ELV ACCELERATORS ARE A TOOL FOR INNOVATION

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Abstract

BINP SB RAS produces industrial electron ELV accelerators for radiation technologies. The main innovative applications are cross-linking of the insulation of wires and cables, production of heat shrinkable tubes and films, production of foamed polyethylene, and radiation modification of rubber blanks for tires.

Model range of ELV accelerators covers the range of electron energies from 0.3 MeV to 2.5 MeV, beam power up to 100 kW, and beam current to 100 mA. All models have similar concept but differ in overall dimensions, length of accelerator tube, and the number of high-voltage rectifying sections. This makes it easy to adapt accelerators to the requirements of technology. The system of automated control of accelerators and communication with technological lines is constantly developing.

ELV accelerator with an energy of 0.3-0.5 MeV and beam current up to 130 mA was developed and tested. The accelerator is compact in size and installed in local steel shielding. Electron beam is extracted through a two-windows extraction system with one titanium foil 180 mm wide.

ELV ACCELERATORS

By now over 170 ELV accelerators were delivered inside Russia and abroad [1]. Due to compactness and high performance properties, ELV accelerators proved to be competitive both in the Russian and in the world markets. Thus, in China they make about 1/3 of the total amount of powerful industrial accelerators, and in Republic of Korea – almost 2/3.

The main features of ELV accelerators:

- High electron beam power in wide energy range;
- High efficiency of electron beam from the main (70-80%);
- High stability of accelerator parameters. Energy and beam current instabilities do not exceed ±2.5%;
- Simple procedure of accelerator control for operator;
- Accelerator has simple design and high reliability;

ELV accelerator common view is presented in Fig. 1.

Parameters of the main models of ELV accelerators are given in Table 1.

ELV-4 accelerator installed at JSC "Belaruskabel" (formerly "Mozyrkabel") in 2016 is shown Fig. 2.

Models of accelerators differ in overall dimensions, length of accelerator tube, and the number of high-voltage rectifying sections.

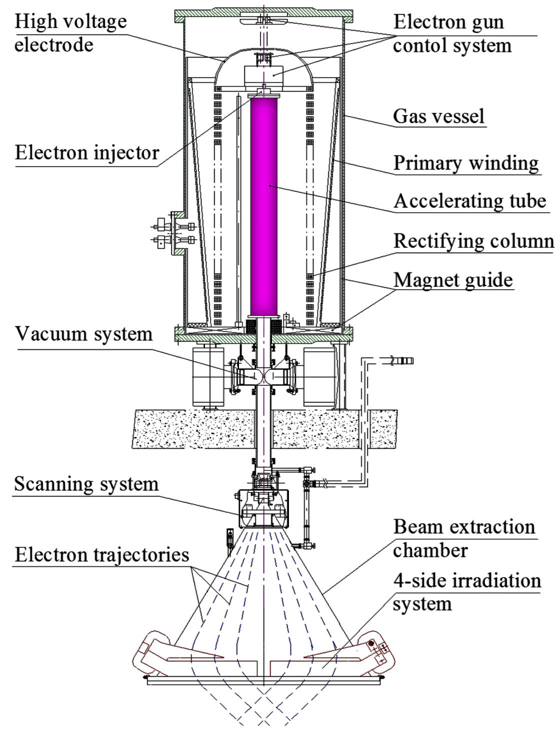

Figure 1: ELV accelerator common view.

Figure 2: ELV-4 accelerator JSC "Belaruskabel" ("Mozyrkabel").

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Table 1: Main Models of ELV Accelerators

Parameters	ELV-0.5-130	ELV-0.5-70	ELV-4-1	ELV-4-1.5	ELV-8
Energy range, MeV	0.3-0.5	0.4-0.8	0.7-1.0	1.0-1.5	1.0-2.5
Max. beam current, mA	130	70	100	67	60
Max. beam power, kW	65	50	100	100	100

INNOVATIONS

Recently, the number of new ELV accelerators in Russia and the former USSR has increased.

2018 - OJSC “Electrocable, Kolchugino”, Russia. BINP delivered two 100 kW accelerators: ELV-8 and ELV-4. Technological lines were supplied by the Chinese company Shanxi Yitaike Electrical Equipment Co. Ltd.(Fig. 3).

2018 - JSC “Orion”, Kazan, Russia. Accelerator ELV-8 for production of foamed polyethylene.

2017 - JSC “Expocable”, the Moscow region, Podolsk. Accelerator ELV-4 and under-beam transportation system.

2016 - OJSC “Belaruskabel” (formerly, Mozyrkabel). Accelerator ELV-4 and under-beam transportation system (Fig. 2).

2016 – The Karpov Institute of Physical Chemistry, Obninsk, Russia. BINP has installed a modern automatic control system for ELV accelerators.

Figure 3: JSC "Electrocable Works, Kolchugino".

Figure 4: dual line for treatment of wires up to 25 mm^2 by one ELV accelerator.

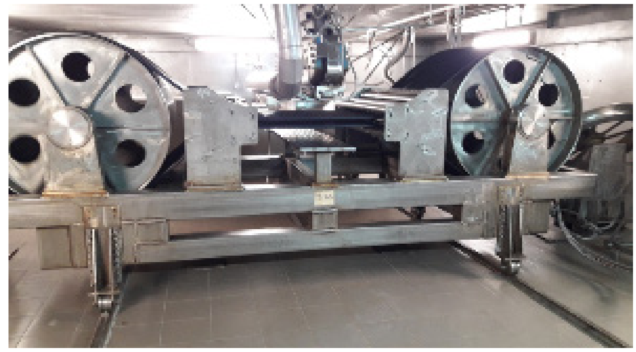

Figure 5: Under-beam transportation system for wires up to 400 mm^2.

A major achievement of BINP is the supply of turnkey technology at the JSC "Electrocable Works, Kolchugino", Russia.

The complex includes:

- two 100 kW accelerators: ELV-8 and ELV-4;
- two dual technological lines for wires up to 25 mm^2 for each accelerator, the maximum speed of each line 400 m/min (Fig. 4);
- technological line for wires up to 400 mm^2 for the accelerator ELV-8, the maximum speed 200 m/min (see Fig. 5);
- a line with a ring irradiation system for wires from 40 to 60 mm in diameter for the accelerator ELV-8 (Fig. 6).

Radiation safety, water-cooling, compressed air, etc. systems are also provided.

The main advantage of under-beam transportation system is the reduction of the conductive core tension during transportation. This advantage is achieved by replacing a large number of passive rollers by one slave drum. In this case, the tension is applied in parallel to all cables but not grows up in series, as with the use of passive rollers. This prevents the deformation of cable.

The speed of the motor is set using the accelerator control system. The drive has a wide dynamic range which ensures the proportionality between the speed of billet travel and the electron beam current, i.e., a constant dose is provided and a soft start of the technology takes place.

ADDITIONAL POSSIBILITIES

Usually, double-side irradiation of wires and cables is used. However, big size cables required high-energy accelerators. To reduce electron energy and improve the absorbed dose azimuthal inhomogeneity, four-side and ring irradiation systems were developed in BINP [2].

BINP has additional equipment and possibilities: 4-sided system for cables treatment; ring irradiation system; under-beam transportation system; double-window frame for beam extraction (Fig. 9), and local steel shielding (Fig. 8).

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Constant improvement of accelerators and expansion of their options allow BINP to introduce innovations in the market of industrial accelerators.

Four-sided irradiation (Fig. 1) is provided by a magnet system that rotates band the beam at the outlet of beam extraction device at an angle of ±45 degrees to the vertical axis. Due to four-side system, it is possible to treat single wires of up to 400 mm² or multi-wires of up to 40 mm in diameter.

Treatment of large cables (up to 60 mm in diameter) can be done by using the ring irradiation system (Fig. 6 and 7).

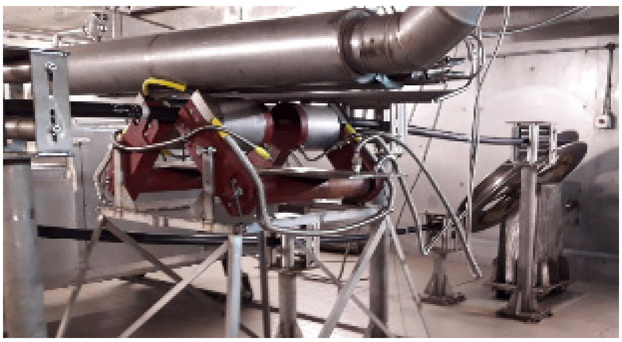

Figure 6: the ring irradiation system.

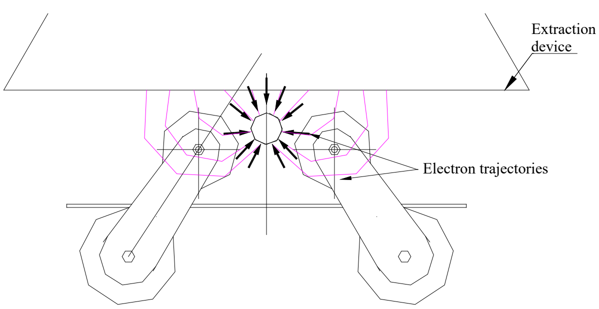

Figure 7: the ring irradiation system operation principle.

Figure 8: ELV -0.5 accelerator in local steel shielding in Bar Flex Company (Korea), 2018.

The ELV accelerator with an energy of 0.3-0.5 MeV and beam current up to 130 mA was developed and tested. The accelerator is compact in size and installed in local steel shielding. Electron beam is extracted through a two-windows extraction system with one titanium foil 180 mm wide.

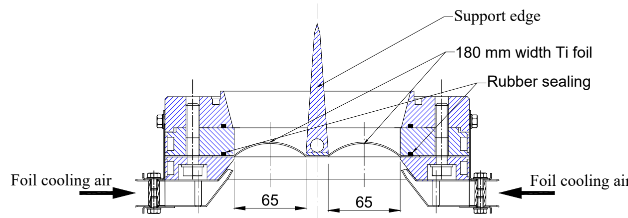

Figure 9: 2-window extraction device.

To extract large beam currents (more than 100 mA) into the air, a two-window extraction device is used. Between the frames of the extraction window titanium foil with a thickness of 50 microns and a width of 180 mm is installed. The beam scans first one window, then jumps to another window. Due to the use of such an extraction device, a beam of 130 mA was released at an electron energy of 0.3 MeV for the accelerator in Zheng Shi Tai Lai Company (China).

REFERENCES

[1] N. K. Kuksanov, S.N. Fadeev, Y.I. Golubenko, D.A. Kogut et al, “High Power ELV Accelerators for Industries Application” Proceeding of RuPAC-2010, Protvino, Russia, 2010.

[2] Fadeev, Salimov R., et al, "Underbeam equipment to expand technological capabilities ELV accelerators", Proceedings of the X International Workshop on the Application of Charged Particle Accelerators in industry and medicine, St. Petersburg, October 1-4, 2001. 68. See also Bulletin "Radteh-Eurasia", Novosibirsk, 2002. p. 8.

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