POWERFUL RF ELECTRON ACCELERATORS AND THEIR APPLICATIONS IN INDUSTRY AND RESEARCH

V. L. Auslender, A.A. Bryazgin, B.L. Faktorovich, G.B. Glagolev, V.A. Gorbunov, V.E. Nekhaev, A.D. Panfilov, A.A. Tuvik
Institute of Nuclear Physics, Siberian Branch of Russian Academy of Sciences
Ac. Lavrentyev av., 11, 630090 Novosibirsk, RUSSIA

Abstract

The brief descriptions of the various RF powerful electron beam machines type ILU designed in the BINP are given as well as the main areas of their application. These machines are compact in comparison with DC machines. The accelerators are working within the energy range of 0.5-4.0 MeV and beam power up to 50 kW. The different irradiation technologies for treatment of cables, wires, tubes, film materials, cellulose sheets are described.

1 INTRODUCTION

Different types of the electron accelerators were designed especially for industrial purposes. Most of them are so called DC (Direct Current) machines - they use the principle of direct high-voltage electron acceleration, i.e., the electron energy is equal to the voltage generated by a rectifier.

Other ones are so called RF (radio frequency) machines, and ILU machines are of that kind. They use principle of electron acceleration in a high-frequency resonator, and as a result none of the accelerator's units has a potential relative to the housing comparable with accelerating voltage.

2 ILU FAMILY OF ACCELERATORS

The industrial pulse linear accelerators ILU are developed and supplied by the Institute of Nuclear Physics since 1970 for industrial applications and research activities. The ILU machines are single-resonator linear accelerators operating in the pulse regime [1]. They have the triode electron gun - the lower electrode in combination with the grid and the cathode unit form a triode accelerating system. The output beam current is precisely and quickly controlled by changing of the value of the positive bias voltage on the cathode with respect to the grid.

The pulse nature of the electron beam generated by ILU machines enables one to direct it into different channels of the extraction device without losses in the average beam power. Therefore, the ILU machines can be adapted easily to the technological processes requiring formation of irradiation zone in accordance with the shape of the irradiated products, thus increasing the efficiency of the beam utilization.

The ILU machines designed and produced in the Institute cover the energy range from 0.5 MeV to 4.0 MeV and have maximum beam power of up to 50 kW. Main parameters of these machines are given in the Table 1 below.

ILU-6 electron accelerator is a basic model in the family of ILU type accelerators.

ILU-10 accelerator is developed to achieve greater beam power and higher electron energy - of up to 4.0 MeV.

ILU-8 accelerator was designed for use inside the usual industrial buildings. It operates at energy of up to 1.0 MeV.

Table 1. Main parameters of the ILU machines.

	ILU-8	*ILU-6*	*ILU-6M*	*ILU-10*	*ILU-10M*
Energy range, MeV	0.5 - 1.0	1.2 - 2.5	1.0 - 2.0	2.5 - 4.0	2.5 - 4.0
Maximum beam power, kW	20	40	20	40	20
Maximum beam current, mA	20	25	20	15	8
Irradiation rate, kg/h, at dose 10 Mrad, max. power	400	850	450	850	450
Mains, V	3x380V	3x380V	3x380V	3x380V	3x380V
Total consumption, kW	80	120	100	170	120
Water consumption, l/min	60	60	60	100	60
Weight, t	1.75	2.2	2.2	2.9	2.5

Weight of local shielding for ILU-8 accelerator is 76 tons.

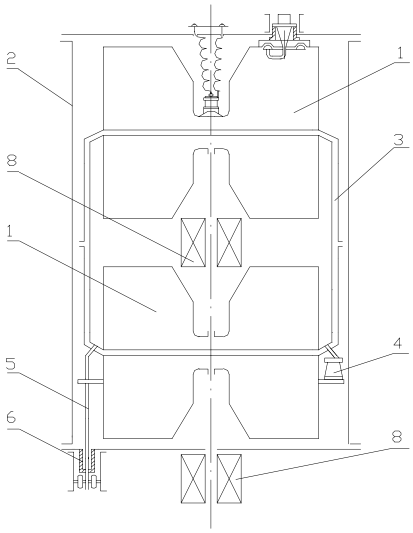

Figure 1. Design of accelerator ILU-11.

The local shielding for ILU-8 machine is designed as a box assembled of steel plates. Its dimensions are 1.8x2.0 m at a height of about 3 m. The front wall of the box serves as an entrance door to the protected area. Thickness of the radiation shielding is 350 mm at the bottom and 160 mm at the top, and its total weight is about 75 tons. At an electron energy of 1 MeV the attenuation factor for X-ray radiation is no less than $5x10^7$.

3 ILU-11 - NEW MODEL IN ILU FAMILY

The increase of energy for more than 4 MeV requires the multi-gap accelerating structure. Figure 1 shows the design of the accelerator ILU-11 designed for the energy range 4-5 MeV, and if one more section will be added the energy of up to 7-8 MeV may be achieved.

The accelerating section of ILU-11 consists of two coupled toroidal resonators 1 placed inside the steel vacuum tank 2. The resonators are coupled via coaxial line 3 having length of $\lambda/2$. The inner parts of both resonators are connected together and installed on the support insulators 4. The triode electron gun 7 is installed on the protruding part of the resonator. The magnet lenses 8 focus the electron beam to ensure its passage along the accelerating structure and further in the extraction device.

The resonators are fed by external RF generator via the air-filled coaxial feeder and power input loop 9. The generator has the same construction as the one of ILU-8 machine and uses standard pulse triode. The feedback is organized via resonator and phase-turner.

4 MAIN FEATURES OF FUNCTIONING

The ILU machines are purposed for wide application range in various technological processes and so are designed for long continuous and round-the-clock work in normal industrial conditions. All ILU-type accelerators are simple in their design, have a high reliability and maintainability, easily serviced and simply controlled. ILU machines and their technological equipment is fully automated and controlled by IBM PC compatible personal computer. Manual control is possible also.

The ILU machines are especially suitable for research works and elaboration of the technological processes due to their flexibility and possibility to quickly start and stop as well as to quickly and precisely control the beam parameters. The parameters of the beam pulse can be set even independently from pulse to pulse.

5 TECHOLOGICAL APPLICATIONS

The installation with ILU-6 machine is working in our Institute since 1977, and many new technologies for different industries were developed on it.

The ILU-6 is now the most widely used ILU machine in many countries for different processes:

- Irradition of cables, wires and thermoshrincable tubes - in Russia, Poland, Hungary, China, Romania and at present under comissioning in Italy;
- Sterilization of medical goods - in Russia and Ukraine;
- Treatment of different products and development of new EB processes - in Russia, Ukraine, Belorussia and India.

ILU-8 machines are operating now in Russia, Czechia, China and Korea mainly for treatment of cables, tubes, films and sheets.

Several types of extraction device compatible for all ILU machines were developed for various technological processes. The design of the extraction devices and irradiation schemes are described in [2, 3].

The simple version is the linear scanner having extraction window 980 * 75 mm or 1500 * 75 mm.

To realize bilateral and four-sided irradiation of products the multi-side irradiation extraction device with three windows was designed.

It has 3 modes of functioning:

- 1 window 980 * 75 mm
- 2 windows 320 * 75 mm
- 4 windows 320 * 75 mm

This universal extraction device is designed for treatment of polymer insulation of cables and thermoshrinkable tubes. Electron beam is extracted at an angle of about 45° to the vertical to irradiate the rewound cable through 4 extraction windows. Cable is irradiated on two levels from four sides. Multi-pass twist-free underbeam transportation systems are developed for wide range of cable and tube products.

4-sided irradiation permits to sharply raise the productive rate of process, to improve quality of production and to expand the nomenclature of treated products without increase of electron energy [4, 5].

Advantages of technological line based on ILU-type accelerator in comparison with the line based on DC accelerator using 2-sided irradiation are:

1. Line equipment has moderate dimensions and is not very expensive.

2. 4-sided irradiation require lower electron energy, so protecting shielding can be thinner.

3. Lower power loss, increasing beam use efficiency.

4. Higher dose homogeneity, improving the treatment quality.

5. Possibility of hard synchronizing of current with treated cable velocity.

These advantages cause decreasing of charges for the facility construction due to decreasing of its dimensions and thickness of shielding. Charges for the technological line maintenance decrease also due to decrease of beam power loss and increase of treated product quality.

The technological lines are supplied by device for synchronizing of accelerator's pulse repetition rate with cable velocity, so the resulting dose remains constant while line starts and stops.

The same universal extraction device can be used for treatment of flat products. Underbeam transportation device for treatment of films and bands of width up to 1 m is developed. Such systems are delivered for installations in China and Korea.

The design of underbeam transportation system for treatment of cellulose sheets is now in progress. This system permits to realize continuous treatment of the sheets with very high beam use efficiency and dose homogeneity.

Continuous work for improvement of the design of ILU machines causes permanent increasing of their parameters. Now we supply the machines in combination with beam extraction devices and underbeam equipment adapted to the customer’s technological process.

4 REFERENCES

[1] V.L. Auslender, V.A.Gorbunov, V.E.Nekhaev, A.D.Panfilov, V.A.Poliakov, A.A.Tuvik, B.L.Faktorowich, V.G.Cheskidov. High-Frequency Powerful Electron Accelerators Type ILU for Industrial Applications. Proceedings of EPAC92.

[2] Auslender V.L., Polyakov V.A., Golnik A.G. et al. The installation for the single-use medical devices sterilization based on the electron accelerator type ILU. Radiat.Phys.Chem. Vol.42, Nos 1-3, pp.563-566, 1993.

[3] Immobilization of Bacterial Proteases on Water-Solved Polymer by Means of Electron Beam. Radiat. Phys. Chem. Vol.48, No 6, pp.795-797, 1996.

[4] R. Bauerlein and H.D. Bickel, (1981). Irradiation Methods and Dose Uniformity in Radiation Cross-Linking of Cable and Wire Insulation. Radiat. Phys. Chem. Vol.18, No 5-6, pp. 837-846. 1981.

[5] V.L. Auslender, V.E.Nekhaev. 4-Sided Irradiation Systems for Cables and Tubes. Proceedings of Conference IMRP#10, Anaheim, USA, May 1997 (to be published in Radiat. Phys. Chem.).