

## **AUTOMATED COMPLEX FOR E-B TREATMENT OF CABLE AND WIRE INSULATION**

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### *Abstract*

The improved electron accelerator for cable insulation treatment equipped with 4-side irradiation system was developed in Budker -Institute of Nuclear Physics on the basis of ELV series accelerator and was put into operation in "Podolskabel Ltd." During the operation it confirmed the high efficiency and proved the advantages of new method of irradiation. The control system of accelerator and cable transporting line through irradiation zone and take up and pay out machines are joined together, that enables to carry out electron-beam treatment of wires and cable parts in fully automated mode. This new methods allow to increase both productivity and quality of electron beam treatment.

### **INTRODUCTION**

The ELV electron accelerators are DC machines purposed for wide application in various technological processes. ELV accelerators are the most popular Russian accelerators. ELV accelerator can be equipped with a wide set of supplementary devices extending the application range. There are systems of ring and double side irradiation, 4-side irradiation system, extraction device for concentrated electron beam, transportation systems for cable, film and grain. ELV accelerators can be easily integrated in technological processing due to excellent control system based on PC computer. The most impressive installation for cable irradiation is completed at "Podolskkabel" company. There are 2 ELV accelerators with maximum energy 2.0 and 1.4 MeV. Both accelerators are equipped with 4-sided irradiation and universal underbeam transportation systems. It provides the high uniformity of absorbed dose distribution and makes possible to treat the wires with core from 0.12 to 95 mm<sup>2</sup>. There are 6 pay out and take up machines around accelerators. Each accelerator can operate simultaneously with any 2 of them. All units of equipment are combined by control-measuring-informational system. So the beam processing is made automatically. The perfect quality of treatment is proved by reliable operation of cables in extreme conditions of oil industry.

*Keywords:* electron accelerator, EB-processing, high power

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The cross-linked technologies are applied very widely in industries. While the improved maximum operating temperature was one of the initial attractions of cross-linking, there are other important product advantages as a result of cross-linking the polymers, such as: reduced deformation under load, improved chemical resistance, increased abrasion resistance, improved impact properties, memory characteristics.

At present the electron-beam technologies are extensively used in a cable industry for cross-linking of insulation made on the basis of polymer compositions. The use of these technologies enabled to develop the manufacture of a wide range of wires, cables and heat-shrinking goods for different markets (power plant, telecommunications, electronics, oil industry, nuclear power plant, submarine and aircraft, etc). All of them are of high reliability, when being mounted and during operation as under standard and extreme operating conditions.

The most perfect instruments for radiation treatment of insulation cable products are powerful industrial electron accelerators. Optimizing the method of electron beam irradiation of products it is possible to sufficiently improve the irradiation quality and the efficient use of a beam and, thereby, to decrease the cost of the treatment. Well introduced irradiation method will prevent complaints and return from customers. Quality helps to save money.

The Budker Institute of Nuclear Physics of Siberian Branch of Russian Academy of Sciences are developing and manufacturing of electron accelerators of the ELV-type for their use in the industrial and research radiation-technological installations. The ELV-type accelerators were designed with use of the unified systems and units enabling thus to adapt them to the specific requirements of the customer by the main parameters such as the energy range, beam power, length of extraction window, etc. BINP proposes a series of electron accelerators of the ELV-type covering the energy range from 0.4 to 2.5 MeV with a beam of accelerated electrons of up to 100 mA and maximum power of up to 100 kW. Special case is 1 MeV 400 kW beam power electron accelerator. The design and schematic solutions provide the long term and round-the-

clock operation of accelerators under the conditions of industrial production processes.

Due to high power of electron beam in wide energy range, high efficiency of conversation of electricity power to electron beam power and simple procedure of accelerator control by operator with the control system based on IBM compatible computer the ELV accelerators are most popular accelerators not only in Russia, but in China, Korea, and etc. By now, over 110 accelerators had been delivered within Russia and abroad.

Essential treated products are the goods with cylindrical symmetry that many times passes through irradiation area. Some of them are empty inside (tubes), some of them have metal core (wire and cables). To achieve qualitative and effective irradiation it is necessary to provide: homogeneity of absorbed doze in a matter depth and by azimuth of a product, the efficient use of electron energy, the efficient use of electron beam current the stability of absorbed dose during time. The cables are treated many tens of years and it seems there nothing to improve. But we try to modify this well known process. The improved electron accelerator for cable insulation treatment provided with 4-side irradiation system was developed in Budker Institute of Nuclear Physics (BINP) on the basis of ELV series accelerator and was put into operation in "Podolsk cable Co Ltd.". This new irradiation system replaced traditional system with usual scanning beam. Additionally this accelerator was equipped with under beam handling system that was developed in BINP also. It improved the quality of the products and increased productivity.

Fig.1 shows the 4-side irradiation method. The cable is distributed under the beam in such a way, that on each winding the upper and lower cable surfaces are changing their places. If the beam trajectories are crossed at 90° angle, than, taking into account the surface changes, 4-side irradiation takes place. It is sufficiently important that the cable have to pass through irradiation zone few times. The cable distribution under extraction device should be flat or "figure-of-eight" with small crossing angle. 4-side irradiation system allows combining a high irradiation quality with high efficient use of the beam and, from our point of view, 4-irradiation system is optimum for treatment of cable products and wires with the outside diameter up to several tens of millimeters.

Fig.2 Presents the Schematic diagram of 4-side irradiation device:

The principle of device operation is based on the electron beam deflection by magnetic field. The electron beam after acceleration is scanned by scanning electromagnets 1. After that it gets into constant field of bending magnets 4 and 5. This field changes the electron trajectories in such a way, that independently on deflection angle all electrons passing through left magnet have an angle with a standing axis  $-45^{\circ} \pm 5^{\circ}$ . Those, which are passing through the right magnet, have an angle with a standing axis  $45^{\circ} \pm 5^{\circ}$  correspondingly.

There is an area between bending magnets 4 and 5, where flux pattern is different from the necessary one. In

this area,  $\alpha$ , in Fig.2, the angle of electron extraction will be different from  $45^{\circ}$ . To avoid beam losses and the overheating of extraction device the beam have to pass through the mentioned area as fast as possible. For this purpose an additional re-switching magnet has been installed. This magnet enables the electron beam to cross  $\alpha$  area with a higher speed. The re-switching moment (the current pole change in winding) is synchronized with scanning current in the longitudinal direction, (LF scanning).

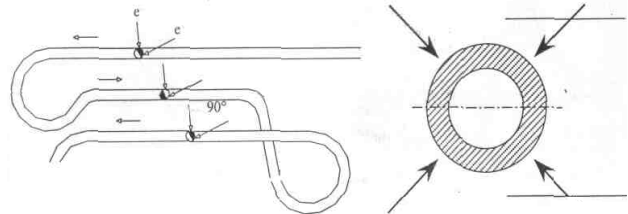


Figure 1: The principle of 4-side irradiation.

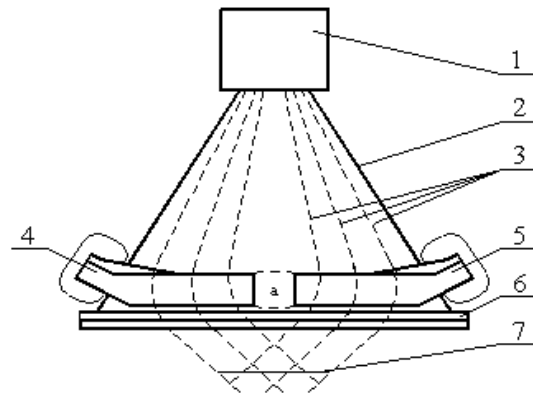


Figure 2: Schematic diagram of 4-side irradiation device: 1 – scanning magnets with re-switching magnet, 2 – extraction device, 3 – electron trajectories, 4 – right bending magnet, 5 – left bending magnet, 6 – extraction window, 7 – radiation zone.

Device adjustment includes raster positioning in the extraction window, determination of beam swing zone (re-switching magnet current value), estimation of extraction electron angle, assigning of radiation zone size. The measurements mentioned above are sufficiently to be done at one electron energy in operation accelerator range. Control program will automatically set (without programmer) required current values in windings at the changes of accelerator operation mode. During the operation this program controls the parameters, which have to be in permissible limit. Before operation special tests for azimuth inhomogeneity of absorbed dose at 4-side radiation in comparison with 2-side radiation have been made. It is shown, that inhomogeneity is enough lower than at 2-side radiation and irradiation degree is

more uniform. For certain goods azimuth inhomogeneity is not higher than  $\pm 5\%$ . The data of comparative assessment of gel fraction content in cable insulation at 2-side and 4-side radiation is given in Table 1.

The absorbed dose value is determined not only by accelerator but underbeam handling system (UHS) also. The main requirements to UHS is that value of transportation speed should be proportional the beam current. The proportionality coefficient, so called "specific speed", depends on type of irradiated material and is adjustable by keyboard.

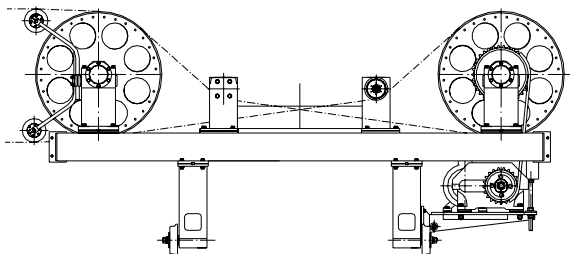


Figure 3. Underbeam handling system 1- drums, 2 – controlling rollers

We developed the universal underbeam handling system for cable and wire transportation through irradiation area. It is shown at Fig. 3. The essential diameters of drums (900 mm) allows to treat the cable

with big single core (up to  $36 \text{ mm}^2$ ), the small controls rollers allow to treat the cables with diameter up to 42 mm. One of drums is leading and another – is driven. It decreases the tensions in treated good and prevents expansion of core. The minimum diameter of treated cables for this device is 1 mm, but during the test we have successfully treated wires  $0.12 \text{ mm}^2$ . The FC drive is used for this device. The good parameters of drive allow making a smooth start and eliminating the beam shutter. Unfortunately the pay out and take up machines are not so universal and during operation together with changing of treated cable we should change handling equipment. So there are 6 take up and pay out machines for 2 accelerators. They allow treating of 3 groups of cable dimensions from 42 to 1mm diameter. Each accelerator can operate simultaneously with any 2 handling system. All units of the equipment (accelerator, UHS, take up and pay out machines) are combined by control-measuring-informational system. So the beam processing is fully carried out in automatic mode. The information of processing is shown on illuminated indicator board. Its dimensions allow reading information from any point of operation hall. The following parameters are continuously displayed: energy, beam current, speed of line, remainder of cable on bobbin, time to finish of bobbin. The perfect quality of treatment is proved by reliable operation of cables in extreme conditions of oil industry.

Table 1: Comparative data of gel fraction content in cable insulation after 2-side and 4-side radiation

Cross section of lead of a cable, $\text{mm}^2$	Insulation matter	Gel fraction content in sectors, %					Average value of gel fraction content, %
		Norm and limit	Sector 1	Sector 2	Sector 3	Sector 4	
2-side radiation							
16	Polyethylen	30–70	54,8	7,1	56,6	75,0	48,3
16	The same		55,5	22,4	59,1	68,6	51,4
16	The same		66,5	73,3	57,5	54,0	62,8
16	The same	30–65	49,9	70,6	69,8	54,3	61,1
4-side radiation							
16	Polyethylen	30–70	70,0	68,2	73,1	73,4	71,1
16	The same		73,4	65,9	68,4	73,1	70,2
16	The same		67,1	70,2	67,6	67,3	68,0
16	The same		71,7	70,5	76,2	76,4	73,7

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