# THE REAL-TIME SYSTEM ELECTRON BEAM DOSE MEASUREMENTS FOR INDUSTRIAL ACCELERATORS

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*Abstract*

The real-time system for electron beam dose measurements for industrial accelerators is considered in the report. The system is acceptable for all types of industrial and research accelerators: CW, DC, RF LINAC and PULSED HIGH CURRENT. The main concept consists in the measurements of beam parameters using partial absorption effect and mathematical treatment of signals from sensors. The 2 modes of operation can be used for this system: manual and full automation. The manual mode includes simple measurements of signals from sensors by oscilloscope with following treatment using simple software. The second mode is used LABView 6.1. for measurements, treatment of signals and presentation on screen PXI-1025 with printed protocol. The system was tested on the pulsed electron accelerator with kinetic energy of electron 400 keV and on the CW accelerator "Rhodotron" for electron with kinetic energy 5 MeV. This system allows to measure the primary kinetic energy of electron beam before product.

## INTRODUCTION

The Real-Time (RT) measurements are main component for physical experiment and for radiation process. The RT measurement of absorbed dose in irradiated product for industrial accelerator is serious problem. The standard film dosimeter routine methods [1,2] are difficult for using with RT measurements. The search of new approaches for solution of this problem is very important at present time.

The new method of RT measurement of electron beam absorbed dose on the basis of effect for partial absorption of electron beam in foil and two systems for realization of this method is considered in this paper.

## METHOD

The main concept of method for determination of absorbed dose *D* in irradiated product is based on the main formula [1]:

$$D_{[Gy]} = \frac{W_{[J]}}{m_{[kg]}} , \qquad (1)$$

where: W is dissipated ( deposited) energy in the irradiated product, m is mass of this product.

The determination of dissipated energy on product for electrons we suggested to use measurements of kinetic energy and of number of electrons in cross section of collimator. The energy spectra electrons after product determines from beam current measurements on the basis of effects of partial absorption of electrons in foil Fig. 1. The mass of product enters to (1).

The distribution of absorbed doses *D* in the irradiated product has typical distribution on the Fig. 2.

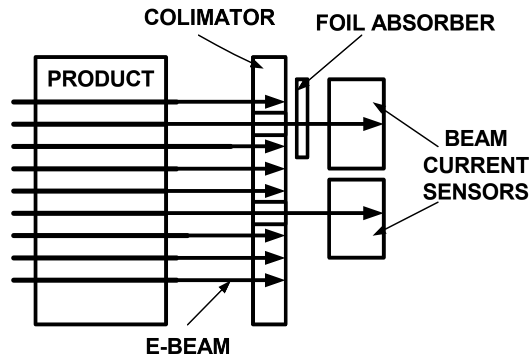


Figure 1: The general principal of method.

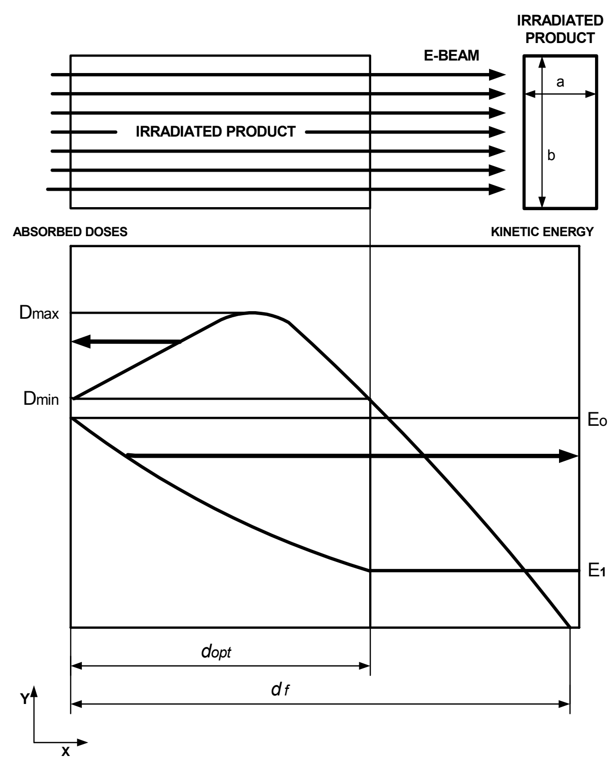


Figure 2: The method of irradiation and distribution of absorbed doses and kinetic energy in irradiated product

The using this parameter we can determine the optimal thickness $d_{opt}$ of product for irradiation (Figure 2).

The value of absorbed dose in irradiated product is determined by formula [1] :

$$D = \frac{E}{m} = \frac{E_k \cdot I \cdot t}{\rho \cdot S \cdot d_{opt}} , \qquad (3)$$

where: $E$ is absorbed energy, m is mass of irradiated product, $E_k$ – kinetic energy ( accelerating voltage), $I$ is beam current, $t$ is time of irradiation, $\rho$ is density of irradiated product, $S$ is cross section squire of irradiated product and $d_{opt}$ is thickness of this product.

The kinetic energy $E_k$ can be determines by simple formula:

$$E_k=E_0 - E_1, \qquad (4)$$

where: $E_0$ is primary kinetic energy of electrons, $E_1$ is kinetic energy after product, ( see Fig.1).

The measurements of kinetic energy for electron beam after product can be used for determination of dissipated kinetic energy in irradiated product:

$$E_J = E_k \cdot 1.6 \cdot 10^{-19} \cdot N_e = [J]$$

The absorbed dose $D$ can be calculated in this case by next formula:

$$D = \frac{W}{m} = \frac{E \cdot I \cdot t}{\rho \cdot V} = \frac{\Delta E[eV] \cdot 1.6 \cdot 10^{-19}[J] \cdot N_e}{\rho \cdot d_{opt} \cdot a \cdot b} \qquad (5)$$

The effect of partial absorption of electron beam in foil was used for measurements of energy spectra for pulsed electron beams [3,4]. The main idea of this method consists in the measurements of factor of absorption of electron beam in thin foils using the current measurements. The factor of transmission for charge of beam can be calculated from well-known dependence [3]:

$$Q = Q \cdot e^{-(\mu/\rho)d}, \qquad (6)$$

where: $\frac{\mu}{\rho}$ is mass absorption coefficient, $d$ is thickness of absorber.

The $\frac{\mu}{\rho}$ determines from empirical formula:

$$\frac{\mu}{\rho} = \frac{[cm^2]}{g} = 17E^{-1.43}, \qquad (7)$$

where: $E$ is kinetic energy of electrons [MeV].

The formula for determination of kinetic energy for electron beam before absorber $E$, after product is next:

$$E = \left[\frac{17 \cdot \rho \cdot d}{\ln \frac{1}{k}}\right]^{0.7} = [MeV], \qquad (8)$$

where: $d$ is thickness of absorber (foil), $k$ is factor transmission of beam current in foil absorbed. The $k$ is ratio of beam current after foil absorber ($I_1$ ) and beam current ($I_0$ ) before foil absorber:

$$k = \frac{I_1}{I_0}. \qquad (9)$$

The beam current or number of electrons determines from beam current and time measurements.

## SYSTEM DESCRIPTION

The 2 variants of system were designed:

1. Manual system with Tektronix scope with software "MATGEN-2002".
2. Automatic system on the basis electronics and Software "STERIS Dose On-Line" on the basis of LabView 6.1.

The manual system includes the sensors, Tektronix scope with manual enter data from sensors to computer program "MATGEN-2002".

Automatic system includes same absorbed beam energy sensors, measurement instrumentation electronics based on a PXI-1025 Chassis: PC, switch and oscilloscope modules from National Instrument, Fig. 3.

The system allows working with all types of electron accelerators:

1. Direct Current Linear Accelerator
2. Pulsed Radio-Frequency Linear Accelerator.
3. Continuous Wave (CW) Radio-Frequency Accelerator.
4. Pulsed High Current Accelerator.

The program can perform two types of dose measurements and monitoring:

a) accumulated dose for static irradiation, when conveyor is stopped (Fig. 4);
b) current dose for product moving on conveyor.

This system has 3 modes of operations it can perform with data from sensors and electron beam parameters:

1. The Real-Time monitoring of absorbed doses.
2. Calibration of primary kinetic energy of electron beam.
3. Calibration of sensors with an external pulse generator.

In addition to logging measurement results to a file, the developed system features printing a protocol/log of the measured absorbed doses, which also include the main information about the beam and product parameters.

The system was tested with good results on the 2 types of electron accelerators:

1. CW "Rhodotron" Electron Accelerator with power of 80 kW and beam kinetic energy of 5 MeV.
2. Pulsed High Current Electron Accelerator with beam current of 1 kA and beam kinetic energy of 200-400 keV and pulse duration of 300 nsec.

## CONCLUSION

The considered method and two systems can be used for monitoring of absorbed doses for the radiation industry.

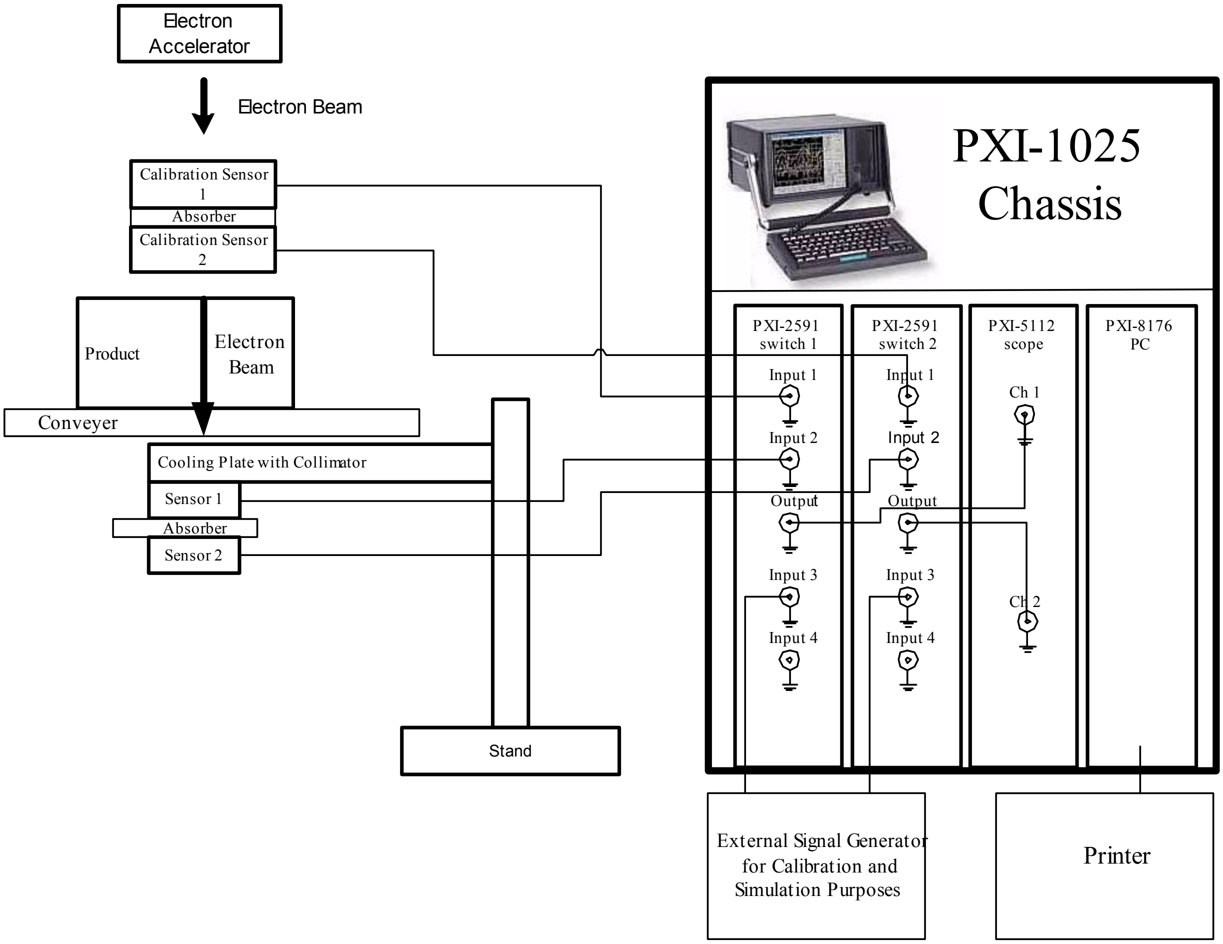


Figure 3: The block-diagram of real-time electron beam absorbed doses monitoring system.

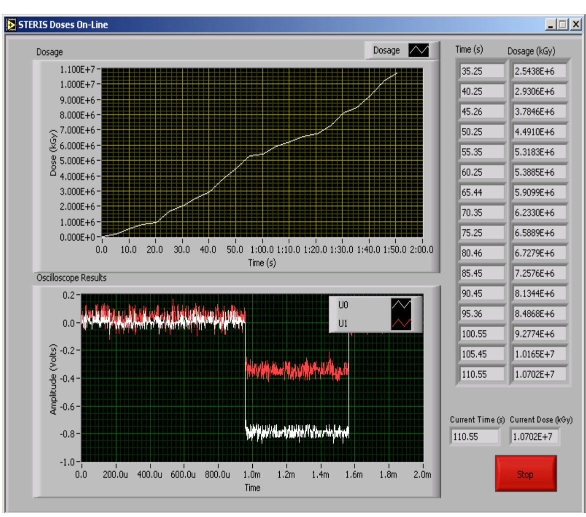


Figure 4: Monitoring screen for accumulated dose measurements.

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