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# Analysis of X-Ray Beams Irradiation Accuracy Using Collimation Test Tools as Well as Illumination Measurement on the Collimator to the Radiographic X-Ray Machine Conformity Test Results

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**ABSTRACT** In the Suitability Test Method there is the Illumination and Collimation Test still using the manual method. This test aims to ensure that the light from the collimator lamp can be seen clearly so that the area of the irradiation field can be identified when irradiating, as well as ensuring that the area of the collimator lamp matches the X-ray beam so that it meets the needs and ensures that the patient does not get an excessive dose. The purpose of this research is to develop the simplest way by which the illumination measurement is carried out simultaneously at four points and the measurement data is directly stored. The contribution of this research is expected to be more testing tools and the data will be stored until the effective time of the next test. This module is designed using the HC-SR04 sensor as a distance meter and the TSL2561 sensor as a lux meter. The TSL2561 sensor allows for precise Lux calculations and can be configured for different gain/timing ranges to detect light ranging from 0.1-40,000+ Lux on the fly. This module is equipped with a display facility in the form of TFT Nextion to display measurement results. In addition, there is also data storage using an SD Card to store display measurement results. In this research, the module has been tested and compared with the suitability test value of the X-ray plane and got an error value of 2.0% with a module efficiency of 98.0% in the illumination test, and an error of 2.2% with a module efficiency of 97.8% in the collimator test. From this research, it can be concluded that the light sensor TSL2561 can be used to measure the illumination area of the collimator lamp.

**INDEX TERMS** TSL2561, HC-SR04, Lux

## I. INTRODUCTION

Testing of the function or performance of X-ray aircraft must be carried out by the facility owned by the Radiation Safety Standards of the International Nuclear Power Agency (IAEA).[1]. In the process of testing the function or performance of X-ray, aircraft must meet the standards of Conformity Test as stipulated in BAPETEN Regulation No. 2 of 2018.[2]. Diagnostic and interventional radiology X-ray aircraft suitability tests need to be optimized for radiation safety for patients, radiation workers, and the public.[3] In the Conformity Test method, there is an Illumination and Collimation Test that aims to ensure that the light from the collimator lamp can be clearly seen so that the area of the irradiation field can be identified at the time of irradiation, as well as ensuring that the area of the collimation lamp is by the X-ray beam so that it is by the needs and ensures the patient does not get excessive radiation doses.[4][5] The danger of excessive doses of radiation X-rays higher than 50 Gy can damage the central nervous system causing death that occurs within a few days, if the patient receives a dose lower than 8 Gy,[4][6] pesien will show symptoms of radiation sickness also known as acute radiation syndrome, which can include nausea, vomiting, diarrhea, intestinal cramps, saliva, dehydration, fatigue, apathy, lethargy, sweating, fever,

headache, and low blood pressure.[7][8]. The collimation test to ensure the irradiation area by the X-ray beam is carried out using Collimation Tools and illumination measurements are carried out at a distance of 100cm from the focal spot in four measurement areas using a Lux Meter.[9][10] Previously, the illumination test with Lux Meter took a long time to measure illumination at four points of the measurement area, namely area I, II, III, and IV, because lux meters only have one light sensor and can only display measurements at one point and must be done alternately.[11][12] Measurement results on the Lux Meter also cannot be stored and must be recorded and documented manually causing data collection errors due to human errors.[13]. Collimation and illumination testing are parameters that affect the accuracy of X-ray file irradiation with a maximum error of ≤2% SID and the minimum illumination is ≥100 Lux.[14][15].

L. R. Bridge and J. E. Ison in 1995 conducted a value survey and illumination testing techniques of several patient examination data to determine efficient illumination values and the results of this study put the average measurement values for S&chr and mobile X-Ray are 123 Lux and 141 Lux.[16]. In 2010 C.C. Nzotta and C. Anyanwu asserted that the parameters of collimation and illumination are parameters that must be tested periodically because the large deviation of X-ray beams shows the nonconformity of the light of the combinator light to the X-ray beam and the standardization of the minimum illumination value of ≥100 Lux.[17]. In 2011, M. Begum conducted a quality control test on an X-ray aircraft with a beam alignment test tool to measure the literary area of focal spots, screen contact films, and HVL. [18]. In 2017, A. S. Moi et al., conducted a conformity test of collimation measurements on examination of thorax that is considered to have important body parts. [19].

I. Jwanbot, et al., conducted a sublimation test using beam alignment tools and HVL on several X-ray aircraft in a region, and from the data obtained there are X-ray aircraft whose performance is not by IAEA standards. [20]. A, J. A. Kareem, S also researched the suitability of the performance of the tool to the specified standards, in this study seven tests (beam alignment, beam collimation, reproducibility, kV accuracy, time accuracy, half-value layer (HVL), and leakage) were carried out so that the results of the test could be used as records of the owner of the X-ray aircraft for adjustment or improvement to the tool. [21].

To measure and analyze the illumination of the concentrator lights on an X-ray plane, a measuring device is needed called a Lux Meter. Jawaaz Ahmad, Romana Yousuf has designed a Lux Meter using LDR as a sensor.[22]. In 2007 A.D. I. Titi Andriani examined illumination measurements using Lux Meters at four points alternately in the vast field of light of conventional X-ray aircraft to determine the feasibility of the X-ray aircraft. X-ray output must correspond to the light of the concentrator light during testing, the magnitude of the deviation of the X-ray beam indicates the nonconformity of the light of the collimator light with the X-ray beam[23]. As technology developed in 2018, Made Satriya and I Ketut made a digital Meter based on light sensors whose measurements are displayed on LCDs can be used to measure illumination.[24].

Based on the research literature above, illumination measurements still use a method manually, which uses an illumination measuring instrument with one sensor which then the results are recorded manually and measurements are taken alternately at four measurement points. So the author wants to create a tool and perform "Accuracy Analysis of X-Ray File Irradiation Using Collimation Test Tools as well as Illumination Measurements In The Collimator Against the Results of X-Ray Radiographic Aircraft Conformity Tests". Because in testing in the field the illumination is carried out at four different points according to the division of the area of the collimation. If these measurements are done simultaneously at four points and the measurement data is directly stored it will be able to minimize the measurement time and human error at the time of recording. From the measurement and storage of this data, it is expected that the tool's testing data will remain stored until the next testing time.

## II. MATERIAL AND METHODS

### A. EXPERIMENTAL SETUP

For the test of lux values that are read on the display is done using a radiographic x-ray aircraft as the next input of the results read on the module compared to digital light meter tools.

#### 1) MATERIALS AND TOOL

The study used a Digital Light Meter with the Kyoritsu model 5202 as a tool to compare results. The TSL2561 sensor is a sensor for reading lux values and the HC-SR04 sensor is a sensor for reading the distance between the module and the focus of the x-ray tube. Both sensors are connected to Arduino as microcontrollers to process data and are then displayed on the Nextion TFT.

#### 2) EXPERIMENT

In this study, researchers placed modules at a distance of 100 cm from the focus of the x-ray tube. Then turn on the litlimator light beam with an area of about 25x25 cm and place the module just below the beam. Then reduce the light in the space too dark and start to measure. The results of the module will be compared to the comparison tool that is a digital light meter.

### B. THE DIAGRAM BLOCK

The system starts working when the device is on. Arduino Mega microcontrollers will initialize connected hardware including TFT Nextion, SD Card, HC-SR04 Distance Sensor, and TSL2560 Light Sensor. The HC-SR04 Distance Sensor measures the distance or focal height of the concentrator to the bucky table (FFD), and the TSL2560 Light Sensor will measure the intensity of light with Lux units. The Arduino Mega microcontroller processes the sensor readings and displays them on the Nextion TFT. The results of the distance sensor readings and light sensors will be stored on the SD Card so that the measurement results that have been done can be seen again if one day needed. These steps can be viewed in Fig 1.

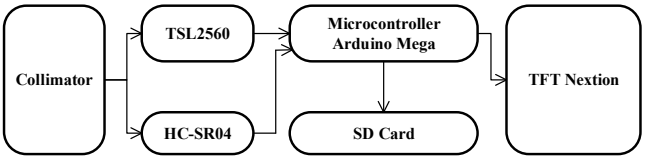


FIGURE 1. The diagram block

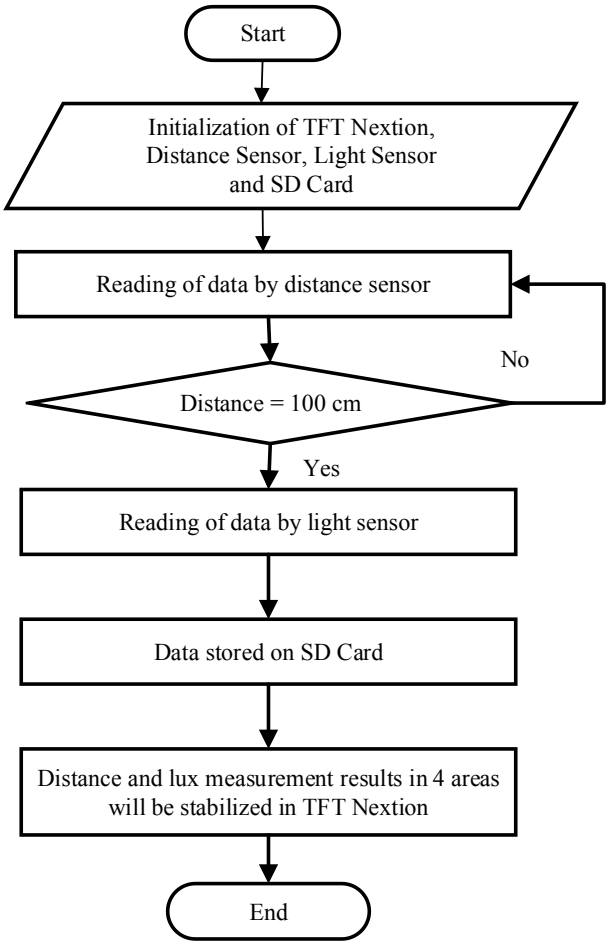


FIGURE 2 The Flowchart of Programs

### C. THE FLOWCHART

The flowchart is based on fig 2. When the tool is turned on it starts with initialization. The distance sensor will read the distance, when the distance is appropriate which is 100 cm then the light sensor will work and detect the lux value. If the distance has not reached exactly 100 cm, then set the distance between the module and the x-ray device so that the distance is appropriate. Then the data read by the sensor will be stored on the SD card and displayed on the Nextion TFT.

### D. ANALOG NETWORK

#### 1) CIRCUIT ON ARDUINO

This circuit is an image of the entire series of modules created. The series consists of the Multiplexer TCA9548A, the HCSR04 distance sensor, the micro SD module, the TFT Nextion, and Arduino mega.

#### 2) MULTIPLEXER

The circuit is connected to 4 TSL2561 light sensors. The output of the 4 sensors becomes the input on the microcontroller by passing through the multiplexer as a link between the sensor and the Arduino mega 2560 on the SDA and SCL pins.

## III. RESULT

In this study, the modules have been tested using a Digital Light Meter. The results of the examination show that the results of the examination can be used as a comparison.

### A. Module Design

This section consists of four light sensors, each of which has a different value to display on the Nextion TFT. Furthermore, the circuit section consists of the Arduino Mega 2560 microcontroller which is the main board, the micro SD Card module is used for data storage of inspection results and TFT Nextion on FIGURE 3.

### B. Nextion TFT Results View

This module uses a TFT Nextion display that can display lux value readings and reading distances in real-time. The use of touch screens on TFT Nextion is more effective because it does not require external buttons to carry out the functions of this module. Everything is available on the screen and the display is wider so that it can display results more clearly as in FIGURE 3.


FIGURE 3. Nexion TFT View

### C. STORAGE RESULTS

This module features storage stored in an SD Card with a txt format. The data in that format presents reading distance data between the tool and the concentrator and sensor readings 1 to 4 that can be processed into graph data in the Ms. Excel application. Through the data stored in the SD Card contained in the module, it can make it easier for users to know the lux value contained in the collimator. This storage is also expected to make it easier for users to see or review the results of the measurement of lux values in the collimator.

### D. LUX VALUE MEASUREMENT RESULTS ON MODULES COMPARED TO DIGITAL LIGHT METER TOOLS

Lux value testing and measurement were conducted with Digital Light Meter under kyoritsu model 5202. Before taking measurements set the distance between the module and the collimator by 100 cm. From the test results can be seen the

largest error value of 2.2% on sensor 2 and the lowest error value of 0.0% on sensors 1 and 4. With an average error in sensor 1 by 0.44%, sensor 2 by 1.23%, sensor 3 by 1.17%, and sensor 4 by 0.7% (TABLE 1, TABLE 2, TABLE 3 and TABLE 4).

**TABLE 1**
**Measurement Results on Sensor 1**

| No. | Comparison (Lux) | Modul (Lux) | Error (%) |
|---|---|---|---|
| 1. | 152 | 151 | 0.66 |
| 2. | 150 | 149 | 0.67 |
| 3. | 148 | 148 | 0.00 |
| | Average | | 0.44 |

**TABLE 2**
**Measurement Results on Sensor 2**

| No. | Comparison (Lux) | Modul (Lux) | Error (%) |
|---|---|---|---|
| 1. | 135 | 132 | 2.2 |
| 2. | 134 | 133 | 0.7 |
| 3. | 130 | 129 | 0.8 |
| | Average | | 1.23 |

**TABLE 3**
**Measurement Results on Sensor 3**

| No. | Comparison (Lux) | Modul (Lux) | Error (%) |
|---|---|---|---|
| 1. | 138 | 136 | 1.4 |
| 2. | 140 | 139 | 0.7 |
| 3. | 139 | 137 | 1.4 |
| | Average | | 1.17 |

**TABLE 4**
**Measurement Results on Sensor 4**

| No. | Comparison (Lux) | Modul (Lux) | Error (%) |
|---|---|---|---|
| 1. | 149 | 149 | 0.0 |
| 2. | 145 | 145 | 0.0 |
| 3. | 145 | 142 | 2.1 |
| | Average | | 0.7 |

## IV. DISCUSSION

From this research, it can be known that this module can be used to show the value of lux readings of light. The module consists of the TSL2561 light sensor which is used to read the lux values found in the collimator. The output of the sensor will be connected via the TCA9548A multiplexer to finally enter the Arduino. The system starts working when the device is on. Arduino Mega microcontroller will initialize connected hardware including TFT Nextion, SD Card, HCSR04 Distance Sensor, and TSL2560 Light Sensor. The HC-SR04 Distance Sensor measures the distance or height of the focus of the collimator to the bucky table (FFD), and the TSL2560 Light Sensor will measure the intensity of light with Lux units. The Arduino Mega microcontroller processes the sensor readings and displays them on the Nextion TFT. This module is also equipped with an SD Card module that is used as a place for SD Card as a data storage medium of measurement results in this module. The results of the distance sensor readings and light sensors will be stored on the SD Card so that the measurement results that have been done can be seen again if one day needed. This module is equipped with a display using TFT Nextion that can display lux measurement results and distances in real-time. TFT Nextion is used. It is more effective because it does not require external buttons to perform the functions of this module. The controls on the module can be done directly on the nextion touch screen and the display is wider so that it can display results more clearly. In research, the module has been tested and has the highest error rate of 2.2% and the lowest worth of 0.0% against the comparison tool. In this study has the disadvantage of the straightness of the X-ray tube that is still unclear, and also in the storage of data in SD car can not be connected to the worksheet and sensor readings are still high.

## VII. CONCLUSION

Based on the results of planning, module creation, writing, and analysis of data can be concluded in the design of lux meter using tSL2561 light sensor as many as four pieces to measure illumination in the area of the lighting field of the collimator with a size of 25x25cm consisting of areas I, II, III, and IV, The Lux Meter design also uses the HC-SR04 distance sensor to determine the height between the collimator (focal spot) and the bucky table, Data retrieval according to the protocol or working method of test suitability of radiographic x-ray aircraft, The results of distance/height measurement between the collimator with bucky table and the measurement of illumination in areas I, II, III, and IV will be displayed on the TFT LCD, Creation of Collimator Test Tools from PCB for measurement of the accuracy of irradiation and the firmness of X-ray beams. The study found a gap between expectations and reality at the time of data retrieval. For the development of further research can be done the addition of water passes to ensure the straightness of X-ray tubes, there is an illumination test module that has been made can only be done data storage on SD-card, but cannot be done connection to the conformity test worksheet (Excel). For further research, programs can be added for connections to worksheets, in order to minimize human error, replacing light sensors with sensors that have a lower reading range.

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# APPENDIX

### E. Program Listing for Arduino

In this article, the software uses Arduino programming. The listing program for Arduino is shown in Program Listing 1. Which consists of a program for the reading of light sensors.

```
1.  TCA9548A(0);
2.  TSL2561 tsl(TSL2561_ADDR_FLOAT);
3.  tsl.setGain(TSL2561_GAIN_16X);
4.  sl.setTiming(TSL2561_INTEGRATIONTIME_13MS);
5.  uint16_tx=tsl.getLuminosity(TSL2561_VISIBLE);
6.  uint32_t lum = tsl.getFullLuminosity();
7.  uint16_t ir, full;
8.  ir = lum >> 16;
9.  full = lum & 0xFFFF;
10. nilaisensor = tsl.calculateLux(full, ir) * 1.058 ;
11. IF (nilaisensor == 161) {
12. nilaisensor = 0;
```

### F. Distance sensor reading program

This program is a distance activation program that enters through the HC-SR04 Sensor by providing HIGH and LOW logic on echo and trigger pins. In addition, there is also a distance reading command from the sensor to start the reading of the light sensor with a certain distance can be seen in program listing 2.

```
1.  digitalWrite(trigPin, LOW);
2.  delayMicroseconds(2);
3.  digitalWrite(trigPin, HIGH);
4.  delayMicroseconds(10);
5.  digitalWrite(trigPin, LOW);
6.  duration = pulseIn(echoPin, HIGH);
7.  distance = duration * 0.034 / 2; // Speed of sound wave
8.  divided by 2 (go and back)
9.  duration = duration*100;
10. dstnc = (distance* 1.375) - 2;
11. Serial.print("Distance: ");
12. Serial.print(dstnc);
13. Serial.println(" cm");
```

### G. Program Listings for Results Storage

Storage program on SD Card when the measurement is taken. The data in that format presents reading distance data between the tool and the concentrator and sensor readings 1 to 4 that can be processed into graph data in the Ms. Excel application. in Program Listing 3.

```
1.  myFile = SD.open("DATA.txt", FILE_WRITE);
2.  IF (myFile) {
3.  Serial.println(" Simpan data");
4.  Serial.println("file->DATA.txt");
5.  myFile.print("Jarak: ");
6.  myFile.print(dstnc);//sensor 5
7.  myFile.print(" ; 1:");
8.  myFile.print(average);//sensor 1
9.  myFile.print(" ; 2:");
10. myFile.print(average1);//sensor 2
11. myFile.print(" ; 3:");
12. myFile.print(average3);//sensor 3
13. myFile.print(" ; 4:");
14. myFile.println(average2);//sensor 4
15. myFile.close();
```