INDUSTRIAL ELECTRON ACCELERATORS TYPE ILU

V. L. Auslender, A. A. Bryazgin, V.A. Gorbunov, V.G. Cheskidov, I.V. Gornakov, B.L. Faktorovich, V. E. Nekhaev, A. D. Panfilov, A.V. Sidorov, V. O. Tkachenko, A.F. Tuvik, L.A. Voronin, BINP SB RAS, Novosibirsk, Russia

Abstract

The report describes ILU type industrial electron accelerators. It describes their main parameters, design, principle of action, electron beam extraction devices, wide set of auxiliary equipment for various technological processes and ways of their usage.

INTRODUCTION

Since 1970, BINP SB RAS has been developing and manufacturing the ILU-type electron accelerators for the work in the research and industrial radiation-technological installations. The design and schematic solutions of the installations envisage a continuous round-the-clock operation under conditions of industrial production.

The ILU-type accelerators cover the energy range from 0.7 to 5 MeV at an accelerated beam power of up to 50 kW. The intrinsic features of these accelerators are the simple design, ease in maintenance and the long term reliable operation under conditions of industrial production. Table 1 shows the basic parameters of the ILU-type accelerators produced by BINP [1,2,3].

Table 1: Basic parameters of the ILU-type accelerators

Parameters	ILU-6	ILU-8	ILU-10	ILU-12 Project
Energy of electrons, MeV	1.2-2.5	0.6-1.0	2.5-5.0	4.0-5.0
Average beam power (max), kW	20	25	50	300
Average beam current (max), mA	20	30	15	60
Power consumption, kW	100	80	150	700
Accelerator weight, tons	2.2	0.6	2.9	5
Weight of local protection, t	-	76	-	-

GENERAL DESCRIPTION OF ILU ACCELERATORS

The basic model of the ILU family is the ILU-6 machine [1]. This machine has rather good parameters at modest dimensions and can be used for wide spectrum of technological processes.

The model ILU-6 is widely used in our country and abroad. A principle of high-voltage acceleration is used in majority of modern accelerators, i.e., the energy of electrons corresponds to the voltage generated by the rectifier. The industrial accelerators type ILU are the exception of this rule. A principle of acceleration of electrons in the gap of HF resonator is used in the ILU machines. Such accelerator does not contain details, potentials of which with respect to the ground is comparable to accelerating voltage. So the ILU machines do not use complex high-voltage units (accelerating tubes, rectifying sections, etc.) which can be damaged by the occasional discharges. And so there is also no necessity to use insulating gas and high-pressure vessels.

Use of a principle of high-frequency acceleration has allowed to develop rather simple design of the machine having modest dimensions and weight. This machine can be placed inside the hall of the smaller dimensions comparing with the halls for high-voltage accelerators having the same parameters.

The pulse nature of electron beam generated by ILU machines enables one to direct the beam into various channels of the beam extraction device without beam losses. Hence, there is the opportunity to design the extraction devices forming an irradiation zone according to the form of a treated product, that permits to increase efficiency of beam usage.

The ILU-8 machine is the result of further development of ILU-6 machine. It is designed mainly for processing of cables and tubes. This accelerator does not require construction of a special protected premise (hall) and can be placed in usual industrial shop. It can work inside the local biological shielding. The local shielding of the accelerator is a kind of a box made from steel plates. This box is divided into two parts. The top part is used to place accelerating system with RF resonator, spallation vacuum pumps and forevacuum system. The beam extraction device, air pipes of ventilation system and technological equipment are placed in the lower part of the shielding. The back wall of the shielding has the channels (labyrinths) for input of cables, air and water pipes. The

0-7803-8859-3/05/$20.00

removable front wall serves as a door of a protective box. The thickness of radiation shielding in side walls part is 330 mm and in top is 240 mm. Gross weight of shielding is 76 tons.

The nest development is the ILU-10 machine based also on the ILU-6 accelerator. It was developed to work at energy of 5 MeV required for some technological processes.

The basic unit of the ILU-10 accelerator is a toroidal copper cavity having operating frequency of 116 MHz. It has axial protrusions forming the accelerating gap having length of 270 mm. The protrusion shape was chosen to form and focus the electron beam so that its injection, acceleration and further passage through the extraction system were performed with minimum losses.

The cavity 2 is placed into the vacuum tank 1 (Fig.1). The electron injector 5 is formed by the cathode unit and the grid mounted in the upper protrusion. The lower electrode and injector form a triode accelerating system.

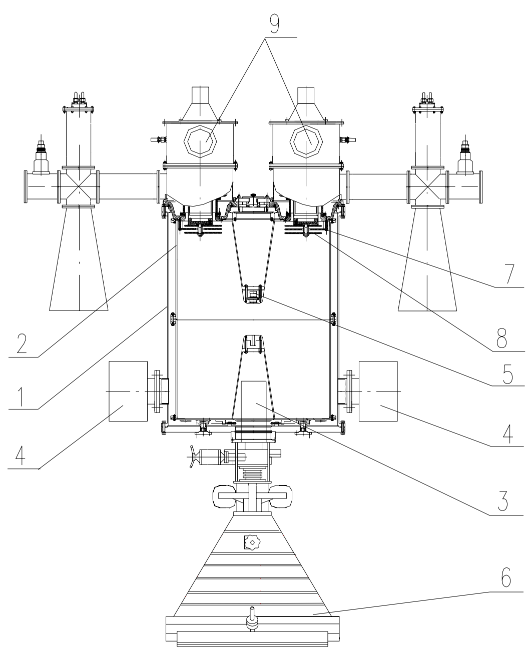

Figure 1: ILU-10 accelerator. 1 – vacuum tank, 2 – copper toroidal cavity, 3 – magnetic lens, 4 – ion pumps, 5 – grid-cathode unit, 6 – beam extraction device with linear scanning, 7–-coupling loop support, 8 – vacuum capacitor, 9 – RF generators.

Under the lower electrode of the cavity there is a magnetic lens shaping an electron beam in the accelerator channel and the extraction device 6.

Two RF self-exciting generators 9 based on powerful triodes type GI –50A are installed directly on the vacuum tank. Generators 9 assembled according to the common grid circuit are working at frequency about 116 MHz that is near the specific frequency of the cavity. Anode circuits are coupled to cavity through the inductance loops. The coupling rate is determined by the square of loop and the tuning of the anode circuits. The generator feedback is provided by the additional capacitance made in the form of a disk inserted between the tube's anode and cathode. The value of capacitance is about 20 pF. The fine tuning of the feedback value and its phase is made by the cathode short-circuited tail with a movable shortcut contact moved by a servo-motor. The coupling rate of generator with cavity is tuned during the accelerator's preliminary adjustment by varying the capacity of the vacuum capacitor 8 and the square of the coupling loop by varying the position of its support 7.

The cavity is placed into the vacuum vessel made of stainless steel. The high vacuum pumping is done by four spallation pumps placed at the cylindrical surface of the tank. The forevacuum pumping is provided by the forevacuum aggregate through the nitrogen trap. All the sealings in the vacuum vessel are made of metal (copper and indium). The operating vacuum is of 10^{-7} Torr. In the normal operation of the accelerator intervals of about two days do not require the forevacuum pumping for switching on the spallation pumps. The vacuum tank pressure is measured by the current value in the spallation pumps.

BEAM INJECTION

As mentioned above, use of the internal injection, when the cathode with the control grid is placed directly at the accelerating gap entrance, is the ILU-type accelerator's feature. The opposite electrode of the cavity acceleration gap is used as an anode.

The grid-cathode unit is located on the upper electrode directly at the accelerating gap entrance (see Fig. 2). The triode gun consists of the cathode, control grid and lower accelerating gap electrode performing the role of the anode. The grid and upper electrode are the united peace made of copper. The cathode unit is installed on the insulator ahead of the grid. The 16 mm diameter cathode tablet is made of lanthanum hexaboride (LaB_6). The cathode heating is provided by a cone helix heater made of tungsten wire of 0.6 mm diameter heated by current of 20 amperes, the working voltage is 12–15 V. The anode hole has 30 mm diameter. A magnetic lens is installed inside the lower electrode allowing the beam transverse size at the output device entrance to be controlled. In this injection method the beam current is formed by RF field penetrating into the grid-cathode gap from the accelerating gap and is determined by the grid penetration factor.

ELECTRON BEAM EXTRACTION

The pulse nature of electron beam generated by ILU machines permits to design the beam extraction devices for radiation technologies forming the irradiation zones for multilateral irradiation of objects having the various forms. It enables one to increase beam usage efficiency and in some cases to reduce the electron energy required for irradiation, or to expand the nomenclature of treated products.

Beam extraction device for extraction of electrons into air, is attached to the vacuum tank's lower flange through

 0-7803-8859-3/05/$20.00

a separating valve. The electron beam extracted into the air through foil. Usually three types beam extraction device can be used: linear scanning device for treatment of flat product, 3-window extraction device for 4-side tube or cable irradiation and beam extraction device with X-ray converter.

In the linear scanning device each pulse of the beam is scanned along the length of extraction window (Fig.1). In the 3-window extraction device beam pulses are scanned sequentially along its upper windows and along the left and right parts of lower window.

In recent years, in the majority of countries the beam technologies are being developed aiming at their use for irradiation products in the food industry. However, in the use of the electron-beam technology one should take into account that the electron beam permeability is rather small thus putting limitation to the amount of the irradiated material. A reasonable alternative seems to be the use of powerful fluxes of X-rays. To generate this radiation the electron beam can be directed to the X-ray converter. The technological process of the product treatment requires the certain type of the extraction device. For example, the beam bent at an angle of 90 grades enables a substantial simplification in the design of the conveyor system for subjecting the treated product to two-sided irradiation.

General view of the bending system design is given in Fig.2 [4]. The beam from the accelerator reaches the bending channel and is turned there through an angle of 90 grades, then it hits vertical optimized X-ray converter, that is an aluminum plate coated by the layer of tantalum.

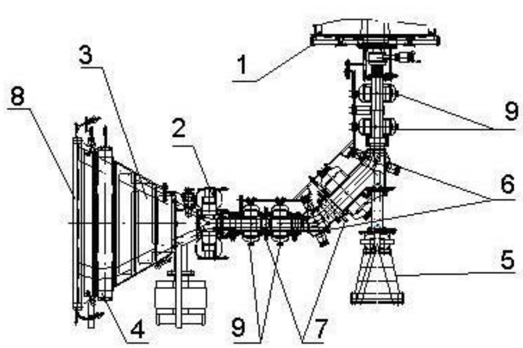

Figure 2: Beam extraction device with X-ray converter. 1-vacuum tank, 2-scanning magnet, 3-extraction device, 4-correcting magnet, 5- direct extraction device, 6-bending magnets, 7-pick-up stations, 8-converter, 9-quadrupole lenses.

The channel is an electron optical system having two 45 grades bending magnets with the parallel ends, quadruple lens with a large radial aperture, two adjustable lens doublets, scanning magnet and correcting magnet. The scanning magnet scans the beam from above to down along the converter having 1 m in length, scan duration is 0.5 ms. The scanning angle is ranging from -25 to +25 grades.

To form the dose field optimal for irradiation processes the electron beam should be incident at the converter edges at an angle close to 90 grades. This is provided by the use of the correcting magnet located at distance of 15 cm from the converter. The ILU-10 accelerator is a pulse machine, the maximum pulse repetition rate is 50 Hz, the pulse duration is 0.4-0.5 ms. In the work with the tantalum converter, a rather homogeneous dose distribution on the irradiated material surface was obtained. At the scanning width of 60 cm, the average dose value was 17 kGy with the conveyor equivalent speed of 1 mm/s.

TECHNOLOGIES

The important direction in works of Institute of Nuclear Physics are medical, biological and pharmacological applications of our accelerators. The electron beam sterilization technology for disposal medical products is well studied and widely used in our country and abroad. This technology was developed as an alternative to the gamma irradiation by the installations with Co and Cs isotopes. The ILU-10 machine that can work with maximum energy of 5.5 MeV ideally suites for the irradiation centers purposed for treatment of wide spectrum of goods. The electron energy of 5 MeV permits to treat the products that can have the surface density up to 4 g/cm^2 if the two-sided irradiation is organized. It means that the products can be treated in the packed form – in the cartoon boxes containing the several sets of products.

The maximum beam power of ILU-10 machine is 50 kW, so the productive rate of the irradiation facility can be up to 300-700 kg per hour assuming the sterilization dose of 25 kGy.

REFERENCES

[1] V.L. Auslender. ILU-type electron accelerator for industrial technologies. Nuclear Instruments and Methods in Physical research, B 89 (1984), 46-48.

[2] Bremsstrahlung converters for powerful industrial electron accelerators. V. L. Auslender, A. D. Bukin, L. A. Voronin, E. N. Kokin, M. V. Korobeinikov, G. S. Krainov, A. N. Lukin, V. M. Radchenko, A. V. Sidorov and V. O. Tkachenko. Radiation Physics and Chemistry, Volume 71, Issues 1-2 , September-October 2004, Pages 297-299, 13th International Meeting on Radiation Processing (IMRP-2003)

[3] Auslender, R.A. Salimov. Electron accelerators of INP SB AS USSR for national economy, Atomnaja energija, v.44, issue 5, 1978. – pp. 403–408.

[4] V.L. Auslender et al. Electron Accelerator for Energy up to 5.0 MeV and Beam Power up to 50 kW with X-ray Converter, Problems of atomic science and technology, 2004, №1, p.21-23.