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COMMISSIONING AND PERFORMANCE TEST OF A LOCALY ASSEMBLED X-RAY IMAGING SYSTEM

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ABSTRACT

The X-ray imaging system should always possess superior image quality in term of both spatial resolution and optimal contrast. The image quality is also linked with accuracy and the superior performance of the X-ray tube itself. Thus, the main objective of this study is to investigate the imaging performance and the commissioning tests required before using a SB-80-250 X-ray tube for imaging. Such system possesses 35-80 kVp and 10-250μA. Prior testing its imaging performance, the system was shielded and joined with a locally fabricated holder as well as locally reassembled with a collimator. The holder of the X-ray tube was locally designed in a way that allows movement in six degrees of freedom. Consequently, the system motion will be in x, y, z directions. This is allowed movement in forward/backward, up/down and left/right directions. , the tube can be used in all geometrical set-ups. In addition, most standard, commissioning and acceptance tests have been applied to the X-ray imaging system to assess its performance. These include tube output, reproducibility, kVp accuracy, stability with change in tube voltage and half value layer. Moreover, the amount of radiation scattered and radiation leakage were measured using both RaySafe and Fluke detectors. The reported results were within the international standards.

Keywords: Performance Tests; Shielded; Geometrical Set-Ups

INTRODUCTION

X-ray radiography imaging system offers the potential of providing opportunities for early detecting of diseases and thus considered the most important technique for diagnose. Therefore, it must possess both excellent spatial resolution and optimum contrast. The image quality from such system is intimately linked to the precise and accurate acquisition of information from the X-ray beam attenuated from the patient **[1]**. Radiation protection considerations must be applied for determining the performance of X-ray tube.

This is very important, as it provides confidence that the equipment offered the appropriate diagnostic information with minimal radiation dose to the subject. The test methods and standards applied, are mainly derived from safety report series NO.39 **[2]** and radiation protection NO.91 **[3]** and the Canadian Guidelines **[4]**.

The main aim of this study is to first make the SB-80-250 X-ray tube geometrically suitable for use in imaging application. This is obtained throughout the fabrication and implying radiation protection consideration. In the initial implementation we were unable to move the X-ray system at any angle or at any direction, i.e. on six axes of movement, so when it is used in the experiments may take advantage of the possibility of change. In other words, the purpose of the reported work was to determine how is a SB-80-250 X-ray tube easy achieve any experimental test, and will be a model for other sources. For example, we will use it for 3D-imaging of the uncompressed breast.

MATERIALS AND METHODS

Figure 1 shows the SB-80-250 X-ray tube that has been used in this study. It possesses a 35-80 kVp, 10-250μA, stability 0.5% **[5]**, and digital interface contains the controls and indicators necessary to operate and monitor. Before testing the X-ray system the tube was shielded by using 3mm of lead sheet. Then the system was fabricated and locally reassembled with a collimator. The collimator is a British made and its model is Picker international limited. It characterized by having a small light that can be used to determine the centre point of the area being imaged.

As a result of this the X-ray machine has the capability to move freely in all directions. These allow using the X-ray imaging system in any configuration set-up. As well as, most standard, commissioning and acceptance testing of the X-ray imaging system will be reported by two dosimeters. The first dosimeter is unfors RaySafe Xi, whose possesses 0.05 – 9999 mAs, reproducibility < 0.5 %, dose range 10 μGy-9999 Gy and 35-160 kVp. The second dosimeter is Fluke TNT 12000 with 0-999.9 mAs, with reproducibility of ±0.5 %, dose range from 5 mGy upto 999 Gy, and kVp from 22 upto 150 kVp **[6]**.

RESULTS AND DISCUSSIONS

Shielding placement & geometric development for the X-ray tube

The X-ray source used in this study is shown in **Figure 1**. Such source is configured to be effectively used for imaging at different positions and angles. Thus, to do so it needs to be held on a mechanism that provides six degrees of freedom motion as seen in **Figure 2**. Therefore, a mounted holder is needed. Luckily such holder is designed locally on site so that it can give a full six degrees of freedom motions. These motions are: Three transla tion in x, y, z directions, and three rotations about x, y, z axes as schematically demonstrated in **Figure 2**.

By implementing the six degrees of freedom on the designed holder, the X-ray device becomes free to be moved forward/backward, up/down, left/right (translation in three perpendicular axes) combined with rotation about three perpendicular axes, often termed pitch, yaw, and roll. A mechanism devise has four degrees of freedom will be upgraded to fulfill the requirement. This mechanism has the following four degrees of freedom: move up/down (z-axis), forward/backward (x-axis), left/right (y-axis), and rotate about z-axis (yaw axis). The other missing two degrees of freedom are: rotate about the x-axis (roll axis) and rotate about y-axis (pitch axis). To add these two missing degrees of freedom, an additional parts need to be manufactured. These parts are first designed using CAD software as shown in **Figure 3**. Part one is the based, part two is the connecting holder, part three is the bolt, and part four is the pin that holds the X-ray devise to the based part.

After that, these parts were manufactured locally, then, it assembled to the X-ray device as can be seen in **Figure 4**. The Final designed was tested by holding it to the four degree mechanism, to check that the new configuration mechanism was given the full six degrees of freedom as can be seen in **Figure 5**.

Before using the new configuration mechanism device, it is very important to isolate the sides of the X-ray machine from all sides except the focal point to insure that no X-ray radiation getting outside from all sided except the focal point. Therefore, a shielding material made of lead with a thickness of 2 mm is used. Then the machine was tested for radiation leakage and scatter at all sides using Xi RaySafe survey meter. Luckily, no scatter or radiation leakages were counted by the survey device and the measured value found to be zero. After that, a filter device to the x-ray beam such as collimator is added to be able to collimate the beam of the X-ray device. The collimator device along with the X-ray tube attached to the standing holder is shown in **Figure 6**. Finally, the X-ray device along with the collimator installed on a long standing holder for the thyroid to make it negotiable to lift and reduction to use it at

Commissioning and Performance Testing of the X-Ray Tube

Before using the X-ray tube for imaging it is necessary to test the performance of the tube to obtain accurate assessment with minimum dose to patients and staff. Therefore, Initially we confirmed the tube voltage is constant over time and the current by get rid of interruptions resulting from the lack of stability in the source of electric current to be as figure 8. Then, we have performed the acceptance for the X-ray source used for our study as follows:

Radiation Leakage

At maximum voltage and current of 80 kVp and 250 μAs for 10 sec, we measured the radiation leakage to the SB-80-250 X-ray by applying a lead sheet stopper to discard the primary radiation beam using Radcal 2026C, was 0.1584 mGy/h at 0.3m, 0.014256 mGy/h at 1 meter, much less than 1mGy during 1 hour of exposure at 1 meter distance from the source according to international recommendations **[2]**.

Also, less than as recommended to the leakage radiation from the X-ray tube housing, with all the shutters closed, must not exceed 2.5 mR/hr at 5 cm from the surface **[3]**.

Tube Output

The tube output of an X-ray system is the dose generated at 1 m distance of the focus, any source to image distance.

per unit of mAs **[8]**. At focus to detector distance FDD=600 mm, the tube output was measured for different kVp settings from 35 to 80 kVp, ten dose measurements were taken by Fluke dosimeter detector TNT 12000 DoseMate at 250 μAs settings and 10 sec. The average exposure was found to be between (39.31 - 239.36) μGy/mAS, consequently the specific tube output at a distance of 1 meter was between (14.15 - 86.16) μGy/mAS. **Figure 8** give an overview of the tube output measurements for every voltage. Such output was within the desirable interval that reported **[3]**.

Reproducibility and Accuracy

For a fixed tube voltage of 35and 80 kVp, the reproducibility was evaluated by repeating the measurement 10 times for each KVp, using the kVp meter. The measured kVp was within the range of (35.1 – 35.3 kVp) and (80 – 80.2) respectively, fulfilling the recommendation to be within ± 0.5 kV **[3]**. The accuracy was assessed by applying a number of tube voltages, covering all the range of KVp used settings (35 - 80 kVp) and the results were all cases within a ± 1 kV error interval **[3]**.

HVL

Half value layer describes both the penetrating ability of specific radiations and the penetration through specific objects. For many years medical physicists had been using half-value layer (HVL) in order to specify the quality of X-ray beams **[7]**. By used different KVp and 250 µA an accurate measurement of the half value layer (HVL) is required to many of the experiments. Such parameter were obtained by adding Aluminium filters of density 2.7 g/cm3 and purity of 99.59 % to the X-ray beam and measuring the attenuation effect according to the following equation **(3.1) [4]**:

$$HVL = \frac{X1 \times Ln\left(\frac{2Y2}{Y0}\right) - X2 \times Ln\left(\frac{2Y1}{Y0}\right)}{Ln\left(\frac{Y2}{Y1}\right)} \qquad (3.1)$$

Where $Y1$ and $Y2$ are the exposure readings, with added aluminium thickness of $X1$ and $X2$ respectively and $Y0$ correspond to the primary exposure.

We found a HVL in the **Table 1** as recommendation **[4]** to be as the following equation **(3.2)**:

$$HVL \geq \frac{KVp}{100} + 0.03\,] \qquad (3.2)$$

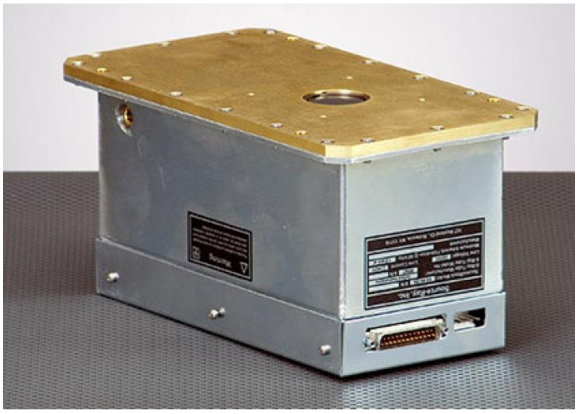

Figure 1: The SB-80-250 X-ray Tube

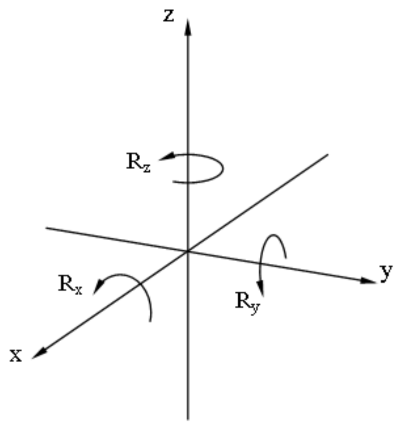

Figure 2: Schematic Diagram of the Required Six Degrees of Freedom for the Locally Designed Holder

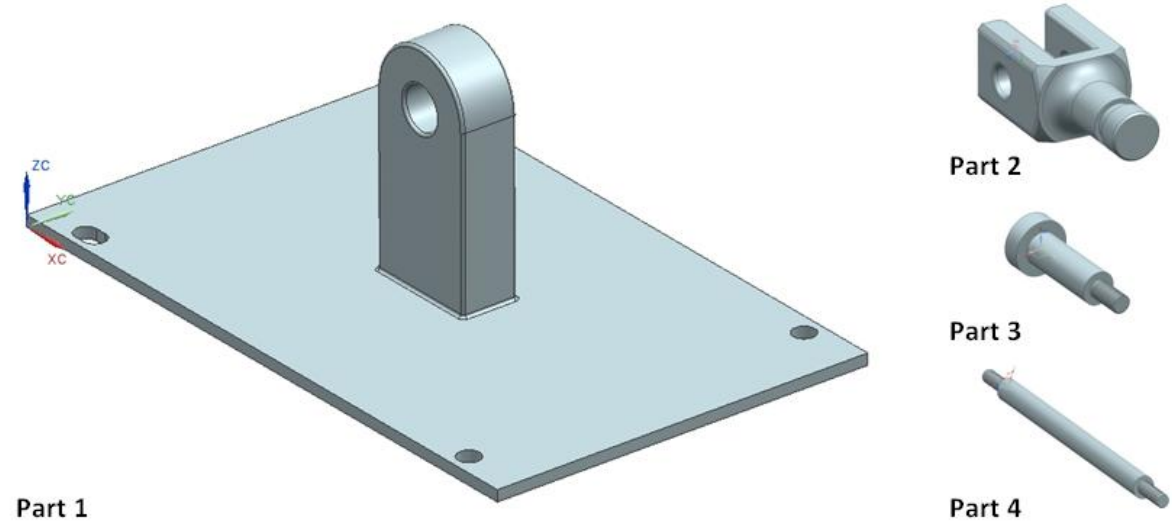

Figure 3: The CAD Models of the Required Parts (1-4)

Figure 4: Assembling all the Locally Manufactured Parts to the X-ray (SB-80-250) Device

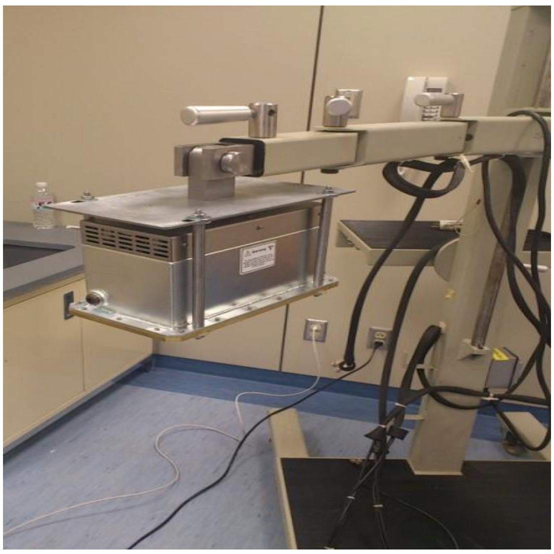

Figure 5: A Photo of the First Test for the New Configuration Mechanism

Figure 6: A Photo of the Imaging System Showing the Placement of Lead Shied on the SB-80-250 X-ray Tube Joined With the Collimator

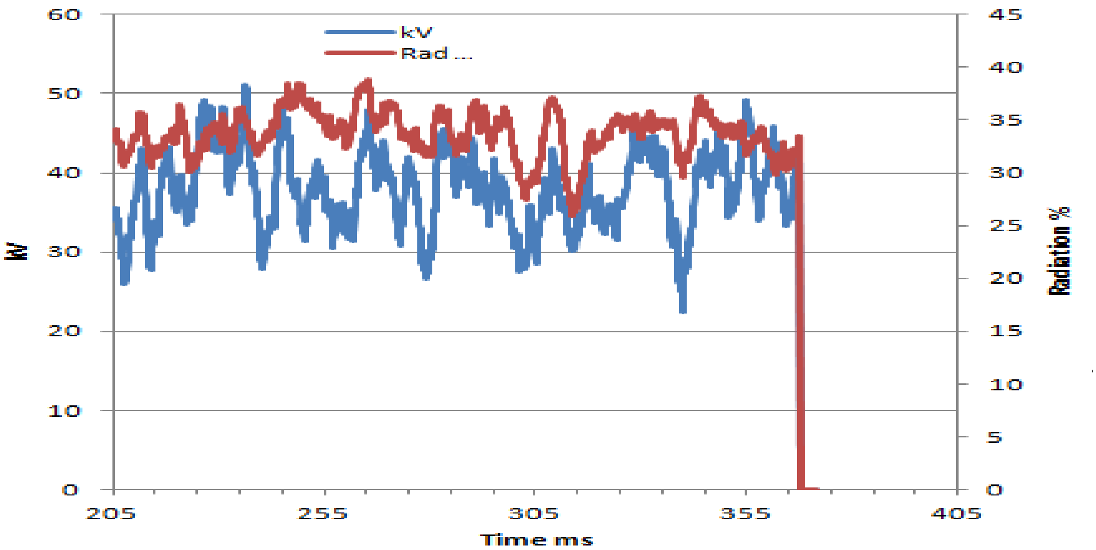

Figure 7

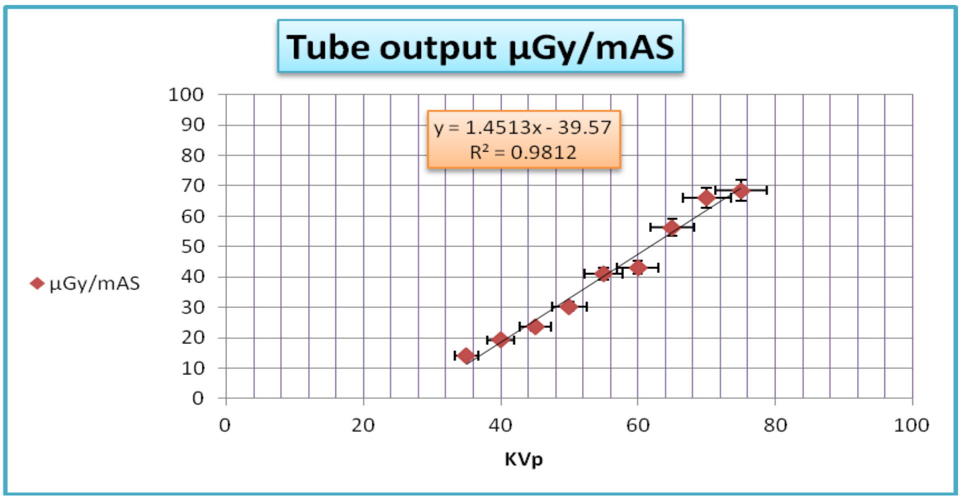

Figure 8: Overview of the Tube Output to the SB-80-250 X-ray Tube

Table 1: HVL to the SB-80-250 X-ray Tube

X-Ray tube voltage KVp	HVL Al mm	Accepted HVL ≥
35	0.926	0.38
40	1.024	0.43
45	1.090	0.48
50	1.296	0.53
55	1.674	0.58
60	1.505	0.63
65	1.299	0.68
70	1.454	0.73
75	1.654	0.78
80	1.352	0.83

CONCLUSIONS

After successsful configuration of the the X-ray tube and the collimator they were optimally assembeld with a localy designed holder. Consequently, the motion of the imaging system became in x, y, z directions allowing movement in forward/backward, up/down and left/right directions. This allow using the X-ray imaging system freely in all geometrical set-ups i.e. getting excellent movement for each activity direction. Then, most of the commissioning and performance tests were performed on such system. The obtained results of all tests were within the international standards. The commissioning and performance testing of SB-80-250 X-ray tube includes tube output, reproducibility, kVp accuracy, stability with change in tube voltage and half value layer.

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