Application of "Electronica 10-10" Electron Linac for Food Processing

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Abstract

The industrial electron linac "Electronica 10-10" have been installated in Experimental Plant for Food Irradiation (INCT) in 1992. The accelerator is a prototype unit, and prior the use for food treatment a long period of optimization was involved in its experimental operation during one year. The accelerator is able to produce scanned electron beam with energy 10 MeV and average beam power of 7 kW. Radiation dose at minimal conveyer speed of 0.25 m/min reaches 50 kGy. The accelerator facility is in use for different food commodities treatment in experimental scale.

1. Introduction

During last five years in Poland the programme of implementation in commercial scale applications of electron beam irradiation for preservation and hygienization of food, an animal feeds, as well as utilization of agricultural wastes have been worked out. The most significant project of the programme was the construction of the Experimental Plant for Food Irradiation [1,2], intended to be the national centre for future testing and implementary works in this field. The plant is equipped with two accelerator facilities: the small one "Pilot" with electron energy 10 MeV and average beam power 1 kW, and the big one, Russian made "Electronica 10-10" electron linac with electron energy 10 MeV and average beam power up to 10 kW. "Electronica 10-10" is the basic facility of the plant.

2. Accelerator's Description

Accelerator "Electronica 10-10" [3,4] is the linear resonance system in which electron beam is accelerated in microwave travelling-wave structure. Block diagram of the system is given in Fig. 1. It's technical characteristics are as follows:

electron energy	5 - 10 MeV
average beam current	1 mA
average beam power	up to 10 kW
pulse duration	2 - 6 μs
pulse repetition frequency	50 - 300 Hz
scanning frequency	1, 2, 5 Hz
scanning length	60 cm
microwave generator frequency	1886 MHz

2.1. *Electron source*

The beam to be injected into accelerating structure is generated by triode electron gun. The gun body is metal-ceramic vacuum-tight tube connected in detachable way with accelerating section. Exchangeable cathode assembly is composed of the heater, thermal screen and emitting capsule. As emitter the porous tungsten matrix filled with barium - aluminium paste is used. The working temperature is in the range 950-1000°C. The cathode life-time is estimated for 1500 - 2000 hours. The gun's operation is controlled by pulse modulator and its current can vary from 0 to 2 A by changing the amplitude of negative pulse applied between the cathode and auxiliary anode in the range 0 to 10 kV. Average injection energy of electron beam lies at 30 keV.

2.2. *Accelerating structure*

The structure has a form of cylindrical iris-loaded wave-guide working in $\pi/2$ mode. Initial section with 2 λ length ensures beam bunching and preliminary acceleration. The phase velocity varies from 0.45 to 1.0 and loading parameter from 0.15 to 1.0. The main section of the structure with the length 9 λ has constant phase velocity and the same dimensions of all resonators. The coupling with supplying waveguide is realized with the use of symmetrized wave-mode transformer.

2.3. *RF power source*

High frequency power supply for accelerating structure is accomplished with high-power pulse magnetron MI-435 working on the frequency 1886 MHz. Its construction and electrodynamic features effect in low sensitivity to the shape of modulating pulse and standing wave coefficient (SWR) of the load. The necessary magnetic field is generated by a solenoid. Basic magnetron parameters are:

peak pulse power	10 MW
average power	up to 25 kW
pulse duration	6 μs
amplitude of modulating pulse	48 kV

The magnetron is supplied from line-typ modulator. As switching commutator serves high-power hydrogen thyratron TGI-1-5000/50. The pulse forming network is charged in resonance way to 20-25 kV and discharged through pulse autotransformer matching wave impedance of forming line to impedance of magnetron. At transformation ratio 3.6, the amplitude of output pulse is 45-50 kV.

2.4. *Beam output* devices

At the accelerator's output there are installed: beam current monitor for undeflected beam, 270^0 beam bending magnet, beam monitor for deflected beam and beam scanning system. Beam deflection is realized with 270^0 achromatic magnet using three sector poles with different coefficients of edge field decay. The vacuum chamber, located between magnet poles, has two outputs for straight and deflected beams. At the straight beam output, a transmission window of 25 mm diameter is located. In deflected beam path, after current monitor, the beam scanning system is installed. The scanning process is accomplished by electromagnet fed with triangular shape current. The frequency of scanning can be varied from 1 to 5 Hz, current amplitude 5 to 15 A. The scanning horn has vacuum window at the end, with dimension 70 x 4 cm. Electron beam is transmitted through 50 μm titanium foil.

2.5. *Electronic and control system*

The system is composed of following blocks:
- supply assembly SA 1, which feeds power to gun modulator, cathode heating, solenoids of magnetron and accelerating section;
- supply assembly SA 2, which contains of power supply of magnetron ion pump, two supply blocks for accelerator's ion pumps and power supply of scanning electromagnet;
- control desk, which provides the remote control of accelerator's operation and monitoring of its parameters. From the desk the particular circuits of the accelerator are switched-on in proper sequence: solenoids of magnetron and section, heating of magnetron and gun, bending and scanning electromagnets, control of beam intensity. On the desk there exist light indicators for operation of accelerator's subsystems, status of fuses and interlock systems. Main output parameters of accelerator are indicated by instruments located in the control desk.

3. Results of Beam Parameters' Measurements

The accelerator has been accepted to experimental operation in May 1992. In preliminary stage of operation a lot of measurements of accelerator parameters have been done. The most important of them were as follows:
- measurement of average beam current outside the window,
- measurement of electron energy and its dependence from pulse current of the beam (beam loading curve);
- registration of scanned beam trace.

To measure the average current of scanned beam, long graphite collector situated 150 mm below output window was used. The results were in agreement with those obtained from current monitor in the accelerator. Difference of both results did not exceed 2%.

Electron energy measurements have been carried out by means of measuring electron absorption curve. For this purpose a wedge made of aluminum with dimensions of 100 x 60 30 mm and PVC dosimetric foil was used. An example of obtained curve is shown on Fig. 2. The most probable energy E_p(in MeV) is determined by the formula [5]:

$$E_p = 5.09\ R_p + 0.2$$

when R_p - extrapolated practical range of electrons in the aluminum wedge, in cm.

Beam loading effect on electron energy is illustrated on Fig. 3. The beam loading curve has been measured at pulse duration 5 μs, pulse repetition rate 300 Hz and average magnetron current 0.75 A. Up-to-date the machine can produce the electron beam with energy 9 - 9.5 MeV at its average power level o 7 kW.

An important machine's feature is the uniform dose distribution. At scanning length 60 cm and scanning frequency 5 Hz, dose distribution uniformity is in the range $\pm$ 5%.

4. Accelerator's Applications

The accelerator with parameters described above is an effective tool for food preservation and another radiation techniques, requiring the electron beam with energy in the range of 7 - 10 MeV. The machine is equipped with roll conveyer to transport the products to be irradiated. The conveyer speed range is 0.25 - 12.0 m/min. At the beam power of 7 kW it allows to obtain radiation dose in the range 1 - 50 kGy. Any dose smaller than 1 kGy may be achieved simply by decreasing average beam current.

In Poland, permissions for the processing of following agricultural products have been issued: spices, garlic onions-permanent, champignons and potatoes - temporary. The permission for irradiation of dry vegetables, dry champignons and gelatine are in preparation. All food commodities mentioned above have been irradiated at Experimental Plant for Food Irradiation in experimental scale.

5. References

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[4] W. Migdał, W. Maciszewski, B. Owczarczyk, A. Gryzlow, Experimental Plant for Food Irradiation: I. Linear Electron Accelerator "Electronika 10-10", its description and destination, Nucleonika, 1994 (to be published).

[5] ICRU Report 35, Radiation Dosimetry: Electron Beams with energy between 1 and 50 MeV, Bethesda, MD., 1984.

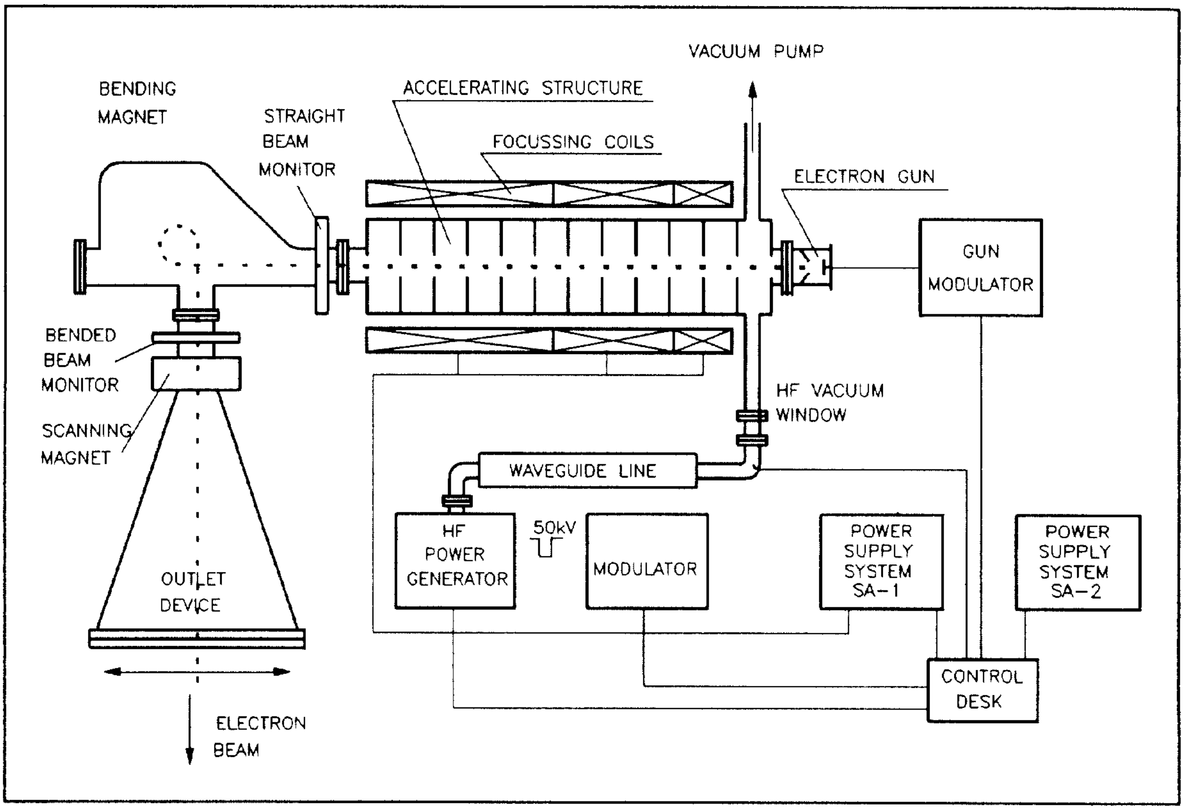

Fig. 1. Electronica 10-10 accelerator's block diagram.

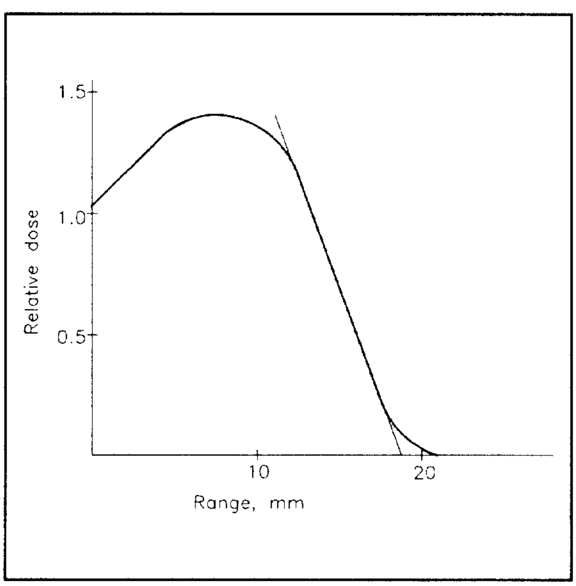

Fig. 2. Electron absorption curve measured with the use of aluminum wedge with dimensions of 100 x 60 x 30 mm and PVC dosimetric foil, at pulse duration 5μs, PRR = 300 Hz and pulse beam current 400 mA.

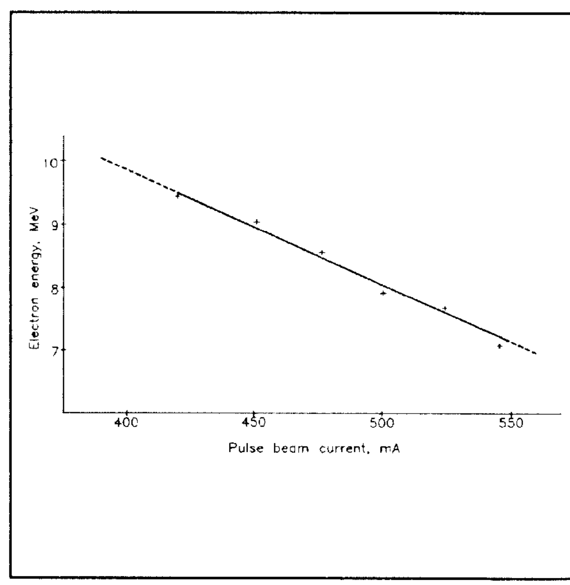

Fig. 3. Beam loading curve, measured at average magnetron current 0.75A, pulse duration 5 μs and pulse repetition ratio 300 Hz.