ELECTRON ACCELERATORS SERIES ILU AND PROSPECTS OF THEIR APPLICATION IN THE FOOD INDUSTRY

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Abstract

This report describes industrial accelerators type ILU as well as their basic parameters and characteristics. Their current applications in a cable industry, medicine and other fields are outlined. Recent experiments with food products irradiation are described, new features and ILU machines application in food industry are discussed. Some information about problems in the Russian legislation related tofoodstuff treatment by ionizing radiation is given.

INTRODUCTION

Research results in fields of radiation physics, chemistry and biology are a basis for the development of many industrial technologies. At present, the application of radiation technologies has been expanding in many developed and developing countries, such as USA, Japan, South Korea, China and others. Cost-effectiveness of the radiation technologies is attractive for industrial use.

Development of new technologies creates a demand for new industrial electron accelerators with improved parameters, namely increased energy and electron beam power, while maintaining operation ease and management.

Table 1: Basic Parameters of the ILU-type Accelerators

Parameters	ILU-6	ILU- 8	ILU-10	ILU-14
Energy of electrons, MeV	1.2-2.5	0.6-1.0	3.0-5.0	7.0-10.0
Average beam power (max), kW	20	25	50	100
Average beam current (max), mA	20	30	10	10
Power consumption, kW	100	80	150	450
Accelerator weight, tons	2.2	0.6	2.9	5
Weight of local protection, t	-	76	-	-

Budker Institute of Nuclera Physics (BINP) is one of the largest Russian research centers, it is widely known in Russia and abroad. BINP is known for fundamental works on problems of high energy physics, plasma physics and controlled thermonuclear fusion physics.

Applied works are also carried out in the BINP, namely creation and use of synchrotron radiation sources and powerful electron accelerators.

Powerful industrial electron accelerators type ILU are working round the clock operation in industrial lines for decades since 1970-s.

The ILU machines cover the energy range from 0.7 to 10 MeV at an accelerated beam power of up to 100 kW. The intrinsic features of these accelerators are simple design, ease in maintenance and a long term reliable operation under conditions of industrial production. Table 1 shows the basic parameters of the ILU-type accelerators produced by BINP [1-3].

GENERAL DESCRIPTION OF ILU MACHINES

A basic model of the ILU accelerators is the ILU-6 accelerator [1]. This machine has rather high parameters at modest dimensions and can be used for wide spectrum of technological processes. The protected hall with inner dimensions 3*4*5 m is big enough for its placement. The required volume of concrete for construction of such hall is about 180 m^3 (the required wall thickness is of about 1.5 m).

The model ILU-6 is widely used as 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 an exception of this rule. A principle of acceleration of electrons in the gap of radio frequency (RF) resonator is used in the ILU machines. Such accelerator does not contain details, potentials of which in respect to the ground is comparable to accelerating voltage. So the complex high-voltage units (accelerating tubes, sections of rectifiers and etc.) which are damaged by the occasional discharges are not used in ILU machines. And so there is also no necessity to use insulating gas and high-pressure vessels.

RF acceleration has allowed us to create rather simple design of the machine having modest dimensions and weight. As a result the machine can be placed inside the hall of smaller dimensions comparing with the halls for high-voltage accelerators having the same parameters.

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The model ILU-8 is the result of further development. It is designed mainly for processing of cables and tubes. This accelerator does not require construction of a special protected premise (hall) as it can be placed in usual industrial shop due to local biological shield hosting the machine and equipment for products transportation. The local shield is designed as a box made from steel plates. Inside the box is divided into two parts (Fig. 1). The top part is used to place accelerating system with RF resonator, spallation vacuum pumps and some other systems. A beam extraction device, ventilation system air pipes and technological equipment are placed in the bottom part of the shield. A back wall of the shield has the channels (labyrinths) for input of cables, air and water pipes.

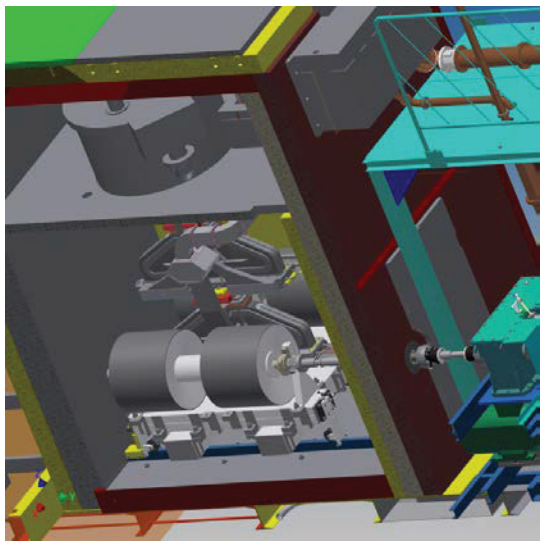

Figure 1: ILU-8 accelerator inside the local biological shield.

The removable front wall serves as a door of a protective box. The thickness of radiation shield in side walls part is 330 mm and in top is 240 mm. Gross weight of shield is 76 tons. The reduction factor for brake radiation (Bremsstrahlung) at electron energy of 1.0 MeV is not less than $5*10^7$.

On the base of the ILU-6 accelerator, an ILU-10 accelerator was developed to satisfy the needs of technological processes requiring the energies up to 5 MeV (Fig. 2).

A basic component of the accelerator is a toroidal copper cavity with an operating frequency of 116 MHz with axial protrusions forming the accelerating gap having length of 270 mm.

The protrusion shape was chosen from the conditions of the formation and focusing of an electron beam in the processes of its injection, acceleration and further passage through the extraction system with minimum losses.

Figure 2: ILU-10 accelerator.

The ILU-10 accelerator is a pulse machine, maximum pulse repetition rate is 50 Hz, pulse duration is 400-500 mks. It can be supplied with a tantalum X-ray converter, a rather homogeneous dose distribution on irradiated material surface can be obtained. At the scanning width of 60 cm, the average dose value was 17 kGy with the conveyor equivalent speed of 1 mm/s [4].

APPLICATION OF ILU ACCELERATORS FOR MEDICAL PRODUCT STERILIZATION AND FOOD TREATMENT

The important directions in BINP works are medical, biological and pharmacological applications of our accelerators. The electron beam sterilization technology for medical single use products is well studied and widely used both in our country and abroad [1]. The ILU-10 machine that can reach maximum energy of 5.0 MeV ideally suits 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 1000-2000 kg per hour assuming the sterilization dose of 25 kGy.

Now one ILU-10 machine in BINP is regularly used for sterilization of single use medical cloths and sets of instruments (Fig. 3). The market for sterilization services is now actively growing and the demand for the irradiation of different products is constantly increasing. A phytogenous raw materials (herbs, ground roots, etc.) are efficiently sterilized by electron beam treatment without loosing of their medicinal action.

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Figure 3: Box of disposable medical linen on the line under the exhaust device of the accelerator ILU-10.

In recent years, many countries in addition to sterilization develop the use of radiation technologies in industry for pasteurization of food products. However, some problems arise. For example, the penetrating power of electron beam is relatively small, which puts limits on the volume of the irradiated material.

In some cases it may be necessary treatment of food products having a complex geometry and with a large mass thickness (20 g/cm2 or more). For this treatment, the use of accelerated electrons is inefficient (their penetration is of the order of 4 g/cm2 for two-sided irradiation and energy 5МэV). As according to IAEA recommendations, the energy of the electron accelerators shall not exceed 10 MeV when using the electron beam tretment and 5 MeV when using X-rays (7.5 MeV in the USA).

ILU machines suits for pasteurization of food products, they can operate in the electron beam mode and can generate X-rays having penetration depth of 40 g/cm^2 for two-sided irradiation. This allows to cover whole range of processed food products using electron beam or X-rays treatment The performance of the accelerator when operating in X-ray generation mode can be up to 300 kg/hour at dose of 10 kGy. Operation mode change (from electron beam treatment to X-rays and back) recquires not more than 30 minutes. This technique significantly expands treated products range.

Electron beam treatment of food products (cool pasteurizatrion process) by ILU machines gives a number of positive effects: reduction of pathogenic microorganisms, an increase in products storage time, insects desinfestation, increase in amount of consumed food due to the increased storage period (import substitution), cheaper products pasteurization compared to traditional methods (for example, the possibility of production of canned meat and canned goods in a plastic bag), improve population health and reduce disability by improving the quality of food consumed.

International studies show that currently about 40% of food is thrown away by customers or sales networks due to the expiry of their shelf life. Pasteurization of food by X-rays generated by ILU machines will help to significantly reduce these losses. It's important to consider the impact of this radiation on the properties of food. In 1980-s the joint Committee of experts (FAO, IAEA and who) reviewed the international research project on the toxicity of irradiated foods and concluded that they are no more harmful than regular foods containing volatile small amounts of mutagen, the dose not exceeding 10 kGy. The doses required for food products pasteurization are usually in a range from 1 to 6 kGy.

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