW230

CW230 stepper motors drivers are designed to control the stepper motors drives of the vertical movement A8 and rotation A7 of the rod.

Exterior view and controls of the CW230 stepper motor driver are shown in Fig. 3.14.

Fig. 3.14.
Stepper motor driver CW230

Step and current of the motor are set via DIP switches according to the tables below:

Step setting

M1	1	0	1	0	1	0	1	0
M2	1	1	0	0	1	1	0	0
M3	1	1	1	1	0	0	0	0
Step	1	1/2	1/4	1/8	1/16	1/32	1/64	—

Current setting

M5	0	0	0	0	1	1	1	1
M6	0	0	1	1	0	0	1	1
M7	0	1	0	1	0	1	0	1
Current(A)	0,9	1,2	1,5	1,8	2,1	2,4	2,7	3

1 - ON state, 0 – OFF state.

3.3.6 Fuses Package FU1

FU1 – 0.5A fuse of MGF power contactor;
FU2, FU3 - 0.5A fuses of phase control relay RM17TG20 KC1;
FU7 – 6A fuse of G1 uninterruptible power supply;
FU24 – 0.5A fuse of K4 vacuum valve;
FU25 – 1A fuse of K2 vacuum valve;
FU22 – Reserve;
FU26 – 1A fuse of K3 vacuum valve.

3.3.7 Fuses package FU2

FU8 – 1A fuse of G3 MDR-60-24 power supply for measuring devices power;
FU9 – 0.5A fuses of G2 MDR-20-5 power supply for temperature and flow sensors power;
FU12 – 2A fuse of G4 DR-240-24 power supply for measuring devices power;
FU19 – 1A fuse of G5 power supply for monitor;
FU20 – 1A fuse of G6 power supply for PC;
FU21 – 0.5A fuse of G7 power supply for the switch;
FU23 – 0.5A fuse of M1-M3 fans power.

4. SPECIALIZED EQUIPMENT OF ACS

4.1 Cooling System Controller A-Vesta TKU-6M

The device is designed to monitor the temperature of coolant in 16 points of cooling system by receiving data through 1-wire line from DS18B20 digital thermometers and by control of coolant flow in 12 contours by means of receiving data from the pulse flow sensors.

Exterior view and controls of the device are shown in Fig. 4.1:

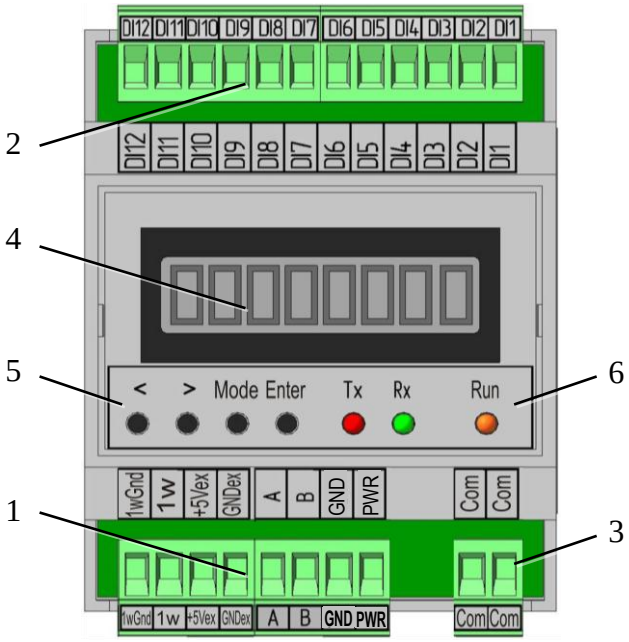


Fig. 4.1. Universal technological controller TKU-6M:

1. Plug-and-sockets of control, connection of the interface lines and power supply;
2. Plug-and-sockets of the pulse flow sensors connection;
3. Plug-and-socket of COM common input of pulse flow sensors;
4. LCD display. Backlight indicates that the device is powered;
5. Navigation panel:
   ◄► - navigation menu buttons;
   Mode - mode selection button;
   Enter - login button;
6. Indication panel:
   Tx - receiving data status LED via interface RS485;
   Rx - data transfer status LED via interface RS485;
   Run - mode status LED: alternating flashes with a period of 2s indicate the serviceability of the device.

The device is equipped with audible sounder of button pressing acknowledgment and notification of mode efficiency - periodic sound signal (2s) indicates that all device parameters are normal.

Instrument menu has a hierarchical structure. If the level of menu has more than one item, the navigation buttons provide moving from item to item back and forth along this level. If the item is attached to the lower level of the menu, then moving to this level is made with the «**Enter**». Button «**Mode**» will return to a higher level. The name of the menu item is displayed on the LCD display.

When switching ON the device automatically switches to the menu «**Show Thermo**». To return to the main menu level, press the button «**Mode**».

Device Menu:

Menu Item	Submenu Item	Action
Thermo	**Show** (subitem name is not displayed)	Displaying mode of digital thermometers data. Choosing the thermometer is performed by navigation buttons (◄ ►) in circles from 1 to 16, then 1, and so on. Data display format: **SVV.V№ NN**, where **"S"** - sign of the temperature "+" or "-"; **"VV.V"** - the temperature in ^{o}C; **"№"** - symbol "№"; **"NN"** - two-digit number of the sensor.
	Enter (subitem name is not displayed)	Pressing the button **«Enter»** proceeds to the recording mode of thermometers numbers. Format data entry: **NN №Pos**, where **"NN"** - two digits of the thermometer number; **"№"** - symbol "№"; **"Pos"** - symbol "Position".
Counters	**Show** (subitem name is not displayed)	Displaying mode of 10-bit pulse counters values. Selection of counter is performed by navigation buttons (◄ ►) in circles from 1 to 12, then 1, and so on. Data display format: **CoNNHH** where **«Co»** - symbol «Counter» (counter); **"NN"** - two digits of the counter number; **"XX"** - two senior decimal places of the counter, after a pause eight low order places are shown: **"xxxxxxxx"**
	Enter (subitem name is not displayed)	When pressing the button **«Enter»**, the indication of the selected counter will be performed without interruption at one time - only the lower eight decimal places. When choosing the next counter, normal mode indicating counters resumes.

WARNING!

Number of connected digital thermometers can be from one to sixteen. The device supports thermometers numbers from **"01"** to **"31"**, but for the correct displaying of data in the ACS, numbers from **"01"** to **"16"** must be used. Number "00" is assigned to the new, still unnumbered thermometers.

The assignment of same numbers for thermometers connected to the device is impermissible!

New unnumbered thermometers should be connected into the system only one at a time after assigning the number for previous one!

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