Modern Equipment for Piezoelectric Ceramic Elements Developed by Research and Design Production Engineering Bureau "Piezopribor".

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Polarization in liquid dielectric medium is considered as a classical method of piezoelectric ceramic elements polarization. If we omit the details of physical processes taking place in the ferroelectric material structure in the process of polarization, the work process looks as follows. A piezo element blank (PE blank) is connected to the contact device electrodes and immersed into a container filled with a silicon-based dielectric fluid. The fluid and the PE blank are heated to a certain temperature; after that, the PE blank is energized with polarization voltage. Then the fluid together with the PE blank are cooled to room temperature under the effect of applied voltage. If temperature and voltage values are selected optimally, the PE blank acquires piezoelectric properties.

It is generally considered that the main advantage of this method is that maximum field strength is created throughout the ceramic piezo element because of additional insulation of the PE blank interelectrode surfaces by dielectric fluid. Such a feature makes this method indispensable at the stages of developing and mastering the manufacture of new types of piezo materials and ceramic piezo elements. Another important advantage of polarization in dielectric fluid medium is evenness of the PE blank heating and cooling; this is especially important when large-size items are polarized. Along with the advantages described above, this method has its shortcomings: low productivity, deterioration of electrode adhesion to ceramics, the need to rinse piezo elements in gasoline after polarization, environment protection problems connected with utilization and disposal of the process fluids.

The equipment implementing this method is in demand, and therefore it is produced by Research and Design Production Engineering Bureau "Piezopribor" at present. The outward appearance of a plant for polarization ceramic piezo elements in fluid medium (PZhS) is shown in Figure 1.

1 - vent hood; 2 - screen; 3 - polarization unit; 4 - polarization bath; 5 - drip pan; 6 - control panel; 7 - automatic module.

Figure 1. External appearance of the PZhS plant

The plant consists of vent hood 1 with triplex screen 2 provided with a system a counterweights. Polarization unit 3 is incorporated in the chamber work surface. It comprises polarization bath 4 with a high-voltage bus installed inside on special insulators and a dielectric fluid temperature sensor. Because of a special design of heaters and coolers, the heating and cooling system reduced total polarization time; whereupon the plant capacity increased

and power consumption decreased. PE blanks that are to be polarized are installed in a cassette whose external appearance is shown in Figure 2.

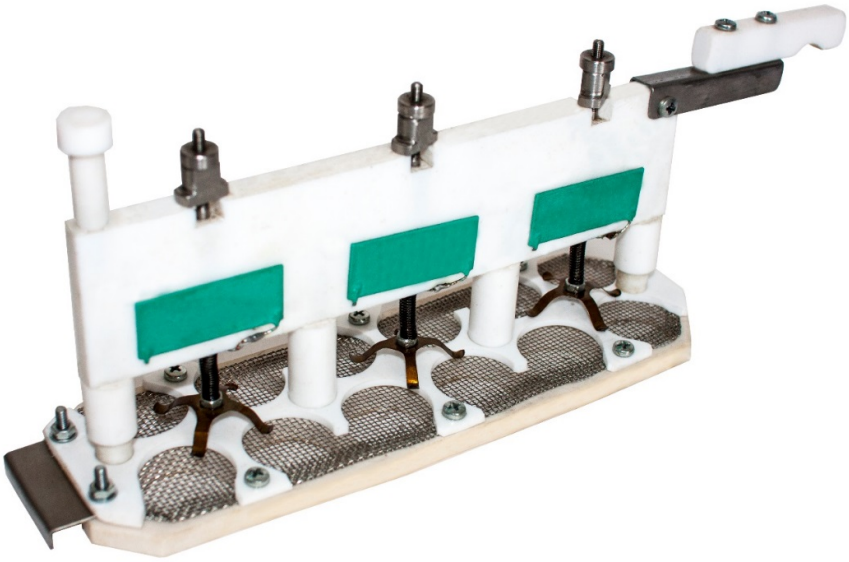


Figure 2 - External appearance of the cassette

The cassette has three groups of cells; four blanks may be installed in each of them. Each cell is served by a current-limiting resistor; in case of an intrinsic breakdown of one blank, one cell is excluded from the polarization process. The maximum capacity of the polarization bath is six cassettes; thereby, 72 PE blanks can be polarized simultaneously. After polarization, the cassettes with piezo elements are taken out of the polarization bath and installed into special drip pan 5 for removing pyro charge from the piezo elements, as well as for running off and collection of dielectric fluid. The drip pan is not fastened; therefore, it can be removed from the hood if necessary.

Polarization modes are set and monitored with the help of control panel 6. The polarization voltage value is set with the help of a multiturn potentiometer. The temperature control system can operate in dielectric fluid heating and cooling modes. The mode is selected with the help of a thumb switch. The control panel is directly connected with automatic module 7 where the power units of control systems are located.

Dimensions of Polarized Items:

Diameter or square diagonal, mm, max.	30
Height (interelectrode distance), mm, max.	8

Technical Specifications of the PZhS Plant:

Polarization voltage range, kV	0. 5 to 20
Maximum field strength, kV/mm	2,0….2,5
Potential capacity, pcs/h, max.	70
Maximum heating temperature, ºC	up to 150
Continuous operation time, h	8
Power consumption, W, max	2500
Dimensions, mm, max	1200×690×2400

Advantages of the plant:

1. A wide range of ceramic piezo elements made of the majority of modern ceramic piezo materials can be polarized;
2. Efficient heating and cooling systems;
3. Ergonomic accessories;
4. Compact dimensions;
5. Low power consumption.

The **shortcomings of the unit** result from the disadvantages of the unit include low productivity and related to the utilization and disposal of dielectric fluid.

Apart from polarization in dielectric fluid, there is a method of polarization in air medium that is free from most shortcomings described above. The foundation of designing process equipment for polarization in air medium was laid by Research and Design Production Engineering Bureau "Piezopribor" in the 1970s on the basis of invention certificate No. 788230 (authors: Yu.A. Vusevker, O.P. Kramarov, A.I. Sokallo, V.A. Khrenkin). Since then dozens of polarization plants for different purposes, with various hardware and degree of mechanization and automation have been developed and manufactured based on this method.

At present, PVS type plants that ensure continuous polarization process are the latest and most popular. The external appearance of the plant is shown in Figure 3.

Figure 3. External appearance of the PVS plant

PVS type plant is a monoblock equipped with a rotary conveyor rotating on a horizontal axis. As the conveyor rotates, PE blanks pass successively through processing zones and acquire piezo electric properties as a result. The arrangement of the zones is shown in Figure 4.

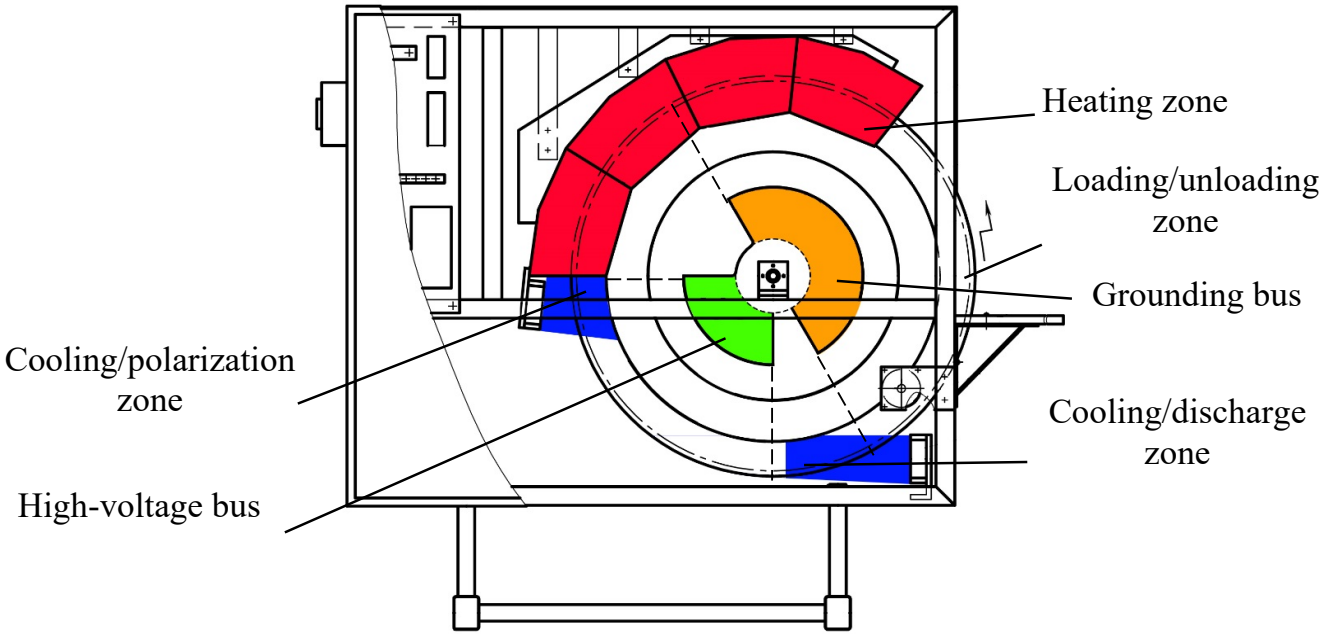


Figure 5 Arrangement of PVS plant processing zones.

The conveyor is equipped with holders that are contacts through which polarization voltage is fed to the blanks. As a rule, one of the holder contacts is electrically connected with the conveyor body and the negative terminal of the polarization voltage source. The

other contact is connected with a high-voltage bus via a polarization current limiting resistor. The bus in turn is connected with the positive terminal of the voltage source. The design and number of the holders depend on the shape and dimensions of the articles being polarized and the necessary capacity. Actual equipment has 16 to 40 holders.

The conveyor rotates unidirectionally with controllable stops. Stops enable the operator to load blanks and to unload finished articles from the holders. The duration of stops can be changed over a wide range. It is chosen depending on the types of ceramic piezo materials and the dimensions of PE blanks. The heating zone is a furnace consisting of several sections. Each of them may comprise several electric heating elements. The sections are linked to form an arc-shaped channel of a certain radius through which holders with PE blanks travel. After the PE blanks leave the heating zone, they enter the cooling zone and the sliding contact comes into contact with the high-voltage bus. After the high-voltage bus, the sliding contact contacts the grounding bus; thus, pyro charge is removed from piezo elements before the unloading zone.

Dimensions of Polarized Items:

Rings, discs, plates	
external diameter, mm	10…30
square side, mm	10…30
interelectrode distance, mm	0,5…8
Cylinders	
external diameter, mm	10…35
height, mm	8…40
interelectrode distance, mm	0,5…8

Technical Specifications Attainable by the PVS Plants:

Polarization voltage range, kV	0.3 to 10
Maximum field strength, kV/mm	0,8…1,2
Potential capacity, pcs/h, max.	1200
Maximum heating temperature, ºC	500
Continuous operation time, h	8

Static rotor conveyor exposure time, sec	1 to 300
Piezo elements loading and unloading	manual
Power consumption, W, max	4000
Mass, kg, max.	200
Dimensions, mm, max	1800x600x1500

Advantages of the plant:

1. Ceramic piezo element blanks can be polarized without using dielectric fluid;
2. High productivity;
3. PE blanks with a wide range of sizes and shapes can be polarized;
4. Compact dimensions.

A shortcoming of the plant is limitation on PE blanks dimensions.

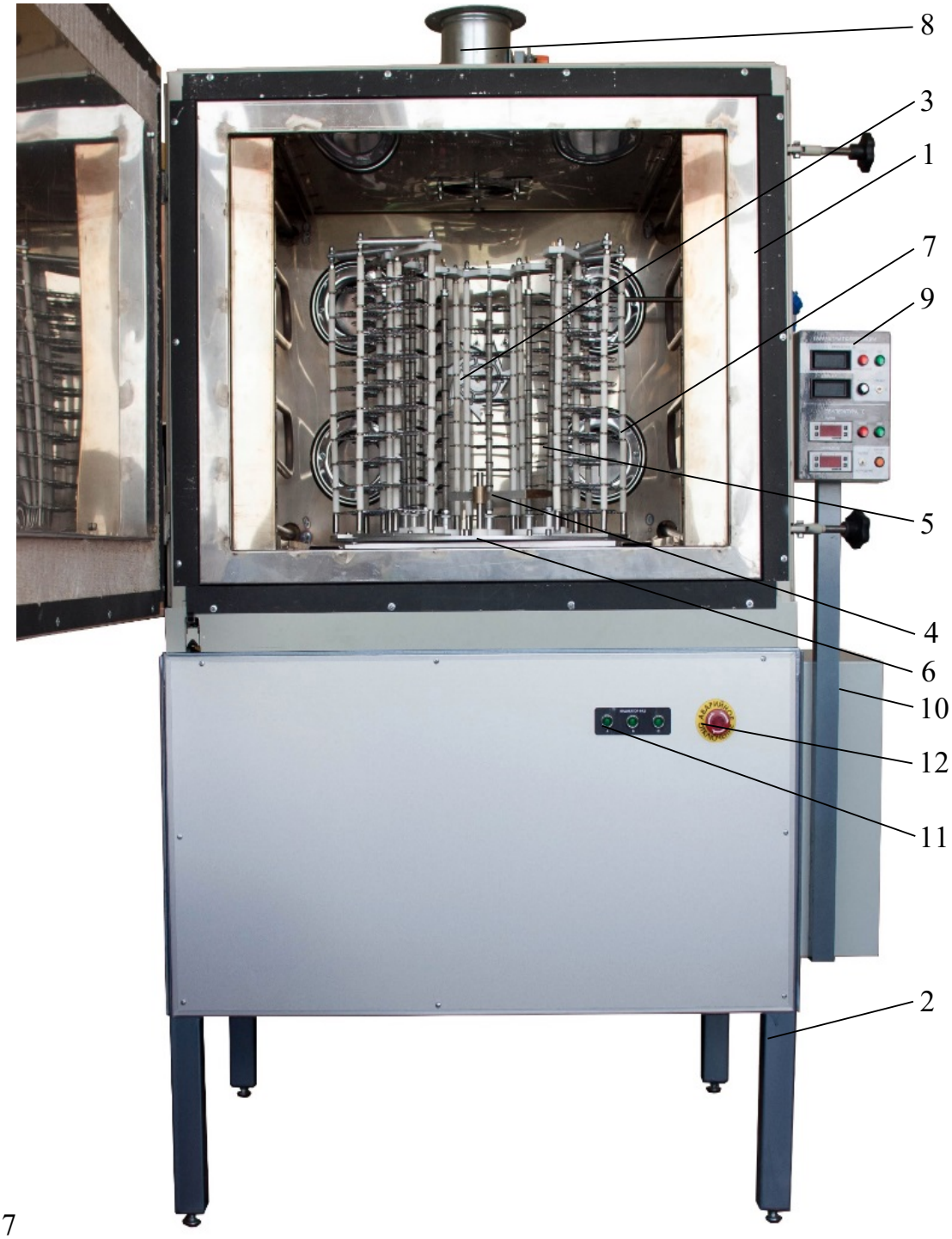
A large quantity of PVS type plants was produced during the period from 2005 till 2015. Variations in the plants were determined by the requirements of specific customers' RFPs. Whereupon technical specifications, shapes and sizes of the polarized articles, maximum furnace heating temperature, technical throughput varied. As a rule, original holders were designed meeting the requirements of efficient retaining of the blanks specified in the RFP and ensuring maximum possible electric field strength during polarization.

PVSK plant is a solution intended for polarization of large-size piezo elements made of ferrorigid materials in air medium. Letter "K" in the acronym means that the plant is of chamber type. In spite of the fact that on the shop floor continuous process plants (PVS type) are more efficient, it turned out that this advantage is lost on large-size articles because of significant increase in heating and cooling time. It was established that with large-size articles it is more advisable to use the process of simultaneous polarization of the maximum possible number of blanks. Whereupon productivity can be increased by efficient loading of the chamber and using two or more chambers that are being downloaded/offloaded or polarized alternately.

The general appearance of a PVSK plant is shown in Figure 5. The plant is based on chamber electric furnace 1 with standard heating elements and a forced air circulation fan. The fan ensures air flow circulation in the working zone and even distribution of temperature throughout the furnace chamber. The furnace is installed on frame 2. Polarization unit 3 is located in the furnace; it comprises high voltage distribution mechanism 4 and ten removable cassettes 5 installed on rotating base 6. The cooling system comprises cooling fans 7 located on the rear panel of the furnace, as well as controlled exhaust ventilation damper 8 installed in the top panel of the furnace. Polarization modes are controlled and their values are monitored from control panel 9 fastened with the help of a square pipe on the side wall of automatic control unit 10. Phase indicators 11 and emergency stop button 12 are located on the front panel of the frame envelope.

Operating a PVSK Plant

Cassettes are loaded on a worktable outside the furnace. 10 PE blanks are loaded into each cassette. The cassettes are installed in the furnace chamber on the hooks of a rotating base intended to facilitate loading.



1 – electric furnace; 2 – frame; 3 – polarization unit; 4 – polarization voltage distribution mechanism; 5 – cassettes; 6 – rotating base; 7 – cooling fans; 8– controlled exhaust ventilation system damper; 9 – control panel; 10 – automatic control unit with a high voltage source; 11 – phase indicators; 12 – emergency stop button.

Figure 5. General appearance of the PVSK plant

unloading of cassettes. 1 to 10 cassettes can be installed on the base. After the necessary number of cassettes is installed, half polarizing voltage value and the necessary heating temperature are set on the control panel, the polarization voltage distribution mechanism is switched on and the heating process begins. When the PE blanks temperature reaches the preset value, a sound and a light signal will be triggered, reporting that the heating process is over. At this signal, the operator must set full polarization voltage and switch the temperature control system to the cooling mode. When the preset cooling temperature is reached, sound and light signals will report that the polarization process is over.

The bulk of the blanks loaded into the plant are partially independent of intrinsic breakdown of one or several piezo elements. Since there is no electric connection between cassettes, in case a single piezo element in one of them breaks down, polarization of the piezo elements in other 9 cassettes will continue under normal conditions. Using a high voltage distribution circuit with a single limiting resistor for all cassettes creates equal polarization conditions for all piezo elements. Upon completion of the polarization process, the operator will be able to locate the cassette with the burnt-out piezo element and its location in it.

Dimensions of Polarized Items:

discs	
diameter, mm	30 to 80
interelectrode distance, mm	3 to 12
rings	
diameter, mm	30 to 80
diameter, mm	10 to 60
interelectrode distance, mm	3 to 12

Technical Specifications Attainable on the PVSK Plant.

Polarization voltage range, kV	0,5 to 20
Maximum field strength, kV/mm	1,3…1,8
Potential capacity, pcs/h, max.	
	100

Maximum operating temperature, ºC	200
Power consumption, W, max	4000
Continuous operation time, h	8
Piezo elements loading and unloading	manual
Plant dimensions, mm, max	1300×850×1700
Plant mass, kg, max.	300

Advantages of the plant:

1. Large-size ceramic piezo element blanks made of ferrorigid material can be polarized without using dielectric fluid;
2. High-performance cooling system;
3. Convenient loading/unloading of ceramic piezo elements;
4. Compact dimensions;

A shortcoming of the plant is its low productivity.

Using modern materials, components and instruments, the Research and Design Production Engineering Bureau "Piezopribor" design team strives to maintain state-of the art level of design and ergonomic in every new plant. As a result, several versions of PVS type plants have been developed. This type of plant has a system of rapid selection of piezo element polarization mode. The system concept is to make it possible to observe the process of change of voltage connected to a piezo element being monitored in the process of its cooling. Using high-performance ring heaters together with state-of-the-art types of heat insulators permitted to improve furnace reliability and efficiency. The latest developments use instruments that permit to improve furnace temperature control efficiency considerably. An important advantage of the latest development is stability of preset polarization voltage value and its independence of power mains voltage fluctuations and voltage variations. Therefore, the risk of an intrinsic breakdown in case of an accidental voltage surge above the permissible level or polarization quality deterioration in case of its unauthorized drop is eliminated. To make the operator's work comfortable, PVS plants have a sit-down workstation with a convenient table and an informative control panel. PVS and PVSK plants are powered from three-phase power network; thus, its quality is preserved to the maximum and additional

power saving is ensured. The plants meet occupational safety and health requirements because they can be connected to the factory ventilation system and they have a system blocking unauthorized switching on high voltage. The plants are equipped with an emergency stop button in order to prevent injury and mitigate harm caused by a possible accident.

Throughout the whole period of its existence, Research and Design Production Engineering Bureau "Piezopribor" was the leading developer and supplier of polarization equipment in the former Soviet Union; it is the worldwide leader in the sphere of polarization in air medium. The processes of ceramic piezo elements production, their chemical formulas, standard sizes and configurations change and improve continuously. Research and Design Production Engineering Bureau "Piezopribor" does it best to keep abreast of the times; it is always ready to cooperate with all enterprises interested in modernization and creation of new types of polarization equipment.