Effect of SSD and absorbing filter in calibration process of Thermo Luminescence Dosimeter TLD-700

W B Nurdin¹, Aswad² and K Bariah²

¹Department of Physics, Hasanuddin University, Makassar 90245, South Sulawesi, Indonesia
²Center for Health Facility Security (BPFK) Makassar, South Sulawesi, Indonesia

Abstract. It had been carried out the study about effect of the skin source distance (SSD) and absorbing filter in the calibration process of Thermo Luminescence Dosimeter TDL-700. This effect used the analysis of dose radiation from output using Cs-137 in the calibration process of TLD-700. The calibration process used different measurement at an SSD of 100, 150, 200, and 250 cms and different scales of 0.1, 0.5, 1.0, 3.0 and 5.0 mSvs, respectively. We found that the larger the radiation source used, the greater exposure dose were accepted. Dose radiation output from source Cs-137 source values obtained optimal dose in distance 200 cm absorbed by using filters. The results of the measurement of the output dose using variation of SSD and the variation of absorbed filter on TLD-700 calibration showed that the value of dose that have deviation with the predicted dose less than 6.0%. The measurement of radiation output dose with Cs-137 source on TLD-700 calibration process shows that the larger required dose at the time of irradiation, the greater the radiation time should be given. Radiation measurement of Cs-137 source without absorbed filter is very high so that the irradiation time is relatively short. This is because the radiation emitted by the Cs-137 source is directly absorbed by the TLD-700 during irradiation.

1. Introduction

Calibration process of radiation measuring instrumentation should always regularly conducted to ensure that they produce correct and accurate reading with tolerated uncertainties and to comply with the regulation given by authorities. Therefore, to reduce the negative effects, it is needed to be applied the provision of radiation safety and security of radioactive sources which were regulated in Indonesia with the Government Regulation No. 33 in 2007 on Radiation Safety and Security of Radioactive Sources, which aims to protect workers, the public and the environment from radiation hazards [1]. One widely used equipment for measurement of personal radiation is thermoluminescence dosimeter (TLD). It is a provision that any radiation measuring devices must be calibrated periodically. This was done to test the accuracy of the displayed value to the value of the actual tool. The difference between the displayed value and the actual should be corrected by a parameter called calibration factor [2]. In measurement process, the displayed value must be multiplied by a factor instrument calibration. A radiation measuring instrument is calibrated by comparing the results of the measuring instrument readings with the standard measuring tools. TLD is used as a tester against radiation dose variation, variation range, and absorbed filter [3].

In order to get an accurate scale reading for the TLD, it must be calibrated before being used. Calibration source to be used is Cs-137. This calibration is done routinely at specified intervals or periodically, as for Varian CX Linear accelerator [4]. TLD is used to measure the dose of gamma radiation, X-rays and beta and neutron. Thermo luminescence (TL) is a luminescence phenomenon that can be observed when the solid material receives heat stimulation. At TL, the intensity of
luminescence is proportional to the ionizing radiation energy absorbed prior phosphor material. At the
time of the reading process, TLD that receives heat will cause the trap to be empty of electrons
trapped. Electrons are still trapped can be emptied by annealing. In the process of reading TLD with
the reading time short and high heating rate, the electrons in stable traps or pitfalls in not entirely
cleaned. Additional dosimeter reading process will yield curve that can be used as dosage information
after dosimeters are exposed to ionizing radiation. In this paper, we are going to find the optimal
distance between source and phantom and absorbing filter influencing the output dose from x-ray
radiation with Cs-137 source in calibration process of thermoluminescence dosimeter TLD-700, to
complete the experiment and simulation data like in [6].

2. Methods and Material
Irradiator with a source of Cs-137, IBT Model 103 had 5 pieces filter absorber made of lead (Pb). This
irradiator was made by BATAN Indonesia. The dosimeter, Merk NE Model 2676, is a type of detector
which is a ionizing chamber with volume of 600 cc, were used to measure the output source of Cs-13.
TLD 700 for individual dosis measurement. Reader TLD Merk Harshaw Type 6600 Plus was used for
reading the exposure dose received by TLD. Cameras and CCTVs are used to monitor the room. Laser
infrared function was used to determine the focal point of radiation The phantom was used as a
substitute for the human body. Meter was used to measure determine the distance between source and
skin (phantom) SSD [5]. Procedure of the measurements were done like follows. After tools and
materials prepared, the stability was checked by determining the air kerma with Cs-137 source. Later
the exposure time was calculated and irradiation TLD-700 with radiation sources Cs-137 with a
variety of distances and absorbed filter were measured. There are six conditions of filters fut in the
experiments, the first is without filter (called None) and the others with different number of filters. In
the Tables they are called Abs 1, Abs 2, Abs 3, Abs 4, Abs 5 due to number of filters used. The
calibration of TLD-700 used the tool TLD reader Harshaw 6600 Plus shown in Figure. 1.
Algorithms for effective dose calculation for personnel dosimetry need limited knowledge of the composition of the radiation field. Response of the dosimeter given in these algorithms is used to determine the type of radiation field and to apply the appropriate calibration factor to convert the indicated value to the value of the measured quantity, the dose equivalent. A algorithm was developed based on neural-network dose for one dosimeter, and a similar algorithm was developed for multi-element dosimeter. In the application of neural networks to personnel dosimetry, the inputs of the training pairs are the TL signals from the various elements, and the outputs are the deep dose equivalent. The input/output training sets are generated by exposing dosimeters to a variety of mixed photon and beta fields. The exercising set consists of energies varied as well as mixture types. As the variability of the type of exposures increase in the training set, it will improve the learning process and usually results in a ‘cleverer’ network, leading to a more accurate algorithm. During the process, the signals from TL measured by the TLD to provide to the input layer, and the desired outputs are given to the output layer of the network. A dosimeter with four-element had the amount of information available as input to the network that is very limited. It consists of indicated values that form ratios from three independent number. This tiny amount of input information limits the capability of the dose algorithm both in accuracy and the variability of dose calculation problems it can solve. The irradiation time of each could be determined using the formula used in [6]

\[
T \ (hr) = \frac{D}{Hp(10)} \tag{1}
\]

where \(T\), \(D\) and \(Hp(10)\) are the irradiation time in hours, doses and conversion factor.

Deviation (\(\delta\)) of predicted dose \(D_p\) that is gained from calculated time from dose from Cs-137 and measured dose \(D\) using TL-700 is defined as

\[
\delta = \left| \frac{D - D_p}{D} \right| \times 100\%. \tag{2}
\]

3. Results and Discussion

Each measurement began with an early stability check in order to know the stability of the tools. The measurement tool were defined to be stable if they have the deviation of the value less than 1%. The total measurements gave average value of the stability with the value of 0.54% which means that the measurement tools were stable. Then the measurements of the rate of air kerma with Cs-137 source were performed for each absorbed filter. The results from the measurement were shown in Table 1 - 4. In these tables, the first row (none) is conditions without filter, meanwhile rows Nr. 2 – 6 are the conditions for measurement with 1, 2, 3, 4, or 5 filters respectively.

| Nr. | Absorption | Average Output (nC) | Air Kerma Rate (mGy/h) | Hp(10) (mSv/h) |
|-----|------------|---------------------|------------------------|----------------|
| 1   | None       | 7.9298              | 24.8409                | 30.0575        |
| 2   | Abs 1      | 0.3330              | 1.0440                 | 1.2633         |
| 3   | Abs 2      | 0.6909              | 2.1642                 | 2.6186         |
| 4   | Abs 3      | 0.8700              | 2.7254                 | 3.2977         |
| 5   | Abs 4      | 0.8103              | 2.5384                 | 3.0714         |
| 6   | Abs 5      | 0.5698              | 1.7851                 | 2.1600         |
Table 2: Rate of Air Kerma Tools (SSD = 150 cm)

| Nr. | Absorption | Average Output (nC) | Air Kerma Rate (mGy/h) | Hp(10) (mSv/h) |
|-----|------------|---------------------|------------------------|----------------|
| 1   | None       | 3.5447              | 11.1050                | 13.4369        |
| 2   | Abs 1      | 0.3202              | 1.0030                 | 1.2141         |
| 3   | Abs 2      | 0.3039              | 0.9520                 | 1.1516         |
| 4   | Abs 3      | 0.3910              | 1.2250                 | 1.4825         |
| 5   | Abs 4      | 0.3623              | 1.1350                 | 1.3718         |
| 6   | Abs 5      | 0.2375              | 0.7440                 | 0.9001         |

Table 3: Rate Of Air Kerma Tools (SSD = 200 cm)

| Nr. | Absorption | Average Output (nC) | Air Kerma Rate (mGy/h) | Hp(10) (mSv/h) |
|-----|------------|---------------------|------------------------|----------------|
| 1   | None       | 1.9407              | 6.0800                 | 7.3570         |
| 2   | Abs 1      | 0.1756              | 0.5500                 | 0.6657         |
| 3   | Abs 2      | 0.1657              | 0.5190                 | 0.6283         |
| 4   | Abs 3      | 0.2151              | 0.6740                 | 0.8155         |
| 5   | Abs 4      | 0.1982              | 0.6210                 | 0.7112         |
| 6   | Abs 5      | 0.1267              | 0.3970                 | 0.4809         |

Table 4: Rate Of Air Kerma Tools (SSD = 250 cm)

| Nr. | Absorption | Average Output (nC) | Air Kerma Rate (mGy/h) | Hp(10) (mSv/h) |
|-----|------------|---------------------|------------------------|----------------|
| 1   | None       | 1.2621              | 3.9540                 | 4.7846         |
| 2   | Abs 1      | 0.1124              | 0.3520                 | 0.4260         |
| 3   | Abs 2      | 0.1095              | 0.3430                 | 0.4149         |
| 4   | Abs 3      | 0.1392              | 0.4360                 | 0.5272         |
| 5   | Abs 4      | 0.1293              | 0.4050                 | 0.4896         |
| 6   | Abs 5      | 0.1267              | 0.3970                 | 0.3062         |

From Table 1 – 4, a graph can be created like in Figure 2 that showed the air kerma rate of different absorption condition as the function of distance. Inset shows details of graphs from data using all filter absorption. Both graph show exponential declining of rate air kerma, but for measurement with filter absorption, the graph shows almost steady functions, as depicted in inset in Fig. 2.

To determine time required for the actual exposure had delivered a known dose to dosimeters, there is a correction factor needed. It is while Cs-137 facing radioactivity and the initial activity having an exponential decays. For every exposure, the parameter in the laboratory was measured and recorded including pressure, relative humidity and temperature. All the calculation involving Cs-137 source, first calculate kerma rate at the location, before determining the exposure time. After measuring the exposure, the values from experiments were collected and analyzed to have the collimation narrow beam geometry. The result of measurement of radiation output dose with Cs-137 source on TLD-700 calibration process shows that the bigger dose required at the time of irradiation, the greater the radiation time should be given. These can be seen in Table 5. The results of the measurement of the output dose using variation of SSD and the variation of absorbed filter on TLD-700 calibration showed in Table 6. It can be seen that the deviation of measured dose with TDL-700 with the predicted Cs-137 dose is less than 6.0%.
Figure 2. Air kerma rate of different absorption condition as the function of SSD. Insert shows details of graphs from data using all filter absorption.

### Table 5: Irradiation Time for calculated Doses (Sec)

| SSD (cms) | Measured Dose (mSv) |
|-----------|---------------------|
|           | 0.1 (mSv) | 0.5 (mSv) | 1.0 (mSv) | 3.0 (mSv) | 5.0 (mSv) |
| 100       | 16        | 64        | 124       | 353       | 593       |
| 150       | 31        | 138       | 273       | 808       | 1344      |
| 200       | 53        | 249       | 493       | 1472      | 2451      |
| 250       | 79        | 380       | 756       | 2261      | 3766      |

### Table 6: Deviation of Measured Doses (δ) to Calculated Dose (D)

| SSD (cms) | Deviation of Measured Dose (mSv) |
|-----------|----------------------------------|
|           | 0.1 | 0.5 | 1.0 | 3.0 | 5.0 |
| 100       | 3.2%| 2.1%| 2.3%| 3.4%| 4.1%|
| 150       | 3.1%| 4.4%| 3.2%| 3.5%| 4.1%|
| 200       | 2.1%| 2.3%| 3.2%| 3.1%| 3.2%|
| 250       | 3.4%| 4.3%| 5.1%| 6.0%| 6.0%|

### 4. Conclusion

In calibration process the sources of uncertainties and estimated values comes from the factors that may affect all uncertainty including factors form environment like fading, residual signals, light sensitivity, contamination temperature and humidity, uncertainty in the TLD and the accuracy of the traceability of the system to a primary standard. A study to determine the overall uncertainty of dose measurements using this system had been conducted by the US Navy [6]. The results that the following contributing factors to the all uncertainty: reader calibration 5.0%, source traceability 5.0%, light sensitivity 2.5%, fading 2.0%, and residual signal 0.3%. By summing all
these factors, a total estimate of all uncertainty reached 10.5%. From these analysis it can be shown that from all factors that can contribute the measurement uncertainty, the total case scenarios results uncertainty of 10.5%. This means that the measurements are only accurate to within 10.5%, and that a measurement could be off by as much as 10.5% if all the possible contributing factors had error under normal condition, happened at the same time and direction. The uncertainty in practical is usually much smaller and a set of dosimeters that were exposed to the same dose had variation of readings only 1–2% [6].

The results of the measurement of the output dose using variation of SSD and the variation of absorbed filter on TLD-700 calibration showed that the value of dose that have deviation with the predicted dose less than 6.0%. The result of measurement of radiation output dose with Cs-137 source on TLD-700 calibration process shows that the bigger dose required at the time of irradiation, the greater the radiation time should be given. The result of radiation measurement of Cs-137 source without absorbed filter is very high so that the irradiation time is relatively short. This is because the radiation emitted by the Cs-137 source is directly absorbed by the TLD-700 during irradiation.

5. References
[1] Indonesian Government Regulation No. 33, 2007, On Safety of Ionizing Radiation and Radioactive Source Security.
[2] Behrens, R. and Ambrosi, P., 2008, Radiation Protection Dosimetry 128, 159–168.
[3] Luo, L. Z., 2008, Radiat. Meas. 43, 365–370.
[4] Nurdin WB, Purnomo A., Dewang S, 2018, Journal of Phys. Conf. Series 979, 012076.
[5] Delzer JA, Hawley JR, Romanyukha, A, 2008, Radiat. Prot. Dosim. 131, 2008, 279–286.
[6] Moscovitch M, John, TJ, Cassata, JR, 2006, Radiat. Prot. Dosim. 119, 2006, pp. 248–254.
[7] Nunn, AA, Davis, SD, Micka, JA, De Werd, LA, 2006, Med Phys., 35 (5), May.