Chelenergopribor

Volt-ampere phase meter **VFM-3**

Manual

It is recommended to store together with the device and read carefully before the operation.

Chelyabinsk

Contents

1 Regulatory references	2
2 Definitions, symbols and abbreviations	2
3 Safety requirements	2
4 Description of the device and the modes of its operation	2
5 Completeness	8
6 Operation of the device	8
7 Adjustment of the device	11
8 Verification of the device	12
9 Labeling, packaging and sealing	12
10 Transportation and storage	12

ATTENTION!

DON'T START USING THIS DEVICE WITHOUT READING THIS DOCUMENT CAREFULLY!

Due to the fact that constant upgrades are made, some changes can be brought to the device not influencing its technical characteristics and not discussed in this document.

This operational manual is designated to instruct the user about the technical characteristics, components, principles and the rules of operation of Volt-ampere phase meter "VFM-3".

1 Regulatory references

GOST 12.3.019-80 Electrical tests and measurements. General safety requirements.
GOST 22261-94 Means for measuring electrical and magnetic quantities. General specifications.
GOST 26104-89 Electronic measuring means. Technical requirements for safety. Test methods.

2 Definitions, symbols and abbreviations

This operational manual has the following definitions, symbols and abbreviations:

- Device – volt-ampere phase meter "VFM-3", technical specifications 4221-015-71693739-2014;
- Voltage measuring pliers – clamp meter;
- LSD – least significant digit;
- PC – personal computer;
- RMS – root mean square;
- AC – alternating current;
- PF – power factor.

3 Safety requirements

3.1 Concerning electric shock hazard protection, the device belongs to class II according to GOST 26104.
3.2 Degree of the protection, provided by the device enclosure according to IEC-529 is IP40.
3.3 Only the personnel who got safety requirements training and studied this operational manual can be allowed to operate this device.
3.4 It is prohibited to connect input circuit of the device with switched on power if there is some voltage in the circuits under test.
3.5 When connecting to the circuits under test, use one hand only.

4 Description of the device and the modes of its operation

4.1 Intended use

4.1.1 The device is intended to measure RMS of three phase and three-port voltage and RMS of the strength of three AC with simultaneous calculation of real, reactive, apparent power and energy in the three circuits, measurement of frequency and phase-shift angle between current and voltage.
4.1.2 The device is manufactured in compliance with the requirements of GOST 22261 and operating standards of State System for Ensuring Uniform Measurement.

4.2 Operation conditions

4.2.1 Normal operation conditions of the device according to GOST 22261:

- Ambient temperature 20 ±5 ºC;
- Relative air humidity (30 – 80) %;
- Atmospheric pressure (84 – 106,7) kPa.

4.2.2 Operation conditions in terms of mechanical impact in compliance with the group 4 requirements according to GOST 22261.

4.2.3 Operation conditions in terms of the impact of environmental climatic factors:

- Ambient temperature (–20 – +55) ºC;
- Relative air humidity is 90% at 30 ºC;
- Atmospheric pressure (84 – 106,7) kPa.

4.3 Power supply and consumption requirements

The device is powered from four replaceable Ni-MH batteries of AA size with total voltage of 4,8 V.
Four batteries of AA size with the voltage of 1,5 V can also be used as power supply for the device. In case the batteries are used it is prohibited to connect the device to the charger.
Maximum power consumption is not more than 1,5 W.
Four batteries, connected successively and totally producing less than 4 volt are considered unsuitable for use. In that case the device is switched off automatically.

4.4 Dielectric strength and insulation resistance

4.4.1 Dielectric strength and insulation resistance comply with the requirements of GOST 26104.
4.4.2 Insulation resistance is not less than 20 megaohm between the voltage measurement inputs of the device on one side and other circuits, available for connecting from the outside on the other side.
4.4.3 Electrical insulation between the voltage measurement inputs of the device and its case, as well as the case of voltage measuring pliers can withstand dielectric test voltage with effective value of 2 kV and frequency of 50 Hz without damage for 1 minute.

4.5 Requirements to the device operation under voltage overload conditions

4.5.1 The device withstands voltage overload of $1{,}2 \cdot U_k$, where U_k is a finite value of voltage range being measured, within 5 seconds.
4.5.2 The device withstands current overload of $2 \cdot I_k$, where I_k is a finite value of the current range being measured, within 5 seconds.

4.6 Specifications

4.6.1 Measurement range of:

- RMS of volts AC, V …………………….. 0 – 460
- RMS of AC, A ………………………….. 0 – 30
- phase-shift angle between voltage and voltage, between voltage and current, degree……………………………………………………………………….. –180 – +180
- real (reactive, apparent) power, W (VAr, VA) ……………................................. 0 – 13800
- frequency of voltage and AC, Hz ……………….. 45 – 65

4.6.2 The limits of permissible relative error of measurement of:

- RMS of volts AC, % …………………………..………..…… $\pm\left[0.2 + 0.01\left(\frac{Umax}{U} - 1\right)\right]$
- RMS of AC, % ………………………….............................. $\pm\left[1 + 0.005\left(\frac{I\max}{I} - 1\right)\right]$
- frequency of voltage AC, % ………………... ±0.1

4.6.3 The limits of permissible relative error of measurement of phase-shift angle between voltage and current (when voltage is more than 30 V and current is more than 100 milliampere), degree .... ±1
4.6.4 The device determines sequential order of phases in three-phase system.
4.6.5 Response time for the device, sec, not more than 15
4.6.6 Input impedance of voltage channels, megaohm, not less than 1
4.6.7 Maximum diameter of the wire covered by pincers, mm... 8
4.6.8 Weight without accessories, kg, not more than 0,3
4.6.9 Dimensions, mm, not more than 150x94x34
4.6.10 Average service life, years, not less than 10
4.6.11 Average time between failures, years, not less than 3000

Note:

1. U – voltage measured value, U_{max} – voltage measurement limit, I – current measured value, I_{max} – current measurement limit.
2. Basic errors in measurement (clauses 4.6.2, 4.6.3) are the characteristics, which determine the failure.

4.7 Device structure and physical operation

4.7.1 Structure

The device appearance is shown in Fig. 1. The device is put into an isolated case made of high impact plastic. The case consists of: an upper cover (1) and a bottom plate, fixed by 4 screws. On the upper cover (1) there is a power on button (2) and a button for switching to the measurement mode (3), LCD screen (4). On the upper side of the case there is a yellow socket (5) for connecting phase A voltage signal, a green socket (6) for connecting phase B voltage signal, a red socket (7) for connecting phase C voltage signal, a black socket (8) for connecting to neutral. Sockets (9, 10, 11) on the side surface of the device are used for connecting clamp meters to phases A, B and C respectively. Socket (12) is intended for plugging in the charger supplied with the device. Connector (13) on the side of the device - mini USB connector for connecting the device to a computer.

Fig. 1. General view of the device.

4.7.2 Current clamp

The appearance of current clamps is shown in Fig. 2. During measurements, the current clamps are should be installed so that the jaws 1 cover the current-carrying wire, while the mark 2 should be directed to the generator side of the electrical installation. Number 3 corresponds to the number of the device, which includes current clamps.

Please note that the device is calibrated together with the current clamps and, thus, the certified accuracy characteristics are provided. The usage of current clamps from kit of another device entails increased errors in the measurement results.

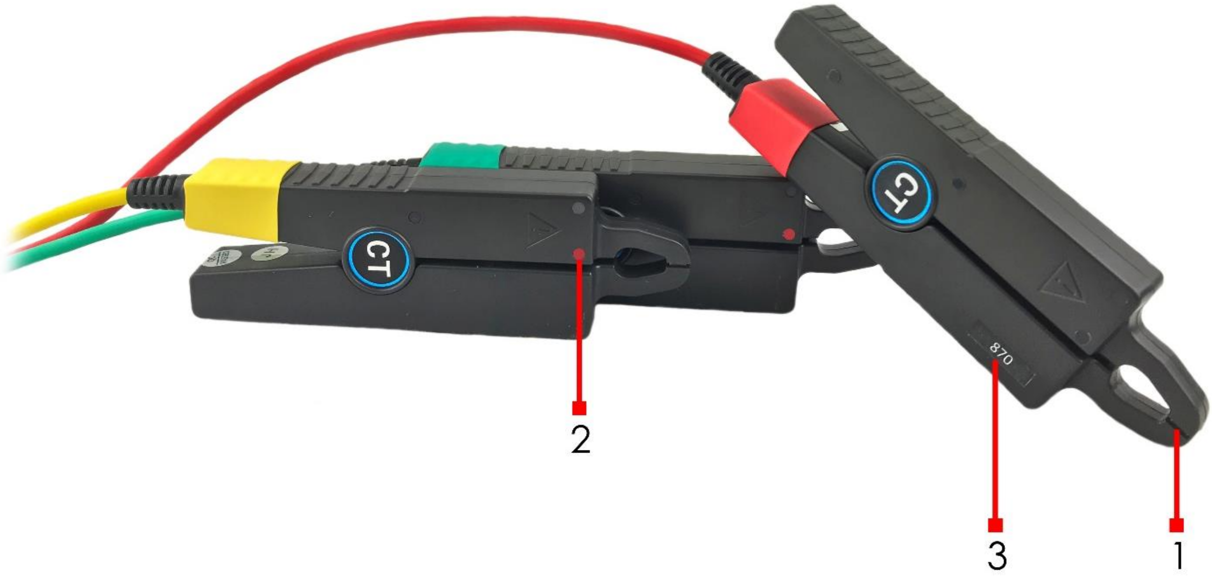

Fig. 2. Appearance of current clamps

4.7.3 The device layout and operation

The device block scheme is shown on Fig. 3. The device consists of three input resistance dividers, a multi-channel analog-to-digital converter (ADC) for digitizing input signals, digital signal processor (DSP) for signal processing, a microcontroller (MC) for controlling the peripherals and batteries charging, LCD screen for showing measurement data, USB interface for connecting to PC, constant-voltage regulator (CVR) and accumulator batteries (AB).

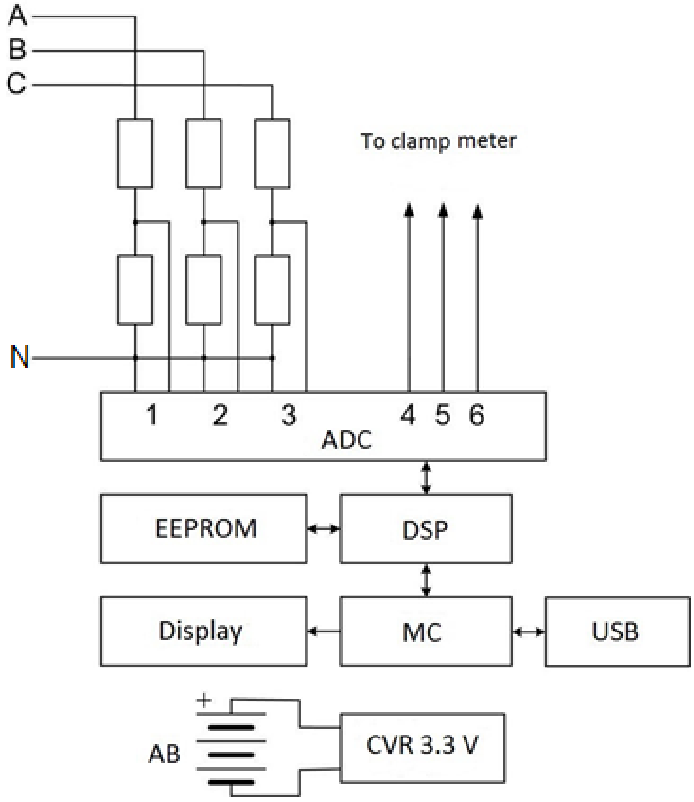

Fig. 3. The device block scheme.

The analog-to-digital converter registers with the frequency of 8 kHz instantaneous value of voltage, applied to its inputs within 1 second. As the result of the measurements, arrays $\{U_{An}\},\{U_{Bn}\},\{U_{Cn}\},\{I_{An}\},\{I_{An}\},\{I_{Bn}\},\{I_{Cn}\}$ each consisting of 8000 points are obtained.

To determine the signal frequency we find out the numbers of all points X_n, in which condition (1) is fulfilled. As a result, array $\{n_m\}$, consisting of M points, is obtained. After creating this array, the signal frequency can be calculated by the formula (2).

$$\begin{cases} X_n \geq 0 \\ X_{n+1} < 0 \end{cases} \tag{1}$$

$$f = f_{sampling} \frac{M-1}{n_M - n_1} \text{ Hz} \tag{2}$$

To calculate effective values of signals X_e, we square their sample values (X_n), then we take the square root of constant component of the obtained signal:

$$X_e = K_x \sqrt{\frac{1}{N} \sum_{n=1}^{N} X_n^2} \, ,$$

where K_x is a gauge coefficient.

To calculate real power it is used formula:

$$P = K_u K_i \sum \frac{U_k}{U_{FS}} \times \frac{I_k}{I_{FS}} \times \cos(\varphi_k - \gamma_k) \times PMAX \times \frac{1}{2^4} \text{ W},$$

where K_u and K_i are gauge coefficients of voltage and current respectively.

To calculate reactive power it is used formula:

$$Q = K_u K_i \sum \frac{U_k}{U_{FS}} \times \frac{I_k}{I_{FS}} \times \sin(\varphi_k - \gamma_k) \times PMAX \times \frac{1}{2^4} \text{ VAr}.$$

Phase-to-phase voltage is calculated by formula:

$$U_{ab} = \sqrt{U_a^2 + U_b^2 - 2K_{U_a}K_{U_b} \cos(\Psi_{ab})} \text{ V}.$$

Apparent power is calculated by formula:

$$S = K_u K_i \frac{U}{U_{FS}} \times \frac{I}{I_{FS}} \times PMAX \times \frac{1}{2^4} \text{ VA}.$$

Power is calculated by formula:

$$W = \frac{1}{f_{sampling}} \sum_{k=1}^{N} P_k \text{ kW*h}.$$

To calculate phase shifts between signals X_1 and X_2 we find out the numbers of points (n and k) $X_{1,\,n}$ and $X_{2,\,k}$, in which the condition (3) is fulfilled. The phase shits between the first signal (1st phase voltage) and the second signal (1st phase current or 2nd phase voltage) are calculated by formula (4):

$$\begin{cases} x_{1,n} \geq 0 \\ x_{1,n+1} < 0 \\ x_{1,k} \geq 0 \\ x_{1,k+1} < 0 \end{cases} \tag{3}$$

$$\varphi = N \times \frac{360° \times f}{f_{sampling}} \tag{4}$$

where N = n - k.

Low currents (less than 50 milliampere) are measured by synchronously detecting current with the signal, formed from the voltage applied between inputs **A** and **N**, of not less than 100 V and of the same frequency as the current.

5 Completeness

VFM-3 includes:

- Measuring device .... 1 pcs.
- Current clamp meter with a wire ....3 pcs.
- Test probes with wires to measure voltage .... 4 pcs.
- Charger .... 1 pcs.
- Carrying bag .... 1 pcs.
- Operational manual and passport .... 1 pcs.
- Test procedure description.. 1 pcs.

6 Operation of the device

6.1 Power supply of the device

6.1.1 The device is powered from four Ni-MH batteries AA size with total voltage of 4.8 V. It is accessible to use batteries of arbitrary capacity. To install batteries, unscrew bolts on the back cover of the device and put 4 batteries in accordance with polarity marking on the battery case.

6.1.2 The device continues operating till battery discharges to the total voltage of 4 V, after that the device switches off.

6.1.3 Batteries charge is indicated by the sign in the left upper corner (). If the sign is red, the batteries are low and they need charging.

6.1.4 To charge batteries, an external battery charger, supplied with the device, should be connected to the appropriate socket. Full charge takes not less than 24 hours.

6.1.5 Quick discharge of the batteries means their failure. In this case the batteries should be changed. All the batteries should be changed simultaneously. Batteries should be of the same type and of equal capacity.

6.1.6 Instead of an accumulator battery it is accessible to use voltaic cells of AA size and with 1.5 V voltage for each cell without connecting to the charger. In case of using non-chargeable voltaic cells, it is prohibited to connect the device to the charger.

6.1.7 Don't store the device with deeply discharged batteries as it can lead to battery electrolyte leakage and damage the device.

6.2 Measurement procedure

6.2.1 Switch on power.

6.2.2 To measure AC voltage, a measuring probe should be connected to sockets **A**, **B**, **C**, **N** (yellow, green, red and black respectively). Then, connect the probes to the corresponding phases of the circuit being measured and to the neutral and take the readings in Volts.

6.2.2 To measure AC, you should grip a current-carrying conductor with a clamp meter. After that you should take the readings in ampere.

To obtain more precise readings, the clam meter should be placed so that the current-carrying conductor is situated at the minimal distance from the opening of the clamp meter.

When measuring low currents (less than 50 milliampere) to improve the accuracy of measurements you should apply the voltage of the same frequency as the current with the value of not less than 100 V to sockets **A**, **B**, **C** and **N**.

Fig. 3 displays the measured values in the mode of reading value, which is set by default after the device is switched on. In this mode, the vector diagram of the circuit being measured is displayed without observing graphical scales.

The frequency of the voltage is displayed in Hz in the last line.

The frequency is measured by phase A.

6.2.3 To measure power and phase shifts the connections similar to those made for voltage and current measurements are performed. Real, reactive and apparent power and energy are read from the screen as it shown on Fig. 5, in Watts, VAr and VA respectively. To determine the sequential order of the phases in a three-wire circuit, you should switch to the 1st mode on the device to display vector diagrams.

PF, real power sum, cosine of shift in each phase are displayed on the screen (fig. 5).

If the obtained values of active power or PF are negative, the clamp meter should be flipped through 180° towards current carrying wire.

PF is calculated as:

$$\lambda = \frac{\sum P_i}{\sum S_i},$$

where P_i (W) - real power of phase i, and S_i – apparent power of phase i.

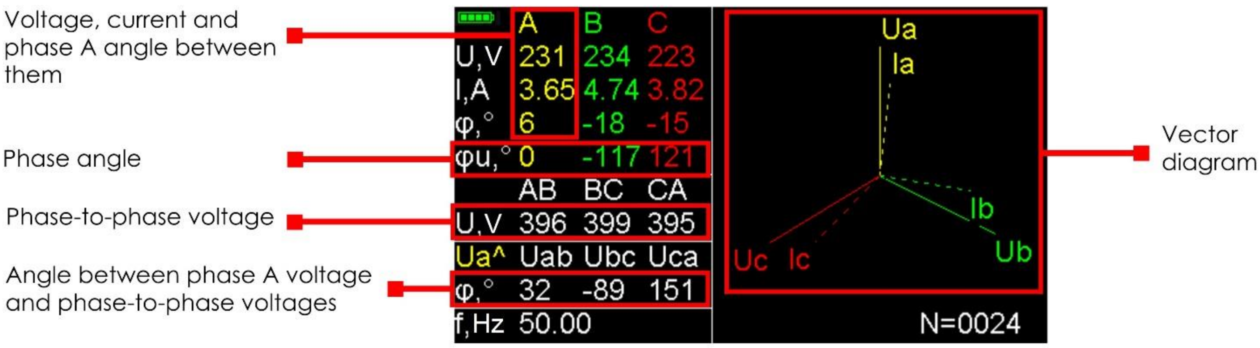

Fig. 4. Indication of the 1st mode on the LCD of the device.

When the sign of phases is displayed, a zero vector is considered to be the first vector in indication. Example is shown on fig. 4.

- When measuring a phase shift between the current and the voltage of one phase, a voltage vector is taken for the initial vector. The number on the screen is read as: Ua outruns vector Ia by 6 degrees.
- When measuring the angle between phase voltages, initial phase Ua is taken for zero one. Initial phases Ub and Uc are displayed as related to initial phase Ua.

6.2.4 If it is necessary to measure a phase shift between phase-to-phase voltage, Uab for example, and phase current, the following should be done:

- connect «neutral» (black wire), to phase B;
- connect phase A (yellow wire) to phase A;
- connect the clamp meter of phase A to the phase current being measured.

The angle, which is displayed as the shift angle of phase A (fig.3, highlighted column), will correspond with the phase shift of the current being measured as related to phase-to-phase voltage AB.

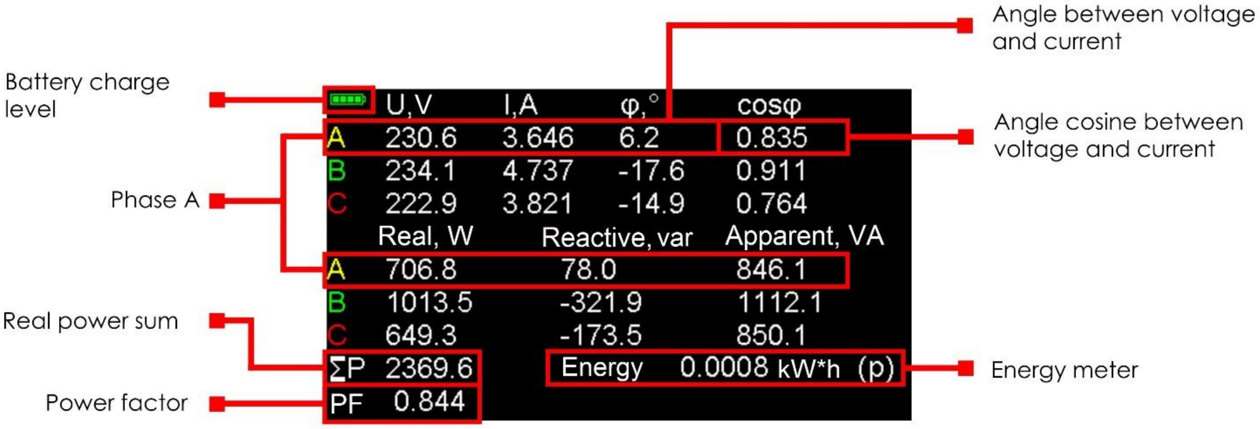

Fig. 5. Indication of the 2nd mode on the LCD of the device.

6.2.5 Switch between the modes by pushing the button «Mode» shortly.

6.2.6 To start the power meter, you should:

- Switch to the second mode;
- Shortly push the button «Power».

The meter is started by letter «s» in brackets («Energy 0,0000 kW·h(s)»).

6.2.7 To stop the power meter, you should push the button «Power» shortly. The meter is stopped by letter «p» in brackets («Energy 0,0008 kW·h(p)»).

6.3 Saving the results of the measurement

The device allows saving the results of 100 measurements. The results are presented as screenshots of the two modes, both in text and graphics format.

To save the results of the measurements while the measurements are being taken, push the button «Mode» and hold it till the inscription «Saving data…» appears. After this message appears the button can be released. On the screen you will see the names of the files in which the screenshots of the two modes have been saved. After the results are saved, the device will automatically return to the measurement mode.

The files without underscore in name are shown the screen in the first mode.

The files with underscore in name are shown the screen in the second mode.

If the maximum possible amount of measurements is saved in the device at the moment, the files will be recorded over the previous ones starting with the earliest one. If there isn't enough memory for saving the results of the measurements in the device due to the user's saving personal data or incomplete deleting of the files, containing the measurements, the device will produce the message «Недостаточно места» (memory is full). In this case the user should delete the data manually. All 4 files of each measurements should be deleted.

It is not recommended to save personal files in the device memory and to save manually after the message «Full memory» appears on the screen.

6.4 Connecting the device to PC

To connect the device to PC, the user should use a cable mini-USB – USB-A. The device should be turned on before connecting the cable. After connecting the device, a new appliance «Removable disk» will appear.

Then these data files, saved in the device memory, can be used as regular files on a removable disk. Graphic data are saved in GIF format and text ones are saved in HTML format in files. It is convenient to look through these files on PC and use them for drawing up protocols and reports with the help of commonly used office applications.

When connected to PC, the device is powered from the computer,

ATTENTION!

DON'T CONNECT THE DEVICE TO PC WHILE MEASUREMENTS ARE BEING TAKEN.

7 Adjustment of the device

The device is adjusted by the manufacturer.

8 Verification of the device

Verification of VFM-3 is conducted once every 24 months in compliance with the document « State System for Ensuring Uniform Measurement. Volt-ampere phase meter VFM-3. Test procedure 25-262-2014», is approved by Federal State Unitary Enterprise «UNIIM».

9 Labeling, packaging and sealing

9.1 The device is labelled with: the name, the type, the trademark of the manufacturing enterprise, the national conformity mark, the serial number, the year of manufacture, symbols for input and output circuits, warning labels in compliance with GOST 26104.
9.2 Packaging, concerning the impact of environmental and climate factors in compliance with GOST 22261, group 4.
9.3 Packaging, concerning the impact of mechanical factors according to GOST 22261, group 4.

Dimensions in package 240×240×155 mm.
Gross weight is not more than 3 kg.
The device is sealed with the sealing mark which breaks when open.

ATTENTION!

DON'T BREAK THE SEAL!

10 Transportation and storage

Terms and conditions of transportation and storage should comply with GOST 22261.

LLC «Chelenergopribor»

1B, Severnaya, Chelyabinsk city, village Shershny

+7 (351) 211-54-01

info@limi.ru

www.limi.ru