# A new quality control method on X-ray radiography units for biomedical technical service applications

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***Abstract*— In the study, a new technical method/protocol is first proposed in the literature for the biomedical technical services. In this context, energy quality control test and focus adjustment test are made for X-ray radiography systems. The method will provide a unique contribution to the application field of the technical services of biomedical and clinical engineering on quality control assessments of radiology equipment.**

***Keywords — radiation; quality control; dose measurement; focus adjustment; x-ray; unfors Xi.***

## I. INTRODUCTION

Recently, the improvement of radiology systems along with the developing technologies has provided an important contribution in the diagnosis and treatment of numerous medical cases. Also, the quality control measurements of the systems have become more complex. In this respect, the development of quality control methods is of utmost importance for usage in a safe, effective and efficient way.

In biomedical and clinical engineering technical service applications, the performing correctly the maintenance, calibration, quality controls of medical equipment in the radiology departments is still one of the difficult problem to be solved. Especially, the quality controls of X-ray equipment which is the most widely used in the world on the diagnosis level is highly important. Today, there is no still any standardized technical service schedule for X-ray units in the biomedical engineering services.

In the literature, the studies related to dose levels of medical devices used in clinical practices have shown an increase in recent years [1]. In this context, dose reduction algorithms that improve visibility of anatomical structures and lesions on a lower level of radiation in the radiological devices are carried out [2]. Moreover, the radiation dose values of patients and radiation workers are measured during orthopedic [3], urological [4] and chest radiography [5] procedures by using thermoluminescence dosimeters [6, 7]. In addition, patient and staff dose measurements are done in dental [8], fluoroscopic [9] and endovascular aneurysm repair applications [10]. The mean absorbed dose [11] and effective dose values [12] to organs and tissues are usually calculated from the entrance surface dose using computational phantoms by the Monte Carlo method [13-15]. All the measurement approaches [16, 17] have followed a principle known as ALARA (As Low As Reasonable Achievable).

In this study, a new radiation quality control assessment method is proposed, for the first time. We present a novel test of energy quality control and tube focus adjustment. The proposed method is described in detail in the next section. In this regard, the proposed method will be implemented practically in biomedical technique service organizations. The method is extremely important to correct the shortcomings in this area as well as to provide a "gold standard" for radiation quality control measurement of X-ray units. The implementation of the method will allow to the elimination of concerns of patients and radiation workers about radiation. Also it will present the opportunity to work in a safe environment for radiologists and radiation workers.

The remainder of this paper is organized as follows. A brief information is given in Section 2 for X-ray radiography systems and Unfors Xi dose measurement device. Measurement results for the energy quality control and focus adjustment tests are presented in Section 3. Conclusions are drawn in Section 4.

## II. MATERIALS AND METHODS

### *A. X-ray Radiography Systems*

An X-ray radiography system consists of three major components for x-ray production and control. These are X-ray Generator, X-ray tube and User Console. An X-ray tube provides the proper environment and components to produce x-rays. An X-ray generator is the source of electrical voltage and user controls to energize the x-ray tube. Also, it provides operator control of the radiographic techniques such as tube voltage (kVp), tube current (mA), and exposure duration [18].

In this study, a new radiation quality control measurement approach is proposed for both energy quality

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test and an X-ray focus adjustment test by using Unfors X-ray dose measurement device on the Europa 2TS X-ray Unit established at Oncology Institute, University of Istanbul.

In biomedical technical service applications, the effective usage of the medical devices and the knowledge of their properties are extremely important. Therefore, this section includes information about the properties in the head structure of a basic X-ray radiography system on Fig.1-2. The head structure of an X-ray unit is given as annotated in Fig.1 as well as X-ray tube, indicators and buttons. Also, the user console of an X-ray unit is shown with the functional properties of indicators and buttons in Fig.2.

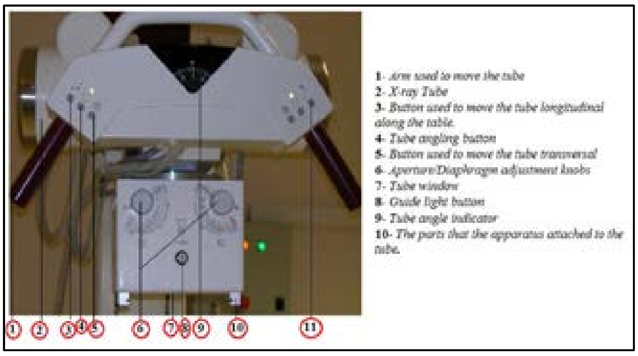


**Fig.1.** The head structure of an X-ray unit and the properties of indicators and buttons.

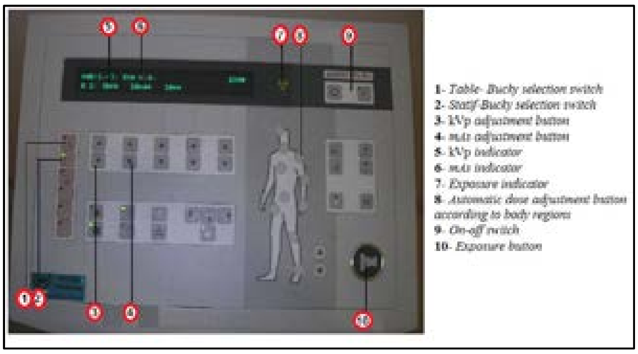


**Fig.2.** The user console of an X-ray unit and the properties of indicators and buttons.

## *B. Unfors Xi*

In the study, Unfors Xi dose measurement device is used on radiation dose quality assessment tests for X-ray radiographic units. The Unfors Xi is a complete device for multiparameter measurements on all medical modalities. It has a base unit and several different external detectors on the dose measurements of medical systems such as radiography/fluoroscopy (R/F), mammography (MAM), Computed Tomography (CT). On the energy test of X-ray generator in the study, RF/MAM detector is used for dose rate measurements. For a healthy radiographic shot, it is extremely important that the focus of X-ray tube is set in the middle of the guide light field as illustrated in Fig.3. A tube focus set incorrectly causes to radiation exposure of patient's healthy tissues. In the study, the measurements are taken by using the Light Field Alignment apparatus for the focus adjustment of X-ray tube.

In this study, a new approach is also proposed for energy quality control and focus adjustment tests on X-ray devices. In this approach, whether the energy released from the X-ray tube is the same with the energy set in the operator console or not is performed by Energy Quality Control Test. Based on the focus point of the X-ray tube, whether the irradiation area of X-ray tube is compatible with the guide light field of gantry or not is made by Focus Adjustment Test.

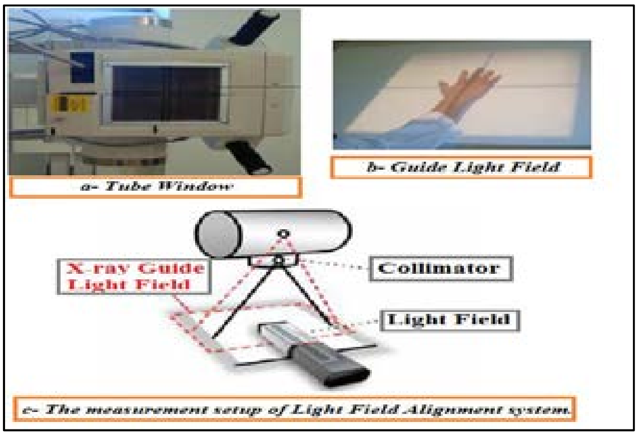


**Fig.3.** The measurement setup of Light Field Alignment.

## III. RESULTS

In the work, the energy quality control and focus adjustment tests was carried on Europa 2TS X-Ray Unit established in Oncology Institute of Istanbul University by using Unfors X-ray dose measurement device.

## *A. Energy Quality Control Test*

On the energy quality control measurement, Source/Focus Distance to Dedector/Table (SDD) is taken as 100 cm. And the head of X-ray tube is positioned towards the table (downward). In this test approach, whether the energy released from the X-ray tube is the same with the energy set in the operator console or not is investigated. Also, the percentage deviation values are calculated. The results of measurements are given in Table-1. In addition, a linearity graphic of the measurement results is plotted in Fig. 4. The measured potential energy values are quite larger than set potential energy values on the operator console. On the measurements, the Unfors Xi component is used for energy quality control tests.

## *B. Focus Adjusment Test*

In an X-ray tube, it is extremely important that the focus field of the tube overlaps with the field of guide light on the clinical applications. In this context, whether the irradiation area of X-ray tube is compatible with the guide light field of gantry/collimator or not is tested by Focus Adjustment Test for Europa 2TS X-ray radiography system.

| Set Value (kVp) | Measured Value (kVp) | Percentage Deviation (%) |
|---|---|---|
| 60 | 73.55 | 22.6 |
| 72 | 97.95 | 36 |
| 80 | 104.7 | 30.9 |
| 92 | 120 | 30.4 |
| 100 | 127.7 | 27.7 |

**Table 1.** Measurement results for the Energy Quality Control Test.

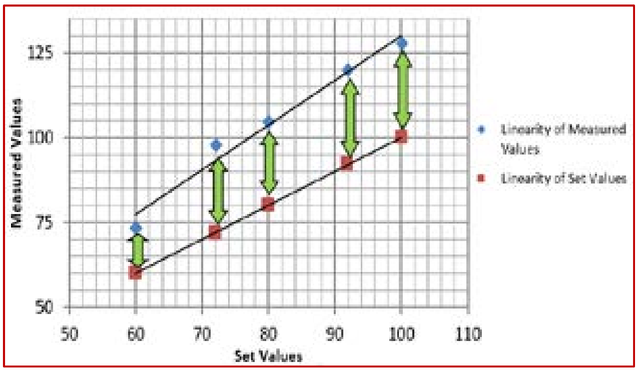


**Fig.4.** The linearity graphic of the results.

On the measurement set-up as shown in Fig.3, the potential energy value of the tube from operator console is set to 60 kVp (300 mA). The guide light field and the focus distance to table are taken as 10x10 $cm^2$ and 100 cm, respectively. For the measurements, the light field alignment apparatus is used. The measurement and field alignment results are shown in Fig.5.

In the focus adjustment test, the drift distances of the focus of Europa 2TS X-ray unit, *a, b, c* and *d* are measured as *2.0 cm, 4.6 cm, 0.25 cm and 2.8 cm*, respectively. By the results, we observed that the focus point of the tube did not overlap with the guide light field of gantry/collimator as shown in Fig.5. As a result, the focus of the tube formed a different irradiation field due to its focus adjustment problem. Therefore, we identified that the focus drift correction is needed. Indeed, this drift problem of the focus alignment is also confirmed by patient radiographic images taken from the X-ray system.

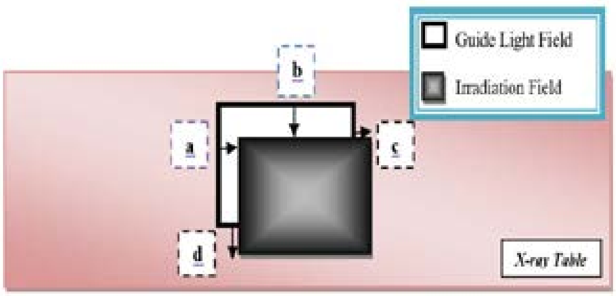


**Fig.5.** Results on the focus adjustment test.

In order to get more information about the tube of Europa 2TS X-ray unit, equivalent dose measurements are made by using Unfors XI dose measurement device. The dose values taken at the distance of 5 cm for the front (*radiation field side*) and back (*operator console side*) of leaded window/screen are 10.97 mSv/h and 302 µSv/h, respectively. Indeed, the equivalent radiation dose value of the tube is measured to be high for clinical applications.

## IV. CONCLUSIONS

### *A. Energy Quality Control Test*

The measurements are taken by using the Unfors XI component for the energy quality control test. And they are given in Table-1. In the table, the percentage deviation values between the set values and measured values are also calculated for defined energy levels. As seen from these results, it is identified that there are significant differences/incompatibilities between the energy released from the tube and the energy value set from the operator console. In order to see better the situation, in addition, a linearity graphic is plotted for the defined energy levels in Fig.4. Thus, the differences/incompatibilities between the values are easily seen from space in the graphic. From the results, the deviation values are observed in the range of 22.0-30.9 %. The value is so high and not acceptable in terms of the acceptance radiation dose limits of ±10 % [20]. This state of the system urgently requires a mechanical repair. Based on the measurement results, it can be said that there may be an inconsistency between the button values on the operator console and the reading values on the display, or may be another problem on the system.

Furthermore, to complete the full energy quality control test, it is necessary to check the focus adjustment of the X-ray unit.

### *B. Focus Adjustment Test*

The measurement results are visually given in Fig.5 for the focus adjustment test. As seen from the results, the incompatibilities between the guide light field and irradiation field are determined. And, it is observed that the focus point of the tube does not overlap with the guide light field of X-ray gantry at the selected energy values. As seen in Fig.5, X-ray beams emitted from the tube falls on black area (irradiation field) instead of white area (guide light field). At the focus-table distance of 100 cm, the drift distances of Europa 2TS X-ray unit, *a, b, c* and *d* are measured as *2.0 cm, 4.6 cm, 0.25 cm* and *2.8 cm*, respectively. If the radiographic shooting distance is thought to be more than 100 cm, the drift values on the radiographic images will be greater. Indeed, this case is also confirmed from radiographic patient images of Europa 2TS X-ray unit taken earlier (before this test). As a result, it is identified that the focus point of the X-ray tube needs to drift correction.

In order to get information about the X-ray Unit due to the problem of the unit, the equivalent dose measurements are made by using the proposed techniques in the study. In measurements made in leaded glass (radiation field side), the dose rate value is calculated as 10.97 mSv/h. This value is quite high for any X-ray unit (approximately 3-4 mSv/h) used in the clinic facilities. Whereupon, after the technical service examination conducted on the X-ray unit, it is identified that the present tube of the X-ray unit belongs to a different CT simulator device. And it is understood that the tube of the unit was previously changed due to a malfunction exists on the gantry system. Also, the leaded glass on the operator console conforms the standard. And it is thick enough to prevent radiation beams. In this way, the procedure provides clarity to the understanding of the principal source of problems.

As a result, the following problems were identified about Europa 2TS X-ray unit established at Oncology Institute:

- The device produces a high dosage.
- The unacceptable deviations in the energy values have occurred on the device.
- The device needs to be made a new focus adjustment of the tube.

Therefore, it was reported that the device is never be used for clinical applications in the current situation. Also in the report, it was specified that the repair of the Europa 2TS X-ray device completing its technological life would not be economical. Instead, it is recommended that a new X-ray system is purchased. After the report was approved by the authorities, the formal proceedings were started. The clinical shots of this device are stopped until the repairs are completed or a new system is purchased.

The proposed method offers a technical protocol for the biomedical technical services in health institutions. In addition, it will lead to the elimination of a serious lack of knowledge and practice in the technical services. In conclusion, it will provide a unique contribution to the application field of the technical services of biomedical-clinical engineering.

**Conflict of Interests**

Authors has no conflict of interests with the trademarks included in the paper.

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