RESEARCH AND DESIGN OF A SHIELDING SYSTEM FOR IMPROVING DOSE UNIFORMITY RATIO (DUR) AND SETTING UP A SET OF OPERATIONAL INSTRUCTION FOR RUNNING THE ELECTRON BEAM ACCELERATOR UELR-10-15S2

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ABSTRACT: The project “Research and design of a shielding system for improving dose uniformity ratio and setting up a set of operational instruction for the electron beam accelerator UELR-10-15S2 at Research and Development Center for Radiation Technology - VINAGAMMA” has been set up and implemented to improve dose uniformity ratio (DUR) for products with the areal densities in the range of 4.5 – 7.0 g/cm² in the irradiation by electron beam of 10 MeV energy and to set up the first set of operational instruction of the accelerator UELR-10-15S2.

By using the shielding system with the areal densities of 1.5 g/cm² and 2.5 g/cm², the DUR values for products with the above range are reduced lower than 2 for food irradiation and the utilization of the accelerator has been significantly enhanced. The set of operational instruction of the accelerator UELR-10-15S2 has been set up and approved by the center’s director in order to put it into force.

1. CONTENT
   - Overview of the electron beam accelerator UELR -10-15S2.
   - Research, design and fabrication of the shielding system to improve dose uniformity ratio (DUR) for products with the areal densities in the range of 4.5 – 7.0 g/cm².
   - Setting up the operational instruction of the electron beam accelerator UELR-10-15S2 in order to put it into routine operation.

2. RESULTS

2.1. Overview of the electron beam accelerator UELR -10-15S2

The electron beam accelerator UELR-10-15S2 was supplied by the company CORAD SERVICE Ltd, Russia and has been put into operation since August of 2012. The accelerator is used for sterilization of health care products, food pasteurization and research and development purposes in the field of radiation technology as well. The main characteristics of the accelerator are showed in table 1:

Table 1: The main parameters of the UELR-10-15S2 accelerator.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron energy, MeV</td>
<td>10</td>
</tr>
<tr>
<td>The peak mean beam power, kW</td>
<td>15</td>
</tr>
<tr>
<td>The pulse amplitude of beam current, A</td>
<td>0.25</td>
</tr>
</tbody>
</table>
The facility consists of the linear accelerator UELR-10-15S2 and roller conveyor placed inside of the concrete bunker. The acceleration of electron has been done through resonant cavities along the accelerator structure by a high frequency wave pumped from a RF power amplifier, Klystron. The beam output system of the accelerator has two scanning horns located opposite each to other with the distance of 900 mm. A product carton goes in between these horns can be irradiated by double side manner. The accelerator UELR-10-15S2 is illustrated in the picture 1.

### Table 1: Specifications of the Accelerator UELR-10-15S2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse repetition rate, Hz</td>
<td>12.5 ÷ 300</td>
</tr>
<tr>
<td>Scanning length, mm, max</td>
<td>500</td>
</tr>
<tr>
<td>Power consumption, kW</td>
<td>110</td>
</tr>
<tr>
<td>Homogeneity of dose along the scanning length, %</td>
<td>± 5</td>
</tr>
<tr>
<td>Beam power stability, %</td>
<td>± 2.5</td>
</tr>
<tr>
<td>Electron energy stability, %</td>
<td>± 2.5</td>
</tr>
</tbody>
</table>

2.2. Research, design and fabrication of the shielding system for improving dose uniformity ratio (DUR)

**System description**

The shielding system consists of two shielding plates (1.5 g/cm² and 2.5 g/cm²) with water inside and a water cooling system. The water circulated inside of the shielding plate is used as a dummy material and coolant material as well as.

A shielding plate is a flat rectangular box which consists of two stainless steel sheets at two sides, connectors for water inlet and outlet. The dimensions of the shielding plates are 800 mm length, 200 mm width, 8.1 mm and 11.1 mm thickness for 1.5 g/cm² and 2.5 g/cm² respectively. The dimensions and main parameters of these plates are presented in the Table 2.

**Figure 1:** Layout of the accelerator UELR-10-15S2 at VINAGAMMA.

**Figure 2:** Principle diagram of the shielding system.
Table 2: Dimensions and main parameters of the shielding plates.

<table>
<thead>
<tr>
<th>Plate</th>
<th>Dimension, mm</th>
<th>Stainless steel thickness, mm</th>
<th>Total areal density, g/cm²</th>
<th>Water flow rate, l/min (at beam power of 15 kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length</td>
<td>Width</td>
<td>Thickness</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>800</td>
<td>200</td>
<td>8.1</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>800</td>
<td>200</td>
<td>11.1</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The water cooling system consists of water copper pipes of 12 mm diameter connected to a shielding plate, water plastic pipes of 34 mm diameter connected to pump, water tank and heat removal part with a fan, water tank with the volume of 0.2 m³, water pump with the electrical power of ¼ HP and the heat removal part.

The system installation under beam and the shielding plate are shown in the Fig. 3 and Fig. 4 respectively.

Figure 3: Installation of the system under the upper scanning horn.

Figure 4: A shielding plate.

Shielding effect

Normally, in the radiation by electron beam of 10 MeV emitted from UELR-10-15S2 accelerator products’ densities batter are less than 4.5 g/cm². For products with higher areal densities, for example, from 4.5 g/cm² to 7.0 g/cm² the DUR value are more than 2 and it is not accepted for food irradiation and for sterilization of health care products. The curve of DUR vs. Areal densities of product in 2-side irradiation by UELR-10-15S2 is illustrated in the Fig. 5.

Figure 5: Curve of DUR vs. Areal density values.
Therefore, the DUR value for food irradiation and for sterilization of health care product should be kept lower than 2 and from 1.3 to 1.5 respectively. For products with using the shielding system with the appropriate selection of a shielding plate the areal density of an object comprising product and a shielding plate is the areal density of a shielding plate plus the areal density of the product and DUR values will be decreased lower than 2.

**Experiment and results**

For estimation of the shielding effect to DUR parameter by using the shielding plates namely 1.5 g/cm\(^2\) and 2.5 g/cm\(^2\), identical rectangular dummy plates have been used. A typical dummy plate is made of wooden material with dimensions of 47 cm length, 37 cm width, 9.4 mm thickness and the weight of 1.28 kg. These plates are stacked with dosimeters radiochromic film dosimeters B3 (GEX company) placed in between and irradiated by the upper scanner with two passes (one pass with the shielding plate and next pass without the shielding place after turning down the stacked dummies) beam.

To simulate the practical irradiation the experiment for a shielding plate has been implemented by the following manner: Pass 1: the stacked dummies covered by a shielding plate are placed on the conveyor and irradiated; Pass 2: After the the first irradiation, the stacked dummies were turned down and placed at higher level in comparison with the conveyor then irradiated in absence of the shielding plate. The arrangement of the experiments is illustrated in the Fig. 6.

The measurement data for the shielding plates with the areal density of 1.5 g/cm\(^2\) and 2.5 g/cm\(^2\) are given in the Table 3 and dose profiles are illustrated in the Fig. 7 and Fig. 8 respectively. The data of the experiments have the accuracy of 2.5%.

![Figure 6: Arrangement of the experiment for determination of shielding effect.](image)

**Table 3: Experimental data for two shielding plates.**

<table>
<thead>
<tr>
<th>Level</th>
<th>Areal density, g/cm(^2)</th>
<th>Dose (kGy) for the shielding plate of 1.5 g/cm(^2)</th>
<th>Dose (kGy) for the shielding plate of 2.5 g/cm(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No shielding plate</td>
<td>With shielding plate</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>7.9</td>
<td>6.9</td>
</tr>
</tbody>
</table>
The data gained from the experiments shows that for both cases using the shielding plates the DUR values are reduced from about 2.3 to about 1.7.
2.3. Setting up the operational instruction for running the electron beam accelerator UELR-10-15S2

The electron beam accelerator UELR-10-15S2 has been commissioned in August of 2012. It is required to issue a set of official operational instructions for operation shifts to run the facility safely in technical aspect and radiation protection as well.

The set of instruction in Vietnamese should be set up based on the following requirements:
- Conforming to all technical instructions of the accelerator which provided by supplier, CORAD Service Ltd., Co.
- Conforming to the rules of radiation safety of Vietnam for working with radioactive sources/facilities.
- Taking into account the condition operation of the facility and product characteristics to be irradiated at the center.
- The set of operational instruction has to cover the following aspects.
  - Starting procedures to put the accelerator into the ready status of irradiation.
  - Setting parameters of the accelerator to irradiate a curtain product at the high efficiency.
  - Overcoming failures of the accelerator during irradiation.
  - Finishing an irradiation and stopping the accelerator.

At present, the set of operational instruction has been completely set up, approved by the center’s director and put in force for the accelerator operation.

3. CONCLUSION

The project “Research and design of a shielding system for improving dose uniformity ratio and setting up a set of operational instruction for the electron beam accelerator UELR-10-15S2 at Research and Development Center for Radiation Technology-VINAGAMMA” has been well implemented and in due time. The results gained from the project implementation have practical values in scientific, technical and economical aspects and give the possibility to the center in effective exploitation of the electron beam accelerator.

REFERENCES