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Effect of Irradiation Distance on Tube Voltage Measurement and X-Ray Device Time Using Scintillator

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ABSTRACT The results of the output of the X-ray device are very important to know how much the correct value, whether it is in accordance with the arrangements made by radiology personnel or there is a difference even deviation of the value out of the arrangement. This conformity test activity needs a testing tool that is often used by BAPETEN personnel to find out how much the output value of KV, Time, Dose, Room leak, mA and mAs from an X-ray device unit. The purpose of this study was to analyze the effect of irradiation distance on tube voltage measurements and X-ray device time using Scintillators. The study used scintillator sensors to detect radiation, Arduino as a programming source, Bluetooth HC-05 as digital communication between hardware and PC, PC / Delphi as display. This research design is Pre-Experimental with After Only Design research type. Where the author takes data compared to standard tools then analyzes the data. The results showed the largest error at a distance of 120cm with a 90 KV setting of 43.52%. And the smallest error is at a distance of 120cm with a 50 KV setting of 0.07%.

INDEX TERMS X-Ray, Scintillator, Arduino

I. INTRODUCTION

With the development of technology in various fields, especially in the field of radiology. Then as a human being has the limitation of not being able to detect the presence of radiation[1][2]. Radiation is something that cannot be seen, felt or known to exist. Ionizing radiation is a type of radiation that is widely used in the field of radio diagnostics with device x-ray radiation sources[3], which are used for various medical purposes such as X-rays[4][5]. In occupational safety, a radiation worker /radiographer is encouraged to receive the minimum possible dose of radiation, namely by monitoring radiation using a radiation gauge[6][7][8].

The results of the output of the X-ray device are very important to know how much the correct value[9], whether it is in accordance with the arrangements made by radiology personnel or there is a difference even deviation of the value out of the arrangement[10][11]. The results of these measurements showed that the greater the tube voltage, time current and pitch used, the CTDI (Computed Tomography Dose Index) of air produced the greater. The smaller the tube voltage, time current and pitch used, the smaller the CTDI of air produced[12]. Therefore, the end of the test activity is carried out the conformity of the results of the X-ray device output so that it can be known what the actual value is, so that the patient does not receive excessive X-ray exposure[13][14]. This conformity test activity needs a testing tool that is often used by BAPETEN personnel to find out how much the output value of KV, Time, Dose, Room leak, mA and mAs from an X-ray device unit. With this we want to analyze based on research. Researchers previously experienced difficulties or difficulties at the time of data retrieval of 50-60Kv[15]. X-ray device suitability tests need a testing tool that is often used by BAPETEN personnel to find out how much the output value of KV, Time, Dose, Room Leak, mA and mAs from an X-ray device unit. Usually, BAPTETEN power using a unit called "Piranha" has a sensor named "Semiconductor" which has not been known until now the type and specifications of the sensor. BAPETEN has its own procedures or standards for measuring KV output on X-ray device, which is at a point 100cm from the collimator. Thus as little as coming out of the BAPTETEN procedure, I will analyze what affects the effectiveness of the Scintillator sensor's performance in reading the tube voltage and time by looking at the effect of the irradiation distance. After this research is expected to be able to find out the ability of the Scintillator to measure the tube voltage and time against the irradiation distance[16]. In 2018 I. Shestakova, O. Philip, J. Wiedemann, and A. Headley, using PMT sensor had the advantage of data reception speed but the readings were still inaccurate[4]. A second study in 2019 using the scintillator method tested with high intensity light had the advantage of demonstrating improved MTF performance while suppressing high frequency noise[17] but had the disadvantage of x-ray images obtained from mammography detectors not directly improved from restoration techniques. Subsequent methods in the same year using several detectors that had the advantage of developed systems had bright prospects given their versatility in the field of radiation detection[18]. But it also has the disadvantage of too many cables [19].

Based on previous literacy, the collection of Tube and Time Voltage data has never been done for the irradiation distance of the general X-ray device[20]. With the data collection aims to determine the limit of what the irradiation distance for Scintillator. When setting the irradiation distance, it is assessed how much Scintillator can work optimally. After research it is expected to be able to find out the ability of the Scintillator to measure the Tube Voltage and Time against the irradiation distance. The purpose of this study is to analyze the effect of irradiation distance on tube voltage measurement and X-ray device time using a Scintillator.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

In this study, measurement analysis is performed on a 10x10cm collimation area at distances of 80cm, 100cm, 120cm, 150cm) with 1S and 346mA tube current using Scintillator detector.

1) *Materials and Tool*

This study is used a Scintillator detector as a radiation detector, a PMT, an Arduino Nano as a microcontroller and programmatically uses Arduino software for data processing, LCD character 16x2 as a display, also a PC (Delphi) as a display, battery as a tools supply.

2) *Experiment*

In this study, KV measurements are made 5 times at each setting (50KV, 60KV, 70KV, 81KV, and 90KV) and each distance (80cm, 100cm, 120cm, 130cm, and 140cm) at a 10x10cm collimation area and compares with a calibrated comparison tool (dosimetry).

B. THE DIAGRAM BLOCK

In FIGURE 1. shows the diagram block of this study, basically, Arduino as data processing derived from PMT and HV Series generator. Data in the form of Tanung Voltage (KV) and time(s) will be sent by Bluetooth HC-05 and displayed on the PC. X-rays will be captured by scintillators and PMT and then processed data on Arduino. And the data that has been processed by Arduino in the form of Voltage Tube (KV) and time(s) will be sent by Bluetooth HC-05 and displayed on the PC.

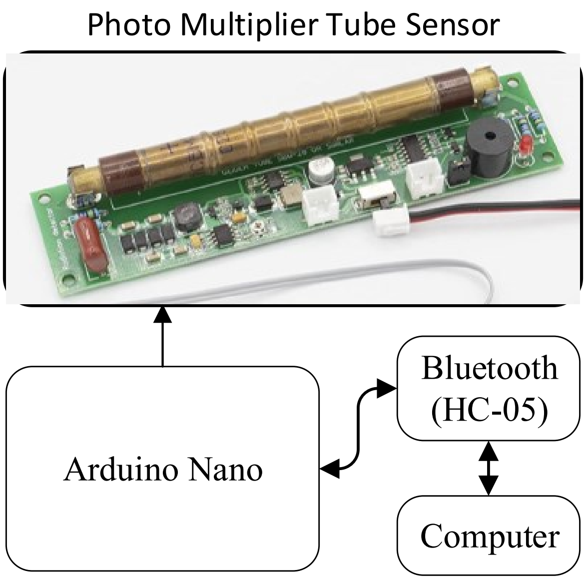

FIGURE 1. The diagram block

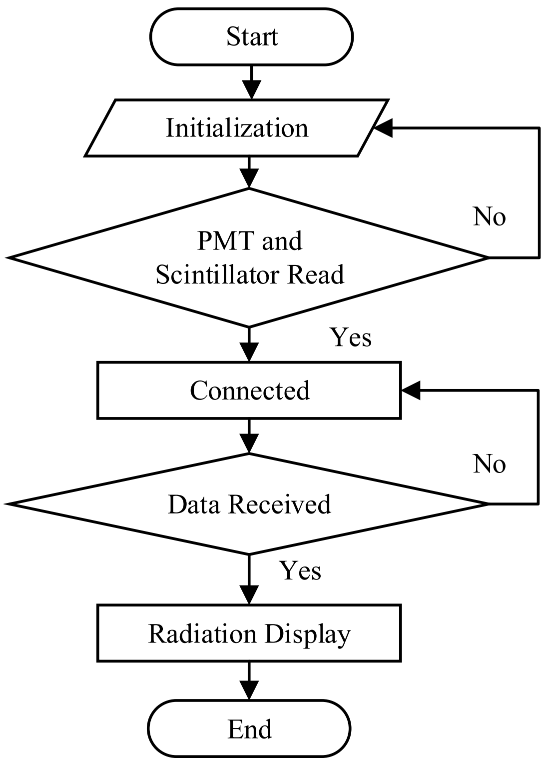

FIGURE 2. The proposed method flowchart

TABLE 1
Mean of KV Measurement Between Module and Dosimetry

Tools	Exposure distance (cm)	Collimation Wide	Tube Voltage (kV)	Tube Current (mA)	Mean (KV)				
					80cm	100cm	120cm	130cm	140cm
Design	80	10x10	50	346	51.2	49.52	50.76	51.52	53.17
			60		52.7	52.16	53.76	56.04	52.57
			70		53.22	52.82	51.92	50.99	51.81
			81		53.12	53.5	52.08	51.93	52.53
			90		51.5	51.4	50.86	54.54	50.9
Dosimetry	80	10x10	50	346	50.4	50.47	50.794	50.67	49.24
			60		60.09	66.05	60.242	60.27	60.29
			70		70.4	70.48	70.18	71.23	70.96
			81		80.9	80.78	80.882	80.99	81.34
			90		90.4	90.12	90.052	91.02	90.81

C. THE FLOWCHART

In FIGURE 2. shows the flowchart of this study, When the device is turned on, the Scintillator Sensor works. Then the sensor can read the radiation from the x-ray plane. The user connects the tool with the PC. If the data is not acceptable, instructions will appear to re-connect. If the data can be received, the data will be displayed on the display.

III. RESULT

In FIGURE 3. shown the results of the entire module in this study. The image above is an overall tool module. It consists of a Scintillator for detecting radiation, Arduino nano as a source of programming and data processing, Bluetooth HC-05 for digital communication between hardware and PC/Delphi, PMT for detecting and doubling electrons generated by photocathodes, character LCDs for tool displays, and transformers as voltage supply on the tool.

FIGURE 3. **The proposed method PMT**

1) *Schematics*

In FIGURE 4. shown the results of the entire schematics in this study.

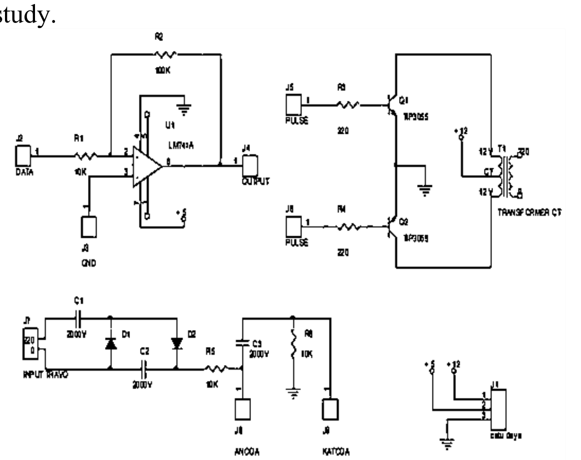

FIGURE 4. **The proposed circuit**

The image above is an entire schematics of this study consist of an inverter circuit, an Cockcroft Walton circuit, and an inverting amplifier. Inverter circuit is an electronic circuit used to convert direct voltage (DC) to alternating voltage (AC). The DC voltage input of 12 V is then changed to a voltage of 220 VAC. The working principle of inverter circuit uses a switch system, when Q1 saturation then Q2 is cut off, vice versa. So that there is a difference in potential in trafo which produces the output voltage on the secondary trafo to 220 VAC. The Q1 and Q2 inputs come from Arduino, namely pins 10 and 11, using a delay system of 10 ms to produce a frequency of approximately 50 Hz. Where Arduino is tasked with signaling High and Low output to the inputs Q1 and Q2. So that the inverter circuit is able to produce ac voltage output of 220 Volts stable and without load. A Cockcroft Walton circuit serves as a photomultiplier tube sensor supply, so the output on this circuit should be completely stable. The working principle of this circuit is like a ladder, functioning to fold the input voltage as much as how many stairs on the circuit, each ladder consists of one capacitor and one diode. The input of this circuit comes from a series of inverters of 220 VAC. The output of this circuit is approximately 1000 VDC if without load. When given a Photomultiplier Tube load, the voltage drops to 790 VDC, although the Photomultiplier Tube sensor can still work at a voltage of 790 VDC, which is actually on the data sheet supply the minimum voltage is 850 VDC and the maximum supply is 1100 VDC. An inverting amplifier Op-Amp strengthening process is needed to strengthen the output voltage of the Photomultiplier Tube sensor whose voltage value is at the milli volt order. The output of the sensor is in the form of minus voltage, so it must use an inverting circuit in order to flip the voltage to positive. Therefore this circuit must be in accordance with what is needed in the ADC reading on Arduino whose maximum value is 5 V. So that the strengthening in this circuit uses 10 times the reinforcement.

2) Measurement Result with Standard Dosimetry

KV measurements are made 5 times at each setting (50KV, 60KV, 70KV, 81KV, and 90KV) and each distance (80cm, 100cm and 150cm) at a 10x10cm collimation area and compares with a calibrated comparison tool (dosimetry). KV average measurement data at distances of 80cm, 100cm, 120cm, 130cm and 140cm measured on modules and calibrated dosimeters can be seen on TABLE I. From the TABLE I, the correction value, the percentage of error value, standard deviation and uncertainty are obtained as shown in the TABLE 2:

TABLE 2
Comparison KV measurement between proposed design and Dosimetry

Setpoint	80 cm	100cm	120 cm	130 cm	140 cm
50	1.59	1.9	0.07	1.68	7.99
60	12.3	21.03	10.76	7.01	12.8
70	24.48	25.07	26.02	28.42	26.98
81	34.34	33.78	35.61	35.88	35.42
90	43.08	42.97	43.52	40.08	43.95

From table above, the largest percentage of errors at 90 KV is 43.08% for 80 cm distance, and the smallest at 50KV setting at 1.59%. From table above, the largest percentage of errors at 90 KV is 42.97% for 100 cm distance, and the smallest at 50KV setting at 1.90%. From table above, the largest percentage of errors at 90 KV is 43.53% for 120 cm distance, and the smallest at 50KV setting at 0.07%. From table above, the largest percentage of errors at 90 KV is 40.08% for 130 cm distance, and the smallest at 50KV setting at 1.68%. From table above, the largest percentage of errors at 90 KV is 43.95% for 140 cm distance, and the smallest at 50KV setting at 7.99%.

3) Comparison Graphic

Graph of tube voltage measurement (KV) comparison between modules with comparison at a distance of 80 cm with 1S time shown in the image FIGURE 5. Graph of tube voltage measurement (KV) comparison between modules with comparison at a distance of 100 cm with 1S time shown in the image FIGURE 6. Graph of tube voltage measurement (KV) comparison between modules with comparison at a distance of 120 cm with 1S time shown in the image FIGURE 7. Graph of tube voltage measurement (KV) comparison between modules with comparison at a distance of 130 cm with 1S time shown in the image FIGURE 8. Graph of tube voltage measurement (KV) comparison between modules with comparison at a distance of 140 cm with 1S time shown in the image FIGURE 9.

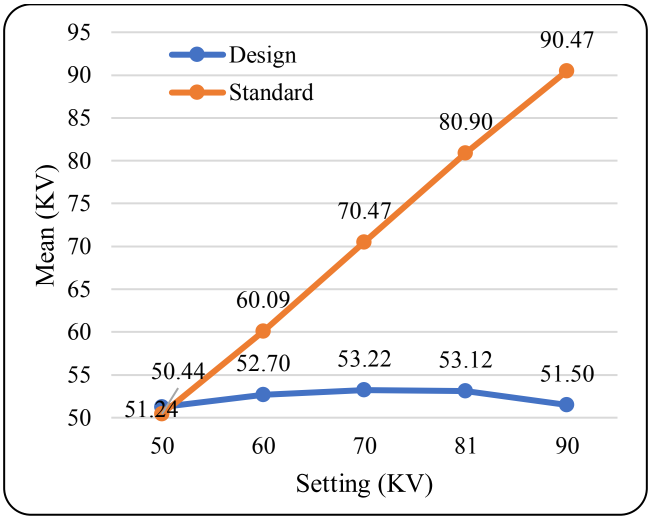

FIGURE 5. KV Comparison Graph of Modules with Comparisons (Distance 80cm 1S)

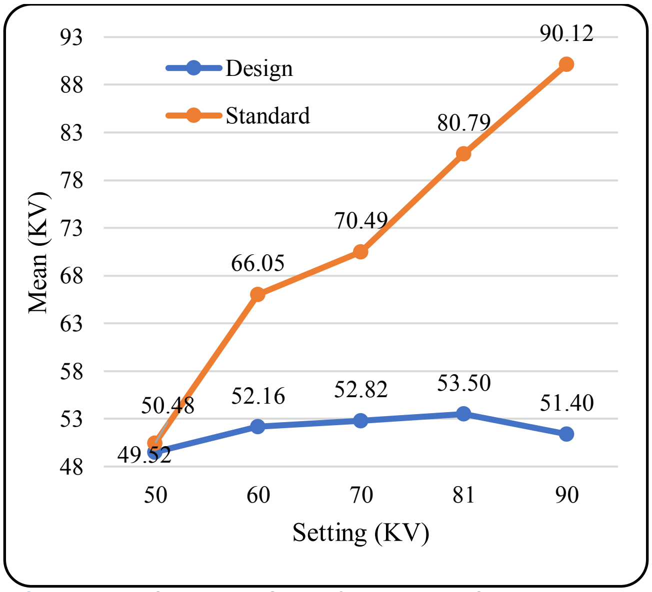

FIGURE 6. KV Comparison Graph of Modules with Comparisons (Distance 80cm 1S)

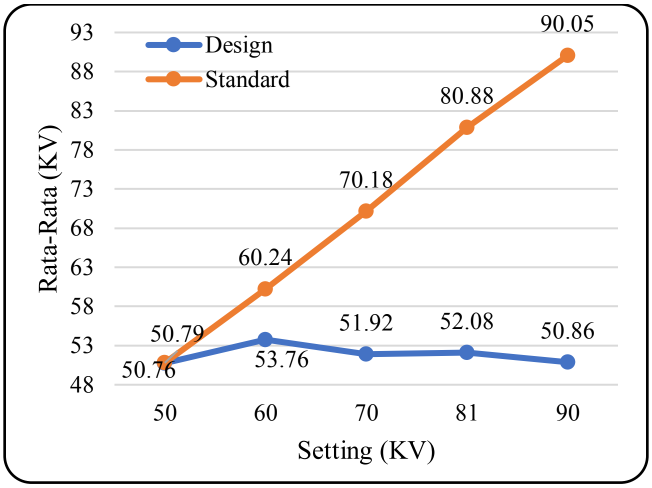

FIGURE 7. KV Comparison Graph of Modules with Comparisons (Distance 120cm 1S)

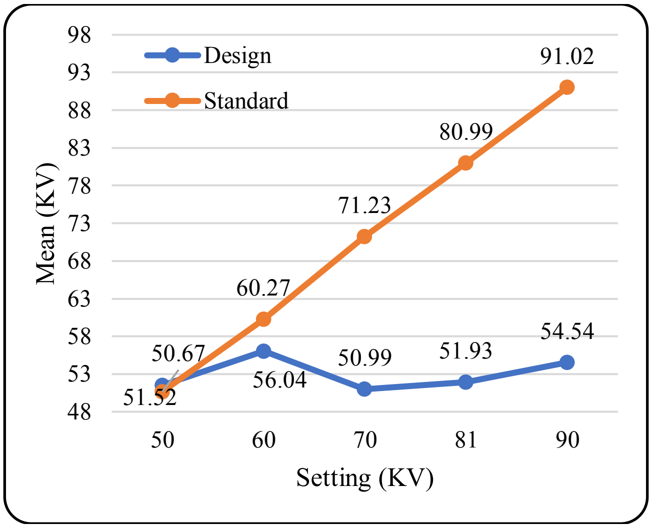

FIGURE 8. KV Comparison Graph of Modules with Comparisons (Distance 130cm 1S)

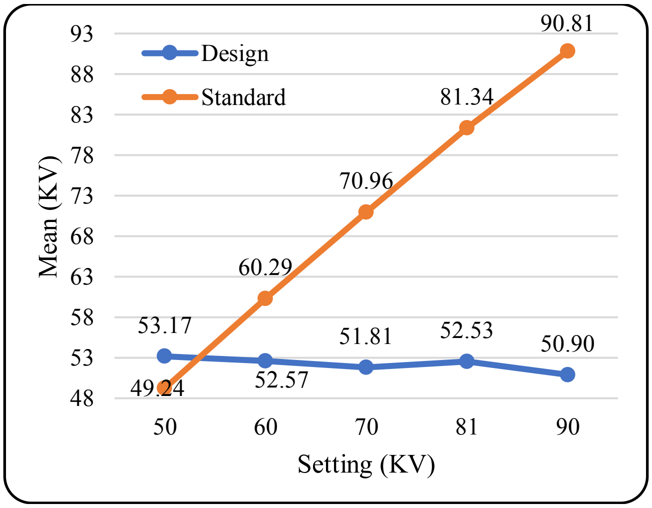

FIGURE 9. KV Comparison Graph of Modules with Comparisons (Distance 140cm 1S)

IV. DISCUSSION

The KV Meter design using scintillator detector has been examined and test completely in this study. Based on the measurement of KV on each setting (50KV, 60KV, 70KV, 81KV, and 90KV) and each distance (80cm, 100cm, 120cm, 130cm, and 140cm) at a 10x10cm collimation area and compares with a calibrated comparison tool (dosimetry Piranha). From the data that has been taken, the Scintillator sensor works optimally on KV 50 at a distance of 120cm, can be seen in TABLE 2 error value of only 0.07%. The result produced by the module at distances of 80cm, 100cm, 120cm, 130cm and 140cm indicates that the higher the tube voltage setting, the higher the error read on the module. So that data analysis is taken at the tube voltage setting of 50Kv because the output is most stable by comparison.

V. CONCLUSION

The purpose of this study is to analyze the effect of irradiation distance on tube voltage measurement and X-ray device time using a Scintillator. The final result produced by the module at distances of 80cm, 100cm, 120cm, 130cm and 140cm indicates that the higher the tube voltage setting, the higher the error read on the module. To improve this study can be done by some modification such as, modifying the size of the tool to be easy to carry and store and improving the error value to be more accurate by increasing the voltage of the PMT sensor plant to 2000VDC and using a transformer that has good stability, so that the voltage does not drop when given a load. For future research it is expected to modify the size of the tool to be easy to carry and store and improve the error value to be more accurate by increasing the voltage of the PMT sensor plant to 2000VDC and using a transformer that has good stability, so that the voltage does not drop when given a load.

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ATTACHMENT

https://drive.google.com/drive/folders/1OqaP7iKkinRrrSpYC3Qjm8sKa4Byh0T3?usp=sharing