LINEAR ACCELERATORS FOR RADIATION STERILIZATION DEVELOPED IN NPK LUTS NIIEFA

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NPK LUTS NIIEFA has been developing linear accelerators for industrial applications during about 30 years. More than 150 linear accelerators for different applications have been manufactured by this company and installed in different regions of Russia and abroad: in Poland, Hungary, Germany, France, China and India. The linear accelerators for radiation sterilization developed in NPK LUTS NIIEFA are reviewed.

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The first industrial linear accelerator LUE-13/9 was put into operation in Warsaw in the Institute of Nuclear Chemistry and Technology in 1972. This accelerator has been designed on the basis of Russian klystrons KIU-15 and KIU-17. The high-voltage klystron KIU-15 with a working frequency of 1818 MHz has pulse power of 20 MW and average power of 20 kW. The modulators of these klystrons were made on the basis of high-power vacuum lamps GMI-37A and GMI-14B. At the output of the accelerator were installed a 270° bending magnet and a scanning system. This accelerator has energy range from 4 to 13 MeV and small energy spread less than 9% of the half of energy distribution curve. The accelerator can operate in 3 regimes with different pulse duration (1.2, 3.2 and 6.5 μs) and different pulse repetition rate (900, 300 and 150 Hz). The maximum beam power in one of these regimes with 13 MeV of energy was 9 kW.

Since 1970 during about 15 years NIIEFA has been manufacturing industrial linear accelerators on the basis of Russian magnetron MI-262 specially developed for this purpose. This magnetron with a generating frequency of 3200 MHz has pulse power of 9 MW and average power of 13 kW. The efficiency of this magnetron is 50%. The modulator of 35 kW average power is made on the basis of ceramic pulse thyratron TGI1-2500/50 made in Russia too. The electron gun of this accelerator has its own modulator with a pulse voltage up to 50 kV. The accelerator produces beam pulses with duration of 3 μs and pulse repetition rate up to 500 Hz. The maximum power of about 6.5 kW is attained in the regime with electron energy about 6.5 MeV. For the effective energy of 8 MeV the maximum average power is about 5.5 kW. In the regime with maximum energy of 10 MeV the average power is about 4 kW. The energy spread of electrons depends on the level of energy. For 10 Mev, FWHM energy spread is about ±3.5%, and for 6 MeV it increases up to about ±10%.

NIIEFA has manufactured and installed 15 similar accelerators. These accelerators where used for treatment of different products with electron beam and for activation analysis by photonuclear reactions. The first such accelerator was installed in 1970 in the Research Institute of Tyre's Production in Moscow.

In 1972-76 two accelerators were installed in Kurgan at the plant of medicine products for the sterilization with electron beam. One of these two accelerators has been working up to now in three shifts per day. Since 1978 up to now our accelerator has been operating on the plant of plastic goods in Budapest; the main product of which is shrinkable pipes.

Since 1979 two such accelerators have been working in Muruntau (Uzbekistan) in the laboratory of activation analysis to detect gold and accompanying elements. Through interaction of X-ray photons produced by this accelerator and gold nucleus, gold isomer ^{197m}Au with a half-life of 7.2 s is generated. The isomer emits photons of 279 keV which can be detected. The sensitivity of this method is about 0.4 gram/ton with 10% accuracy. Two more accelerators for the same purpose were installed in Yakutia and Magadan.

Such accelerators have been operating more than 10 years in radiation centers of the Bio-Physical Institute (Moscow) and the CoRAD company (St.Petersburg). Figs.1 and 2 show the accelerator LUE-8-5 which was installed in Sichuan province of China in 1996. This accelerator was combined with a drum-type conveyer system. This drum 3 m in diameter has three shelves. During irradiation the goods placed on these three shelves automatically go through electron beam with fixed speed and fixed number of cycles. This system is very well suited for the irradiation with high doses. For example, at irradiation of shrinkable pipes with doses about 120 kGy, the full time necessary to irradiate the products on these three shelves is about 5 hours.

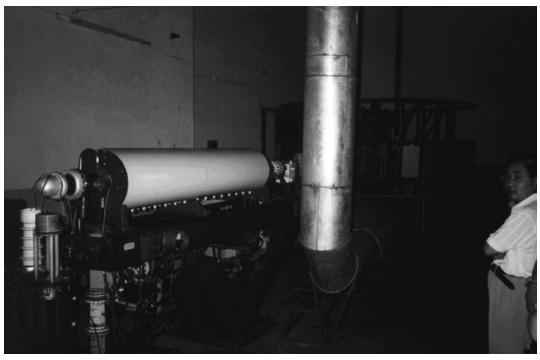


Fig.1. LUE-8-5 accelerator installed in Sichuan

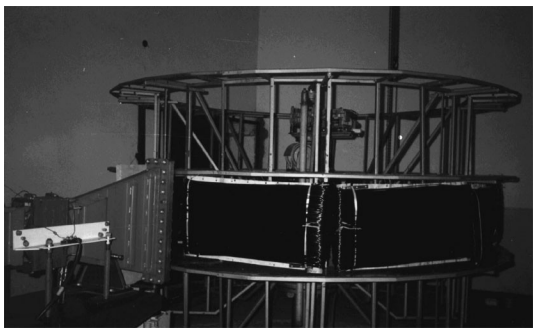
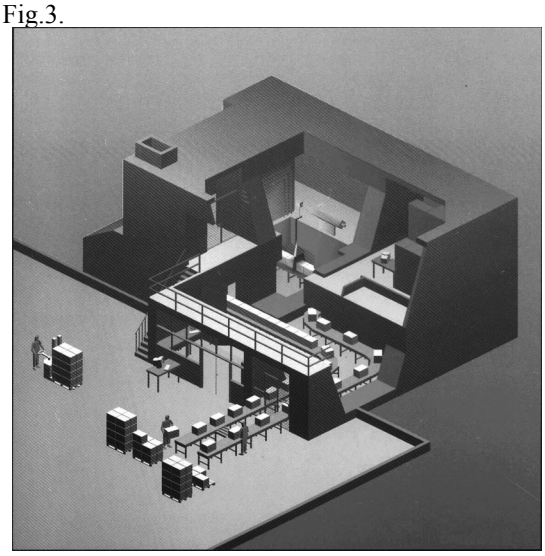


Fig.2. The drum-type conveyer system of LUE-8-5 accelerator

The last such accelerator was installed in France at "RADIENT Nord". The fully automated facility of "RADIENT Nord" was put into operation in May 2000 for on-line sterilization. This facility can sterilize, under the on-line quality control up to 25.000 m^3/year of medical products with one operator and one assistant per shift. The whole Facility (building, annexes, conveyor and computer control systems) has been designed, created and put into operation by COFRAR.

The facility was placed on a two- level 250 m² area. The conveyor and control room is located on the ground floor, the accelerator's equipment and annexes are on the first floor. The scheme of RADIENT Nord is given on Fig.3.



.Fig. 3. The accelerator installed in France at "RADIENT Nord" – scheme of facility

The main control and supervision computer manages the conveyor, accelerator, security, operation and dosimetry. The annexed equipment such as security system, ozone ventilation and cooling system are under the main control of the same computer. The parameters of each of the above-listed equipment are validated for each product to be sterilized. Accordingly, once the operator sets the treatment order barcode, the main computer manages the proper regime for the facility (electrons energy, beam power, scanning length and conveyor speed) and the treatment starts; all parameters are continuously measured and stored as the treatment runs; each product is stamped on line just before treatment with sensitive logo, box number, time of treatment, and dose; on-line dosimetry results confirm the treatment acceptance. The main parameters of the Electrical Source Treatment: current, dose and energy of electrons are measured each week with a plastic wedge; a calorimeter controls the dose delivery each day. The accelerator and conveyors stop when any parameter of the irradiation goes out of boundaries.

From "each" stamp of "each" box, it can be demonstrated that at the *minute of the treatment* the *treatment parameters* of the facility conform to the *validated parameters*. This solves the treatment efficiency and *traceability.*

The accelerator has a computer control system based on an Octagon Systems 6020 microcontroller and Advantech main computer. The beam measurement system of this accelerator contains a bending magnet, a beam current coils monitor, an ionization chamber and a moving beam stop. All these systems allows us to measure the beam current, the scanning length and the electron's energy on-line ensuring the stabilization of these parameters with an accuracy of ± 2.5%. The beam stop equipped with an additional aluminum plate allows the effective electron's energy measurement. The bending magnet is designed to measure the electron's energy spread.

The accelerator section and a high frequency generator (see Fig.4) are located in a 25 m² room with a radiation protection. On Fig.5 is placed the output scanning system of the accelerator.

Fig. 4. Accelerator section and h igh- frequency generator

Now NPK LUTS offers for customers four models of linear electron accelerators for industrial applications: UEL-10-10S, UEL-8-5S, UEL-3-2.5S, UEL-3-1S.

The irradiators of UEL-10-10S and UEL-8-5S accelerators are located in a room with radiation shielding. Models UEL-3-2.5S and UEL-3-1S are equipped with a

Fig. 5. Output scanning system of "RADIENT Nord" facility

local radiation shielding providing complete safety for operating personnel.

The automated control system of the accelerator is built on the basis of a panel-type industrial computer.

We have designed two modifications of UEL-10-10S accelerator. UELV-10-10S accelerator with a traveling wave accelerating structure 2.05 m long is able to operate in the energy range of 5...10 MeV with an average power of 10...12 kW (Fig.6). UELV-10-10S accelerator with a standing wave accelerating structure only 1.1 m long has smaller energy range of 8...10 MeV (Fig.7).

Fig. 6. Traveling wave irradiator

Fig. 7. Standing wave irradiator

MAJOR SPECIFICATIONS OF ACCELERATORS

PARAMETERS	MODEL			
	UEL-10-10S	UEL-8-5S	UEL-3-2.5S	UEL-3-1S
RF energy source	Klystron	Magnetron	Klystron	Magnetron
Accelerated electron energy, MeV	10	8	3	3
Average beam power, kW	10	5	2.5	1
Average electron beam current, mA	1	0.63	0.83	0.33
Pulse repetition rate, Hz	300	500	360	300
Pulse duration, 1/μs	16	3	8.5	4.5
Scanning length, mm	600 or 800	500	350	500

A facility with local radiation shielding (Fig.8) has been constructed on the basis of linear accelerator UEL-3-2.5S for sterilization of foodstuffs and mail with a beam of accelerated electrons.

Sterilization is performed in a special cassette installed by an operator into an object transportation system located inside the irradiation chamber. The system allows both one-sided and two-sided irradiation of objects.

The ELS-900 electron-beam sterilizer (Fig.9), constructed on the basis of UEL-3-1S, is intended for radiation sterilization of medical utensils directly in clinics, hospitals and other medical institutions. Syringes and needles, surgical utensils, implanted materials and tissues, dressings, surgical clothes and gloves, transfusion systems, etc. undergo sterilization. ELS-900 allows the treatment of 30-40 packages per hour with dose 15 kGy. Overall dimensions of the suggested sterilizer are comparable with those of steam sterilizers nowadays used in medical institutions.

Fig.8. UELV-2.5S accelerated-based facility

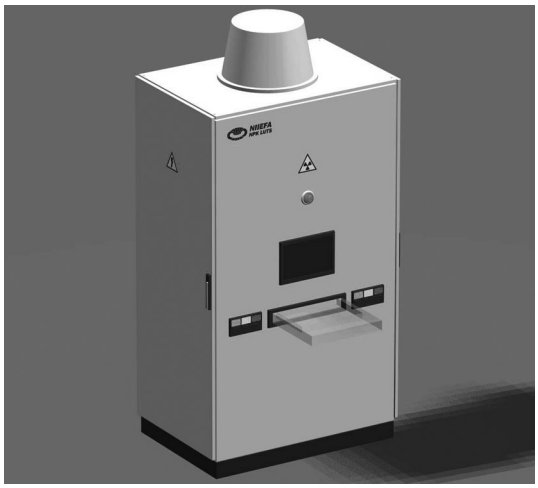


Fig.9. ELS-900 – compact electron medical sterilizer

ЛИНЕЙНЫЕ УСКОРИТЕЛИ ДЛЯ ЛУЧЕВОЙ СТЕРИЛИЗАЦИИ, РАЗРАБАТЫВАЕМЫЕ В НПК ЛУЦ НИИЭФА

М.Ф. Ворогушин, Ю.Н. Гавриш, М.И.Демский, В.М. Максимов

В течение 30 лет в НПК ЛУЦ НИИЭФА разрабатываются линейные ускорители промышленного назначения. За это время были изготовлены и установлены в различных областях России и за границей: в Польше, Венгрии, Германии, Франции, Китае и Индии более 150 линейных ускорителей. В работе приведен обзор основных характеристик этих ускорителей.

ЛІНІЙНІ ПРИСКОРЮВАЧІ ДЛЯ ПРОМЕНЕВОЇ СТЕРИЛІЗАЦІЇ, ЩО РОЗРОБЛЕНІ В НПК ЛПЦ НДІЕФА

М.Ф. Ворогушин, Ю.Н. Гавриш, М.І. Демський, В.М. Максимов

На протязі 30 років у НПК ЛПЦ НДІЕФА розробляються лінійні прискорювачі промислового призначення. За цей час були виготовлені і встановлені в різних областях Росії і за кордоном: у Польщі, Угорщині, Німеччині, Франції, Китаї й Індії більш 150 лінійних прискорювачів. У роботі приведений огляд основних характеристик цих прискорювачів.