

High Power ELV Accelerators For Research and Industries

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Abstract. Beginning from 1971, the Budker Institute of Nuclear Physics Siberian Branch of Russian Academy of Science (SB RAS) started its activity in the development 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.. INP proposes a series of electron accelerators of the ELV-type covering the energy range from 0.3 to 2.5 MeV with a beam of accelerated electrons of up to 400 mA and maximum power of up to 400 kW. The design and schematic solutions provide the long term and round-the-clock operation of accelerators under the conditions of industrial production processes. The ELV accelerators are especially popular accelerators not only in Russia, but in China, Korea, and etc.

1. Introduction

The main features of ELV-accelerators are as follows:

1. High power of electron beam in wide energy range, it means high productivity of EB processing;
2. High efficiency of conversion of electricity power to electron beam power. The efficiency is limited by frequency converter and in case of transistors frequency converter efficiency is increased up to 80-92%;
3. Simple procedure of accelerator control by operator due to control system based on computer. It allows operating accelerator in on-line mode.
4. Accelerator control system comprises a set of software and hardware covering all the accelerator units required an operative control and diagnostics.
5. Accelerator itself has simple design and high reliability. If some troubles appear our customers repair accelerator by themselves with our consulting by phone, as a rule.
6. After warranty service. It means we delivery spare parts or parts with limited lifetime or make any accelerator service after warranty period by separate contracts with the low price.
7. A set of additional equipment (such as transportation line, ring or double side irradiation system, 4-side irradiation system) increases the accelerator possibility.
8. ELV accelerators are stable in operation. The energy and beam current instabilities practically do not exceed +/-2%.

Basic parameters of the ELV-type accelerators are given below at the Table1 and diagram of ELV-4 is shown at Fig1.

By now, over 114 accelerators had been delivered inside Russia and abroad and the total operation time exceeds 800 accelerator-years. .

50 accelerators were delivered inside of former USSR

40 accelerators were delivered in China

12 were delivered in Korea

2 accelerators were delivered in Japan

2 accelerators were delivered in Poland

1 accelerators was delivered in Germany

1 accelerators was delivered in Chech Republic

1 accelerators was delivered in Bulgaria, etc.

Separate units and systems of ELV accelerators are widely used in installation for scientific research.

Table 1

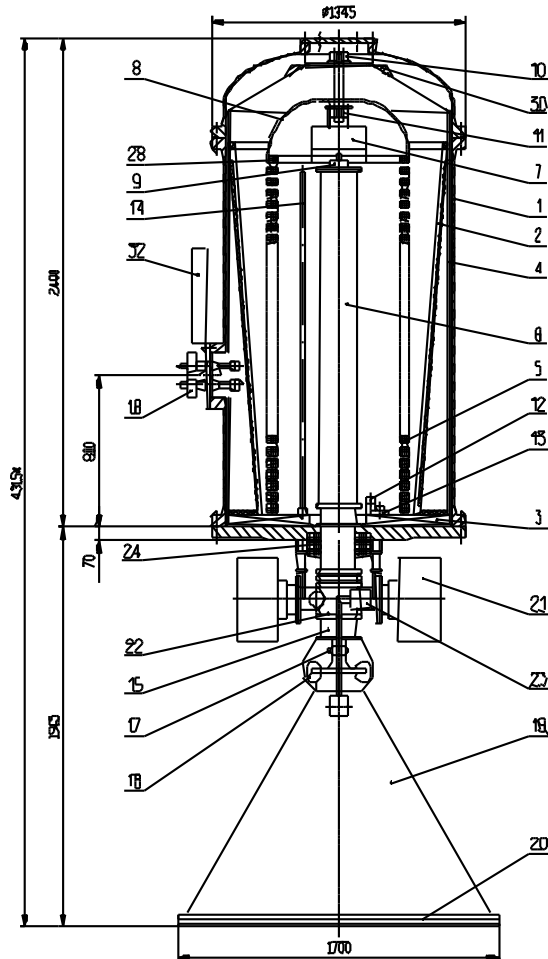


Fig.1. General view of ELV-4 accelerator

1 - vessel, 2 - primary winding; 3,4 - magnetoguides; 5 - rectifier sections; 6 - accelerating tube; 7 - injector control unit; 8 - high voltage electrode; 9 - injector; 10,11 - optical channels for injector control; 12 - section divider; 13 - capacitor unit; 14 - energy divider; 15 - vacuum gate; 16 - primary winding terminals; 17,18 - scanning coils; 19 - extraction device; 20 - extraction window frame; 21 - vacuum pumps; 22 - cross head; 23 - vacuum gate; 28 - base of high voltage electrode; 29 - magnetic lens; 30 - high voltage shield; 32 - clamp set.

2. Design of accelerator

ELV high voltage power source is cascade generator with parallel inductive coupling. The rectifier column is installed inside the primary winding. The primary winding is supplied with frequency converter on IGBT transistors. The operation frequency is near 400 Hz. The coil of secondary winding has maximum induced voltage on its ends 20 kV. This voltage is rectified with the voltage doubling circuit. Thus, the output voltage of the rectifying section is 40 kV. The rectifying sections are connected either in series. The rectifier section column is terminated

	Energy range, MeV	Beam power, kW	Max. beam current, mA
ELV-0.5	0.4 - 0.7	25	50
ELV-1	0.4 - 0.8	25	50
ELV-2	0.8 - 1.5	20	25
ELV-3	0.5 - 0.7	50	100
ELV-4	1.0 - 1.5	50	50
ELV-6	0.8 - 1.2	100	100
ELV-8	1.0 - 2.5	90	50
ELV-6M	0.75 - 0.95	160	200
ELV-12	0.6 - 1.0	400	500

with the high voltage electrode inside of which there is the injector control unit. The accelerating tube are located inside the column of high voltage rectifier. All these elements are installed inside of pressure tank filled with SF₆. Due to these circumstances ELV-accelerators are the most compact among the devices of this class. Accelerator is equipped with gas system that allow to recovery SF₆ during service and maintenance. The vacuum system components and extraction device are fixed to the bottom of the tank. Electrons emitted by the cathode, placed on the upper end of the accelerating tube, have the total energy eU_0 on the output of the accelerating tube. Passing through the vacuum system they reach the extraction device where they are homogeneously distributed along the foil by the scanning electromagnets and then extracted into air. The beam is scanned in 2 directions along and across the foil window. The irradiated material is transported under the frame of the extraction window. Due to special electronics device the beam raster position on extraction window is monitored by oscilloscope.



Fig.2 ELV-8 accelerator

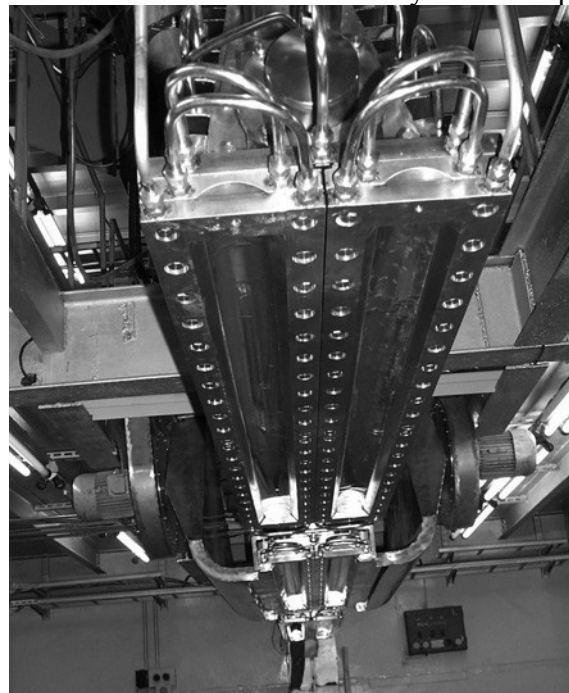


Fig.3 Double window extraction device of ELV-12 accelerator

The accelerator control system comprises a set of the software and hardware covering all the accelerator units required an operative control and diagnostics. The multifunctional control system enables one:

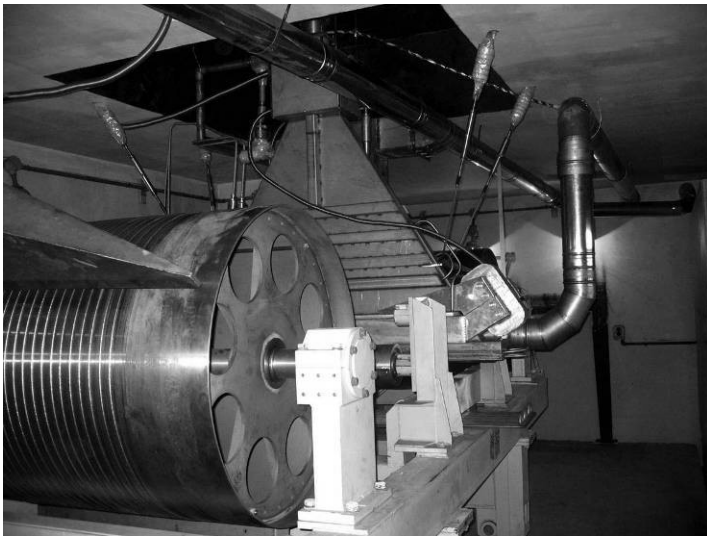
- to make the automated control of the accelerator. Algorithms introduced into the accelerator control program, solve the problems of the preparation of the accelerator to its operation (switch on of frequency converter, switch on of the foil blow motor, switch on scanning and if necessary, technological equipment), watch the status of interlocks and after switching on of the accelerator and install an energy and current of an electron beam in the given regime;
- to stabilize safely the main parameters of an electron beam (electron energy, beam current, size and position of the raster on the foil of the extraction window) which provides the high quality of radiation treatment;
- to provide the continuous diagnostics of the high voltage rectifier and selftesting of the other accelerator systems during the operation of accelerator;

- to synchronize the accelerator operation and technological equipment; in this case, the operation of accelerator integrated into technological line in completely automated regime is possible.
- provides for the personnel a wide choice of commands for the regimes of testing and adjusting the accelerator to be preliminary issued.

3. Application of ELV accelerators

ELV accelerators are used practically in all technologies where electron beam is needed.

1. The main application of ELV-accelerators is modification of polyethylene insulation of cable and wires. The irradiation allows changing the properties of insulation: to make it thermo-, fire-, oil-, radiation- resists or with combined resistivity to these agents. The square of wire treated by ELV accelerator is from 0.1 to 120 mm. sq. The productivity (depended on composition and properties) is up to 500 m/min.



We developed the system of 4-side irradiation for cable and pipes. This system increases the quality of irradiation, because improves the azimuth homogeneity of absorbed dose. Simultaneously it decreases required energy for irradiation, i.e. increase efficiency of treatment. 4-side irradiation system is especially effective for treatment of big diameter cables. Now we equip with such system both new accelerators, and delivered before also.

Fig.4.Extraction device equipped with underbeam transportation system and 4-side irradiation

2. Another profitable application of ELV accelerators is production of thermoshrinkable pipes, films and bands. The productivity can be up to 1000 kg per hour. As a rule the accelerators for cable and thermoshrinkable irradiation operate round-o-clock (24 hours per day).
3. The production of artificial leather. It means the polymerization by EB the several compounds for manufacturing leather-like material with heat-, fire-, oil-, cool, and etc. resistance. Radiation-chemical technology allows obtaining both non-base material and coats on the substances of different type. This material is for shelters, overalls, shoes, and bags. Productivity is up to 1000 m.sq. per hour.
4. The production of self-adhesion bands and rubberizing items. It is also the polymerization by electron beam.
5. Composite material for soft roofing. Intended for making roofs of residential, public and industrial buildings and structures. It is a roll polymerfabric formed of rubber mix based on rubbers of general application with subsequent vulcanization by EB.
6. Accelerator is used for manufacturing of polyethylene-oxide gel.
7. Accelerator is used for production of pre-pregs based on carbon fiber fillers and polymer binders.

8. Curing lacquer-paint coatings on different bases for the building industry with productivity of up to 500-m.sq./per hour. 2 accelerators for this purpose are in Russia (but they are not operated now).

9. Desinsectization of grain with productivity 200T/hour per each 20 kW power of accelerator are operating since 1980 in Odessa. In China the grain desinsectizer with 2 ELV-8 accelerator is constructed. The productivity is 1000 T/hour.

10. Purification of flue gases of thermal station from Sulfur oxide and Nitrogen oxide. For this purpose we develop high power accelerator ELV-12. It's design adapted to environmental application.

11 Waste water treatment. ELV-12 is also used for this purpose. Such installation was put in operation in Korea.

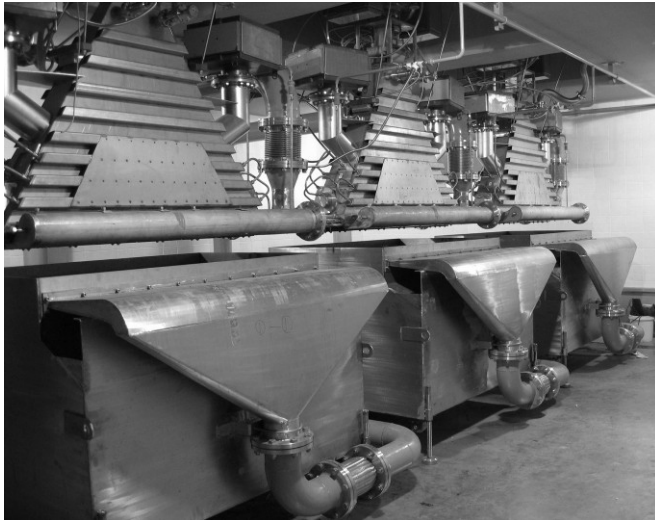


Fig.5 Irradiation hall for waste water treatment with ELV-12 accelerator



Fig.6 1.2 MeV focused beam extracted into atmosphere

12. ELV accelerators can be equipped by system for extraction to atmosphere the focused electron beam. It allows using accelerator for other kind of application such as: production of catalysts for the ammonia synthesis; evaporation of any materials for producing super fine powders; surfacing and hardening of metals; welding, melting and cutting of metals, producing the special types of ceramics and etc. Unfortunately such extraction device did not use in industry.

13. 8 accelerators are installed in research and irradiation centers. Accelerator here is not connected with determined technology but is used as multifunction device. ELV accelerator is very convenient for this purpose due to wide range and high stability of beam parameters and irradiation fields, simplicity of control. Practically, researchers (chemists or others specialists) operate with accelerator themselves without special training. Set of software allows obtaining required doze with high accuracy and repeatability.

14. Also in BINP we have special accelerator for investigation and developing of radiation processing. Our potential customer can make experiments with electron beam here. This accelerator has power up to 100 kW.