EQUIPMENT FOR BEAM CURRENT AND ELECTRON ENERGY MONITORING DURING INDUSTRY IRRADIATION

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Abstract

The electron beam irradiation sterilization is placed first among all types of medical items sterilization. The quality of sterilization is determined by value of dose, which is in one's turn determined by beam current, electron energy and beam scanning system parameters. Therefore these parameters have to be controlled during the irradiation process. The equipment for beam current and electron energy monitoring allows to control beam current, electron energy spectrum and nominal deflection of electron beam when scanning during the irradiation process each scanning period or, for example, each tenth scanning period by request. The equipment consists of induction beam current sensor with registration equipment and two grounded electron collectors. The simplicity of this equipment allows to use it for irradiation quality monitoring practically in all electron beam irradiation technology processes.

1 INTRODUCTION

One of wide used and perspective methods of sterilization of medical items and materials, such as syringes, blood transfusion packages, various electrodes, dressing and surgical packages, is accelerated electron beam irradiation. The quality of sterilization is determined by the dose absorbed by all parts of sterilized object. In one's turn the dose is determined by beam current ***I***, accelerated electron energy ***W***, electron beam scanning on the object surface and the product of thickness τ and density ρ of irradiated object. The effective value $\tau\rho$ is constant for the same objects at conveyor irradiation. Therefore it is necessary to control values ***W***, ***I*** and normal operation of the scanning system.

2 MONITORING SCHEME

2.1 Fan scanning beam monitoring

The accelerated electron beam scanning systems are used in modern facilities for commercial irradiation [1]. The object moves perpendicular to the scanning plane. The monitoring scheme, which may be used in fan beam scanning irradiation, is shown in Fig.1.

The electron beam, accelerated by LINAC 8, is shaped to fan beam by scanning system 7. The fan beam excites the alternating magnetic field in the magnetic core 1, surrounding the electron beam and correspondingly the

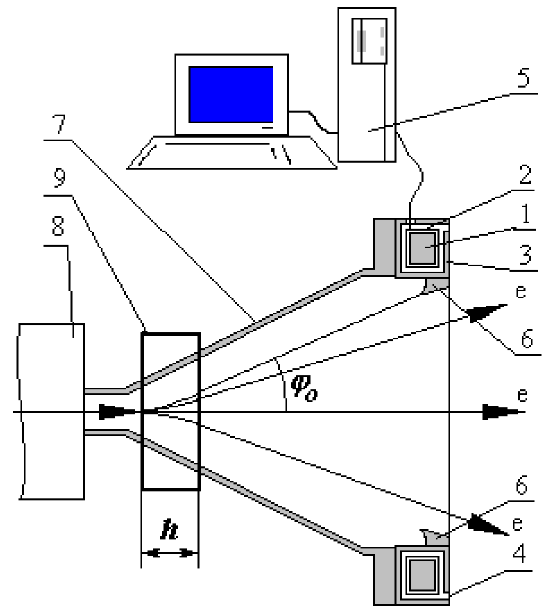

Figure: 1 Fan scanning beam monitoring.

electromotive force in the winding 2 on the core 1. The core 1 and winding 2 are placed into the body 3 with the slot 4. The electromotive force creates the voltage proportional to the beam current ***I*** on the resistor. This voltage is passes to the registration equipment (5) and analyzed by computer. This is well known induction beam current sensor [2].

Two grounded beam collectors 6 are placed in the scanning system. The beam passes out the scanning system and is not collected by collectors in the usual scanning regime. Let's increase the amplitude of saw-toothed magnetic field in the scanning system and correspondingly increase the maximum deflection of the beam so as to collect beam by collector at maximum deflection. If magnetic induction of deflecting field depends on time as ***B(t)*** that the deflection angle $\varphi(t)$ for electrons with energy ***W*** and for poles shape shown in Fig.1 depends on time as

$$\varphi(t) = \arcsin\frac{echB(t)}{W} \qquad (1)$$

where ***e*** is electron charge, ***c*** is light velocity.

The accelerated electron beam has typical energy spectrum shown in Fig.2.

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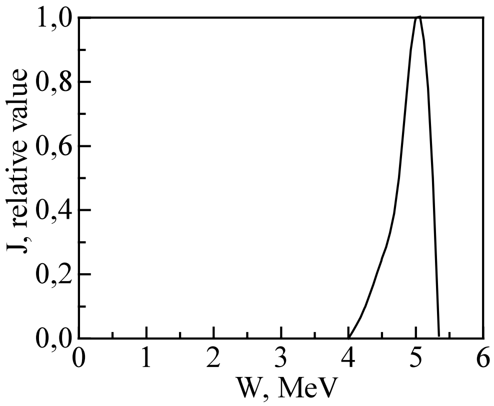

Figure: 2 Accelerated electron beam energy spectrum.

At changing ***B(t)*** in time the energy ***W(t)*** of electrons getting to the collector edge is changed too:

$$W(t) = \frac{echB(t)}{\sin\varphi_0} \tag{2}$$

The electrons with energies $W \le W(t)$ are collected by collector.

Thus the registration equipment measures the current

$$I_m(t) = I - \int_0^W J(W)dW = = I - \frac{ech}{\sin\varphi_0}\int_0^t J(W(t))\frac{dB(t)}{dt}dt \tag{3}$$

The energy spectrum is determined by expression (2) and following parametric expression

$$J(W(t)) = -\frac{\sin\varphi_0}{ech}\frac{dI_m(t)}{dt}\left(\frac{dB(t)}{dt}\right)^{-1} \tag{4}$$

Thus there is the possibility of the measurement of beam current ***I***, beam energy spectrum ***J(W)*** and the control of operation regime of the scanning system during each scanning period.

2.2 Belt scanning beam monitoring

The belt scanning beam monitoring system is shown in Fig.3.

The collectors 6 are placed between first and second bending magnets. On the whole the poles of bending magnets have arbitrary profile and the dependence of energy ***W(t)*** of electrons getting to the collector edge is determined by (2), where value ***h*** is clear from Fig.3. The energy spectrum may be found using expression (4).

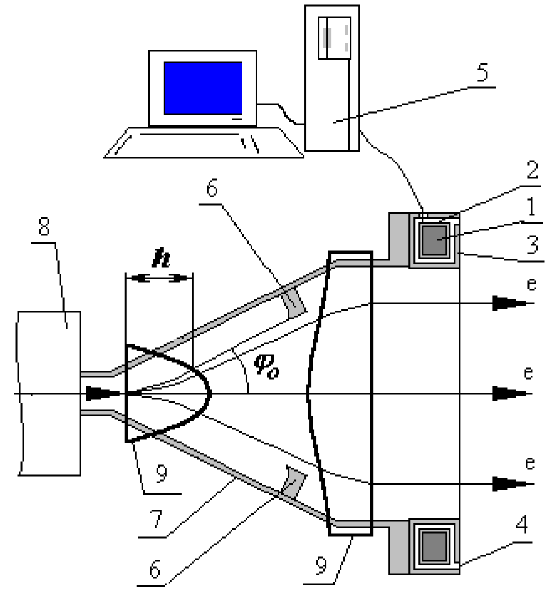

Figure: 3 Belt scanning beam monitoring.

3 DEVELOPMENT OF FULL-SCALE MODEL MONITORING SYSTEM

The beam parameters monitoring system was developed for medical items industry sterilization facility. This facility consists of 5 MeV standing wave electron LINAC and the belt beam scanning system analogous to one shown in Fig.3. The accelerating section, the scanning system with horn and two bending magnets and the beam parameters monitoring system are shown in Fig.4. The cardboard boxes with medical items are moved by means of rectilinear conveyor under the output foil window of scanning system horn. The box sizes are 49.5õ41õ27 cm. The belt scanning beam width is 43 cm.

The wire winding is winded up on the magnetic core with cross-section 2x2 cm and is loaded by 50 Ohm resistor. The voltage on this resistor is ***U=kI***, where ***k*** = 1.25 Â/À.

The accelerator operates in the pulse mode with beam duration 6-12 μs and pulse beam current ***I***=0.2 A. The voltage pulse form coincides with electron beam pulse form very well in case of axis pass of the beam. The pulse voltage amplitude on the resistor changes in the range from 0 to 0.625 V during beam scanning with full collecting. This pulse voltage may be looked at the oscilloscope in case of need or in the operating mode it is passes to the registration equipment and analyzed by computer to get the beam current and the average electron energy. The beam current, the electron energy and known pulse repetition rate and conveyor velocity allow to control the dose and thus to control the sterilization quality of each box.

The conveyor operates in the continue mode. The sterilization quality may be controlled during all

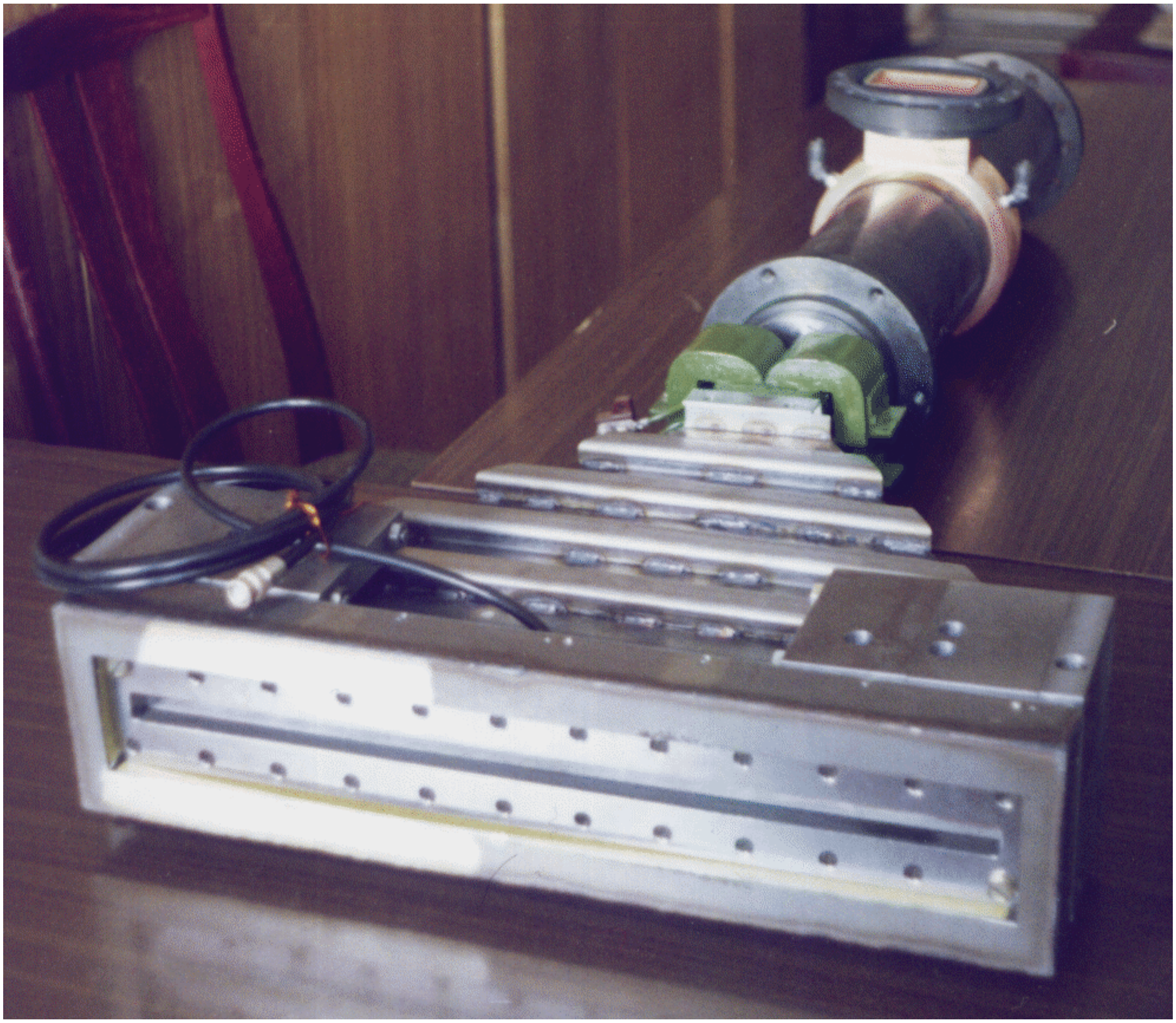

Figure:4 Full scale model monitoring system.

sterilization time each scanning half-period or more seldom. For example the scanning angle for measuring of electron energy is increased, when beam is between boxes. It allows to control the electron energy without decreasing of irradiation dose. The beam current is measured continuously.

The number and the dose of each box and the sterilization date may be marked on the box surface by means of laser marker or bar-code marker coupled with the control computer. The computer may store an information of the dose got by each box and give signals to operator about defective sterilization.

4 CONCLUSION

The described equipment allows to have accelerated electron beam parameters monitoring and therefore the necessary dose monitoring during the irradiation process. This monitoring may be carried out ones or twice every day, every tenth scanning period or every scanning period by request without interruption of the irradiation process.

5 ACKNOWLEDGEMENTS

The author wishes to thank S.N.Puchkov for help in manufacturing and testing of the core and winding of full-scale model monitoring system.

REFERENCES

[1] A.A.Zavadtsev, Electron Beam Scanning Systems, Proceeding of this conference.

[2] V.A.Moskalov, V.G.Shestakov and G.I.Sergeev, The Measurement of Charged Particles Beams Parameters, M.: Atomizdat, 1980. (in Russian).