OVERHAUL OF A TRANSFORMER WITH A SEPARATE ACTIVE PART

O.A.Qosimov
Andijan State Technical Institute
ORCID: https://orcid.org/0009-0006-5504-6980

Abstract . During the overhaul of a transformer with a separated active part, the technology of repairing the winding and magnetic system and the procedure for subsequent assembly work must be as close as possible to those of the manufacturer of the transformer. During this type of repair, drying and oiling of the active part of the transformer must be carried out. After the overhaul, a set of tests is carried out in accordance with the "Rules for the Operation of Consumer Electrical Equipment" (IEUIQ), on the basis of which a test report is drawn up, which is considered the main document of the repair. During the transfer of the repaired transformer to the customer, an acceptance certificate is drawn up, which indicates all the work performed, and in the special requirements section, descriptions are given regarding the operation of the transformer (parallel operation, symmetrical modes, etc.).

Keywords: Transformers, Coils, Active part, Reactive part, Insulation, Plates, Magnetic system, Parts, drums, straightening device, paper wrapper.

Annotatsiya: Ajratilgan faol qismga ega bo'lgan transformatorni kapital ta'mirlashda o'rash va magnit tizimni ta'mirlash texnologiyasi va keyingi yig'ish ishlarini bajarish tartibi transformator ishlab chiqaruvchisiga imkon qadar yaqin bo'lishi kerak. Ushbu turdagi ta'mirlash vaqtida transformatorning faol qismini quritish va moylash ishlari amalga oshirilishi kerak. Kapital ta'mirdan so'ng "Iste'molchi elektr jihozlarini ishlatish qoidalari" (IEUIQ) ga muvofiq bir qator sinovlar o'tkaziladi, uning asosida ta'mirlashning asosiy hujjati hisoblangan sinov dalolatnomasi tuziladi. Ta'mirlangan transformatorni buyurtmachiga topshirishda barcha bajarilgan ishlarni ko'rsatadigan qabul qilish dalolatnomasi tuziladi va maxsus talablar bo'limida transformatorning ishlashi (parallel ishlash, nosimmetrik rejimlar va boshqalar) bo'yicha tavsiflar beriladi.

Kalit so‘zlar: Transformatorlar, Bobinlar, Faol qism, Reaktiv qism, Izolyatsiya, Plitalar, Magnit tizim, Qismlar, barabanlar, tekislash moslamasi, qog'oz o'rami.

Аннотация. При капитальном ремонте трансформатора с отделенной активной частью технология ремонта обмоток и магнитной системы, а также порядок последующих сборочных работ должны быть максимально приближены к принятым на предприятии-изготовителе трансформатора. При данном виде ремонта должны быть проведены сушка и смазка активной части трансформатора. После капитального ремонта проводится комплекс

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испытаний в соответствии с «Правилами эксплуатации электроустановок потребителей» (ПЭЭП), на основании которых составляется протокол испытаний, являющийся основным документом ремонта. При передаче отремонтированного трансформатора заказчику составляется акт приемки, в котором указываются все выполненные работы, а в разделе «Особые требования» даются описания, касающиеся эксплуатации трансформатора (параллельная работа, симметричные режимы и т.д.).

Ключевые слова: Трансформаторы, Катушки, Активная часть, Реактивная часть, Изоляция, Пластины, Магнитная система, Детали, Барабаны, Выпрямляющее устройство, Бумажная обёртка.

Introduction

When inspecting the active part of the transformer, its individual elements and details, including the magnetic system, windings, insulation gaps, etc., are measured, drawing up a sketch of the active part of the transformer (Fig. 1). In addition, the results of intermediate tests during the repair of individual parts of the transformer are also entered into the measurement card. In order to avoid errors, it is advisable to compare all dimensions with the general dimensions of the magnetic system during measurement. When identifying defects in the assembled state, the scope of overhaul includes full and partial replacement of windings and main insulation, full and partial re-insulation of the magnetic system plates, restoration or replacement of individual devices, cooling systems, connections, etc. During overhaul, it is necessary to disassemble the active part of the transformer. Before its disassembly, the transformer is sequentially disassembled into parts, as mentioned above. After the upper half is removed from the casing, the windings and insulation are removed. If necessary, the magnetic system is disassembled after the plates are re-insulated. After the transformer is disassembled, the parts and details that require repair and replacement are identified and separated.

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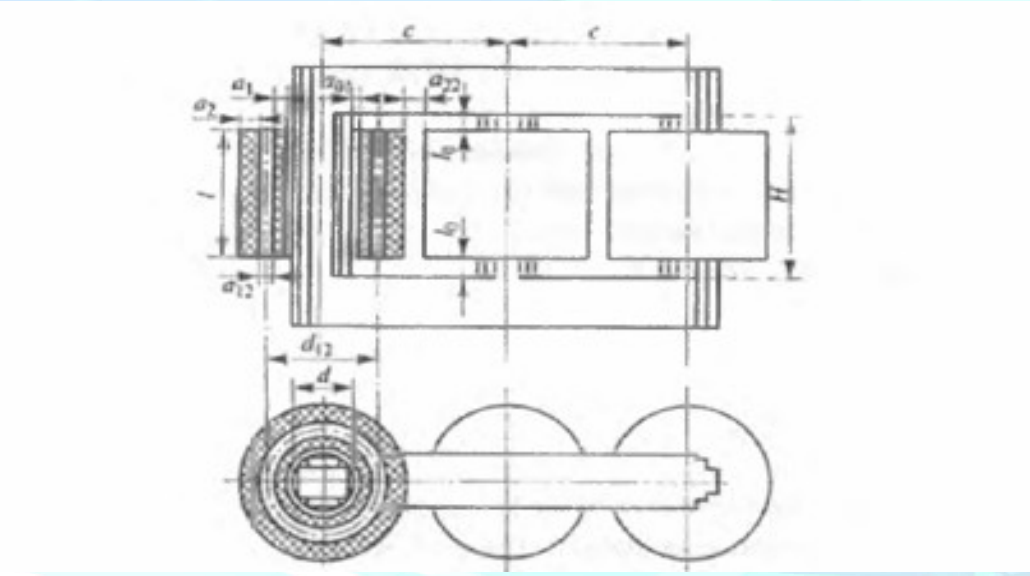


Figure 1. Sketch of the active part of the transformer

Each transformer accepted for repair is assigned repair numbers corresponding to the designation of all disassembled parts used in the repair. Before disassembly, it is determined that the transformer is complete, a separate list of all missing parts is compiled and added to the inspection and disassembly log. The tank is inspected to detect oil leaks, the leaking areas are marked with chalk. Then the condition of the input part is determined. The process of identifying defects in the assembled state also includes preliminary tests to determine the damaged areas and their nature; such damage includes: oil extraction for chemical analysis and determination of the electrical strength of the oil; insulation characteristics. When disassembling the transformer, damage to each detail and part removed from it is determined, and the volume of repairs necessary for further work is determined. Let us consider the sequence of work and technological operations performed from the moment of removing the active part from the tank (for transformers of sizes II and III). When inspecting the active part, the insulation and condition of the winding and connections, the quality of the winding pressing, the absence of deformations and other defects are determined.

The paper insulation is checked for damage and its mechanical strength is conditionally divided into the following characteristics: elastic (category 1 of strength that does not break even when bent twice), hard (category 2 of strength that cracks when bent twice), brittle (category 3 of strength that breaks insulation when bent twice) and rotten (category 4 of strength that breaks when bent at a right angle). At the same time, the condition of the main insulation, the absence of winding deformations and winding displacements are determined. Depending on the structure and the reasons for the appearance of defects, the issue of complete replacement of the winding structure and main insulation is considered. The

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connections, reconnection, contacts and welding points, tensioning pins and their insulation conditions are inspected, the suitability of the grounding of the magnetic core is checked, the short circuit contour in the magnetic system is determined and measures are taken to eliminate the possibility of its occurrence and are entered into the defect register. If it is necessary to separate the active part, then a sketch of its placement and fastening of the plates is made before separating the connections.

If the scope of repair requires a complete identification of defects, the dimensions of the coil and its parts, individual insulation gaps, dimensions of the insulation cylinders, the number of windings of individual coils, the condition and structure of the internal coil, as well as the condition and structure of all internal insulation (from the coil to the stator and between the coils) are determined. When identifying defects, it is important to determine the size of the conductors and the number of windings of the coil. If there is no technical passport for the transformer, the number of phase windings can be determined using a control winding wrapped in a soft electrical cardboard insulating cylinder over the transformer winding assembly. In order to avoid errors in the separation, a calculation is carried out and the results obtained are compared.

Separation of the active part of transformers

Disassembly of the cover and the joints. Disassembly of the tank cover was discussed above. When inspecting the inlet parts, their reusability is determined. If there is no local damage (burnt, cracked, insulation is pushed), the joints are disassembled (the joint is separated from the insulation with a knife at the point of connection with the hose). If all the joints have good insulation and do not need to be replaced, they are removed together with a frame-shaped timber, which helps to reduce the amount of work during assembly. Before dismantling, the joints are marked (the inlet and re-connector clamps are marked). After or before removing the cover from the active part, the inlet and re-connector branches are disassembled. Removing the upper rope from the stack, dismantling the hose and insulation.

Disassembling the active part begins with removing the hose and the upper rope from the press. The half-beams of the cargo side and the JV side do not have interchangeable properties (Fig. 2), therefore they are marked before dismantling. During the dismantling of the upper half, the quality of the insulation of the upper half and the need for its restoration are determined based on the first plates taken. In most cases, the upper half of the assembly, disassembled into all parts, is placed in a container and sent to the varnishing plant. When the assembly and insulation are disassembled, it is possible to assess the condition of the assembly and, after repairing the damaged areas, make a decision on their use. If the assemblies are not

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replaced, but only repaired, or are dismantled due to a damaged magnetic core (in the rod or lower half), then the main insulation details are dismantled, inspected, some damage is eliminated and then used.

When a single assembly is damaged, in most cases, all assemblies are dismantled from the rods, since the metal melt and soot formed under the influence of the electric welding arc settle on the entire assembly and insulation. Heavy assemblies are dismantled using special equipment. During repair, this equipment, for example, in transformers of sizes I and II, is in the form of a double-sparking traverse. This allows not only to dismantle the transformer, but also to place it, and transport it in a vehicle (Figure 3).

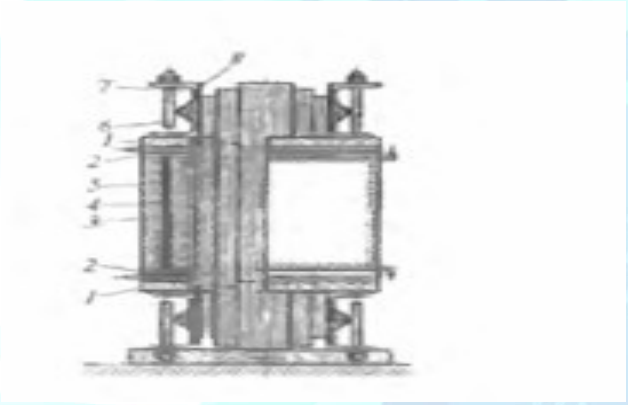


Figure 2 Transformer active part: I- equalizing insulation; 2-half insulation; 3 and 4- Load and PK bushings; 5- insulation cylinders; 6- vertical tensioning pins; 7- top half beam; 8- insulation gasket.

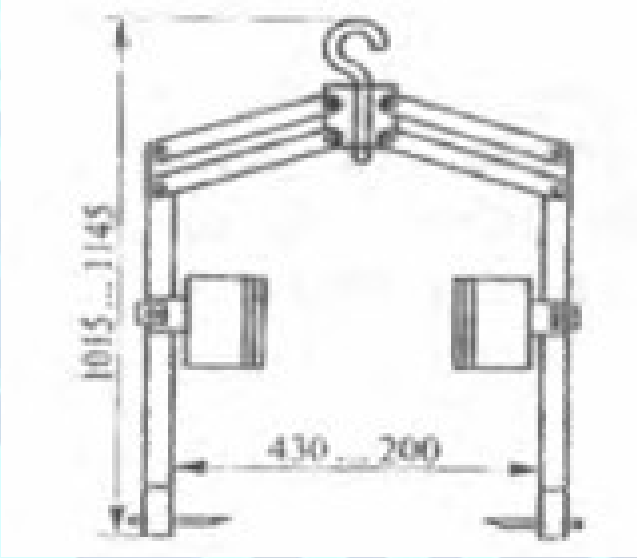


Figure 3. Equipment for stripping transformer coils of sizes I and II.

The stripping device has sliding rubber-coated claws. The claws of the stripping device are inserted into the base of the tap in such a way that they do not pinch the adjacent tap and its insulation. For transformers of sizes IV-VII, the tap stripping device is made with three sparks (with three pulling forces) at an angle of

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120°C.After the coils are removed, the lower half and balancing insulation, the electrical cardboard cylinder, and the inner coil's hollow cores are removed from the rod. If the coil insulation needs to be replaced due to long-term operation and wear, the wooden parts are also replaced.

Repair of transformer winding. If the insulation is pressed strongly with a hand, it is damaged, in which case it is necessary to make a decision about replacing the winding. In some windings, in case of an emergency, such as a short circuit in which the winding and insulation burn out, only a part of the winding is replaced. During such winding repair, the old insulation is removed from the winding conductor, then it is annealed, straightened and insulated with new insulation. To remove the old insulation from the winding and annealed, the winding is wound into a separate coil (coil) and heated in a closed furnace to a temperature of 500-600°C. During this, the insulation burns out and the internal bending stress of the copper is relieved - it becomes “soft”. To prevent them from getting mixed up during annealing, the coils are tied with wire bandages and mounted on special supports. A mechanical method can also be used to remove the old insulation during repair. In this case, the wire is passed through a device, in which the insulation is cut longitudinally, scraped and cleaned with the help of shovels and straightened. For straightening, the coil is passed through a steel roller system, and then rewound onto a drum with a diameter of 400-500 mm. The ends of the 0' conductor are electrically welded to metal.

The welded area is ground and cleaned with sandpaper, then the conductor is insulated using a special paper winding machine (Fig. 4). Using the pulling device 4, the conductor is pulled from the drum 4 through a straightening device 2, consisting of a system of steel rollers, vertically and horizontally located, and then passed through a paper winder 3 rotating around it, and then wound onto the drum 5. When fully or partially rewinding the coil, the necessary insulating materials and details (paper-Bakelite rings, rails for channels between layers, electrical cardboard track, paper-Bakelite cylinders, side walls, etc.) are prepared in advance. The coil preparation technology must comply with the plant.

After winding, helical and continuous coils have a larger size compared to the calculated shaft size, therefore they are pulled with steel plates and pins, dried and pressed to obtain the required height. The upper plate is covered with a plate (most often in a plate-shaped form), under the influence of which the pipes dry out and the insulation shrinks, and as a result, they are automatically pressed. Between the plates and the pipes, wooden pallets are placed on the sides opposite the sealing columns. In stationary factory conditions, the pipes are dried under vacuum in a

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special thermo-cabinet, in individual repair - in a closed metal tank heated without vacuum, in a cabinet with an electric heater or with an induction cooker.

After drying, the pipes are additionally pressed for 10-15 hours at 100-105 ° C, the tightening plate stud nuts are tightened evenly until the given size is obtained. To give the coils monolithicity and sufficient mechanical strength, transformer coils of size I and sometimes size II, as well as all layered coils, after drying and subsequent stretching, are dipped in ML-92 varnish and heated to a temperature of 50-70°C before dipping in varnish. The soaking time depends on the coil size, structure and voltage and ranges from 15-40 minutes. When the excess varnish has drained, the soaked coil is placed in a heat-treated oven for 10-12 hours at a temperature of 100-105°C.

To ensure sufficient mechanical strength of the un-soaked and un-treated wire, the wire conductors are pulled, the windings are placed more densely and secured with external rails. After drying, the wire is pressed using a special press and processed as follows: the ends of the rails, wedges and insulating tapes are cut, the conductor passages are knocked out, the wire ends are placed in accordance with the drawing and the rows of gaskets are installed.

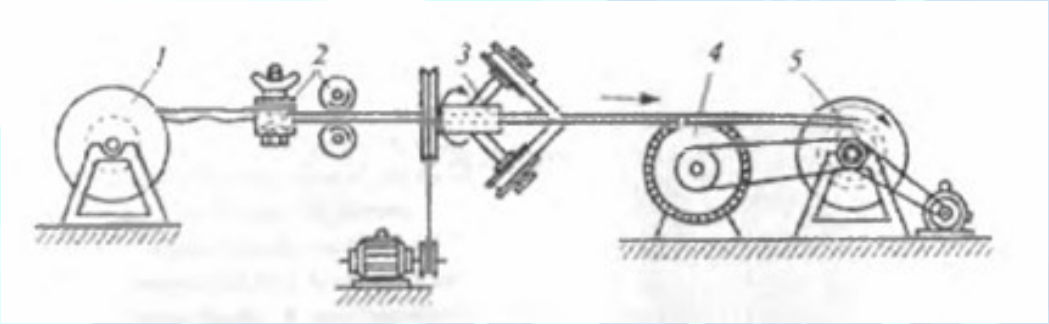


Figure 4. Paper - winding machine: 1 and 5 - drums; 2 - straightening device; 3 - paper-winding machine; 4 - drawing device.

After processing the wire and final pressing, it is pulled with steel frames (Fig. 5). In this way, the whole is transported and stored until installation in the magnetic system.

Repair of the transformer magnetic system. Only after the coil is removed from the magnetic system, it is possible to determine the extent of damage to the magnetic system and the extent of its repair. After the rod and lower half are cleaned of dust and soot, the insulation of the magnetic system plates and the insulation of the half beam and plates are checked for quality and mechanical strength. It is necessary that the varnished plates are not heated, and the varnish film (coating) does not come off under the influence of a blunt object. If there are no signs of damage on the tension pins and the plates of the pole and their insulation is in good condition, the magnetic system is considered suitable for further

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assembly and operation. If minor damage is detected, the magnetic system is partially repaired without completely removing it.

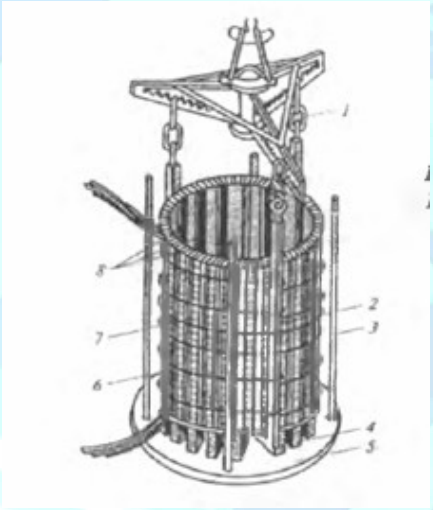


Figure 5. Lifting the sled: 1- traverse; 2- lifting paw; 3- pulling pin; 4- lower support wooden block; S- lower steel plate for pulling the sled; 6- rope for fastening the paw to the sled; 7- sled; 8- vertical rails of the sled.

Complete repair of the magnetic system is a laborious process and includes the following operations: horizontal installation of the magnetic system; dismantling and removal of the stator and lower windings from the stack; separation of the plates into usable ones and repair; manufacture of new plates; assembly and testing of the magnetic system. Dismantling of the magnetic system is carried out in a horizontal position (transformers of sizes III and IV are dismantled on a special metal lathe). Most often, repair of the magnetic system is limited to insulating the upper winding plates. Each winding of the upper winding increases the no-load loss by 5-8% (with full dismantling of the magnetic system, this increase reaches 25%). Therefore, attempts are made to eliminate damage to the magnetic system as much as possible without dismantling it. The old insulation of the plates is removed mechanically (using a moving PoMat brush cleaning machine or manually using a cord tape or brush) or chemically (in a bath heated to 80-90°C with a 10-15% caustic soda solution, then rinsed in hot water and dried in hot air). To remove the paper insulation from the plates, it is steamed in hot water, then dried or burned. The plates are re-insulated in a varnishing device (Fig. 6)

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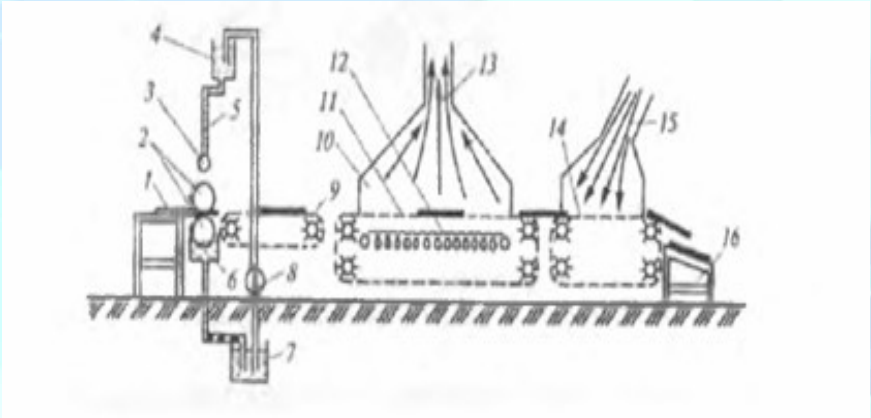


Figure 6. Lacquering device: 1- plate; 2- rubber rotating roller; 3- perforated pipe; 4- waste tank; 5- pipe; 6- bath; 7- tank; 8- pump; 9- conveyor; 10- conveyor; 11- transported workpiece; 12- electric furnace; 13 and 15- pipes; 14- conveyor; 16 - receiving table

After varnishing and tempering, the plates must be completely dark brown and have a flat and smooth surface. During the varnishing process, the thickness of the varnish layer, the electrical resistance of the plate insulation and the composition of the varnish are constantly checked. The plates are placed flat, without warping, without bulges and without one plate protruding above the other. Unevenness and large gaps in the joints are corrected by hitting them with a non-metallic hammer and filling them with fiber during the stacking process. To control the correct placement of the plates, the diagonal distances of the holes (pressing pins) are constantly measured. The thickness of the packages is measured with a caliper, the skewness and verticality of the flange are checked using a right angle meter. When the base (base) is removed during transformer repairs, the rods are replaced with old steel ties and pin pullers, and glass ties are applied using a special mechanism, as shown in Figure 7.

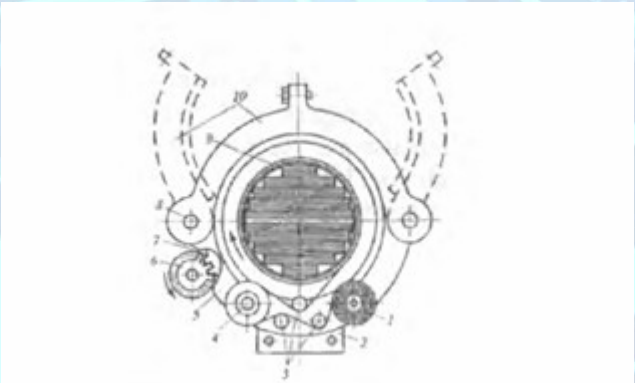


Fig. 7. Glass banding mechanism : 1- glass ribbon roller; 2-pressing beam fixing plate; 3-guide rollers; 4- pulley coupling; 5-steel box ring; 6- gear wheel on the motor shaft; 7- toothed crown washer; 8- finger; 9- rod; 10- separating segment

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The assembly of the magnetic system requires great care and accuracy, since the plates are not laid out in a mold and the quality of their installation depends on the thoroughness of the work. Each 15-20 mm thick plate package is tapped with a wooden hammer and the correctness of the assembly is checked with a mold. After all the plates are placed in the step packages of the frame, the birch planks and rails are placed in the same order as before (before the frame was dismantled) and temporarily fixed with a keeper tape. Then the magnetic system is pressed with clamps, chain or temporary tape binding. First the frames are pressed, then the halves. After pressing, the temporary pressing devices are removed in turn and permanent bindings are installed. The assembled base (frame) is lifted onto the lifting mechanism and placed in a vertical position. A wooden beam is placed under the base boards and the vertical pressing pins are tightened as before removal. All the pulling pins are tightened for the last time and the insulation resistance of the half-beam and the pins relative to the magnetic system is checked with a megger. If there are no defects, the base is submitted for testing. If the test results are satisfactory, the upper half is removed from the bearing and placed in the pulley.

Conclusion

Disassembly of the cover and the elements. Disassembly of the tank cover was discussed above. When inspecting the inlet parts, it was determined whether they could be reused. After the rods are removed, the lower half and the balancing insulation, the electric cardboard cylinder and the inner rod are removed from the rod. If the rod insulation needs to be replaced due to long-term operation and wear, then the wooden parts are also replaced. After pressing, the temporary pressing devices are removed in turn and permanent bindings are installed. The assembled base (frame) is lifted onto the lifting mechanism and placed in a vertical position. A beam is placed under the support planks and the vertical pressing pins are tightened as before removal. All the pulling pins are pulled one last time and the insulation resistance of the half-beam and pins relative to the magnetic system is measured with a megger. If there are no defects, the base is submitted for testing. If the test results are satisfactory, the upper half is removed from the casing and placed in the casing.

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