Study on The Characteristics of TLD-700H (LiF:Mg, Cu,P) For Eye-Lens Dosimeter

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Abstract. *The method used for testing the characteristics of TLD-700H is based on ISO 12794/2000. According to the Regulation of BAPETEN Head No. 4/2013, monitoring of eye lens dose should be implemented in March 2016 for radiation workers who work in special places such as interventional radiology, nuclear medicine, beam ports, glove box and cardiology and for the work area that requires dose monitoring more intensive for the eye-lens dose of radiation workers. This is due to the change on the recommendation of ICRP No. 103 for radiation dose to the eye-lens, Hp (3). The uniformity of TLD-700H was investigated by irradiating TLD-700H using* ^{90}Sr *beta source at a dose of 0.34 mSv and was fairly uniform, with a standard deviation of 1.65% (CL: 67%). The response of TLD-700H to the X-ray at W (80) with the variation of angle of incidence was :* $R(\Theta) = -0.0943\Theta^2 + 0.4583\Theta + 326.2$; $r = 0.914$. *Calibration curves of TLD-700H for X-ray at N(80) , N(100) and N(120) are* D_m *(mSv) = 0.0289 R+ 0.0082 with r = 0.9993,* D_m*(mSv) = 0.0404 R - 0.0303 with r= 0.9998, and* D_m *(mSv) = 0.0357 R+ 0.1706 with r = 0.9987 consecutively. The Energy response, R, of TLD-700H at the range of (80, 100 and 120) kV x-ray energy was* $R = 0.093*(kV)^2-20.311\ (kV)+1222.2$ *with r = 0.914. By knowing the characteristics of TLD-700H eye-lens dose monitoring services can be performed so that the eye-lens dose from radiation workers who work in special places as mentioned above can be obtained.*

Keywords : TLD-700H, eye-lens dosimeter, eye lens dose, radiation worker.

Introduction

Utilization of ionizing radiation in the medical, educational and research institutions as well as in the nuclear fuel facility increases along with the development of industry and technology. This is not only providing the advantages but also have the potential dangers, which can be detrimental to workers, beneficiaries, and the environment, when its use does not comply with safety rules. Every worker has the risk of radiation exposure to radiation during work with radiation, therefore, to protect workers from the dangers of radiation, radiation safety efforts are needed. Utilization of ionizing radiation requires the guarantee of safety for the workers, the public and the environment. Safety requirements and guidelines on radiation protection of workers is a major component of the radiation safety that should be provided by a License Holder.

Based on the IAEA Safety Fundamentals Publication on Radiation Protection and the Safety of Radiation Sources (IAEA, 1996) such as objectives, concepts, principles of radiation protection and safety has been presented. The requirements should be designed by License Holder for the use of ionizing radiation in order to achieve safety objectives and applicable principles in safety fundamentals, including requirements for the protection of workers exposed to radiation sources, as defined in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (IAEA, 1996) related to the Recommendations of Radiation Protection against Radiation Workers developed by the International Commission on Radiological Protection (ICRP) (ICRP, 2007).

Based on the Government Regulation of Indonesia Republic No.33 year 2007 (PP RI No.33, 2007) about Ionizing Radiation Safety and Security of Radioactive Sources, stated the necessary safety measures to protect workers, the public and the environment from radiation hazards. The Center for Technology of Radiation Safety and Metrology (CTRSM) is a center that has the task to conduct research and development especially in the field of radiation safety and metrology and has an important role as a radiation safety center.

Pursuant to the Rule of the BATAN Head No. 21/2014 (Perka BATAN, 2014) on the details of the Unit Task of work in the BATAN article 164, the subdivision of occupational safety and radiation protection (OSRP) has the task to give a service in the fields of occupational safety, radiation protection, monitoring of safety and environment, and waste management. In the field of occupational safety, one of the services given by this subdivision is personnel radiation dose monitoring using BARC and Harshaw TLD Badges. In performing dose evaluation service, the OSRP uses the methods appropriate with national and international requirements, implements management systems including trained human resources, calibrated and maintained equipment, and organization support.

The CTRSM-BATAN is a testing laboratory accredited by KAN based on ISO-SNI 19-17025: 2008 (ISO-SNI, 2008) and has served about 1,500 companies (until May 2015) for radiation dose evaluation services with strong penetrating, Hp(10). Based on Regulation of BAPETEN Head No.4/2013(Perka BAPETEN, 2013) about the Protection and Radiation Safety in the Use of Nuclear Power, in transitional provisions chapter V, article 56 said that "Provisions on the Limit Value of Worker Radiation Dose to the eye-lens as referred to Article 15 in letter c shall be implemented in 2016. To be able to give the service in evaluating the eye lens dose the CTRSM BATAN performs a research to obtain the evaluation method for the eye lens dose using TLD-700H.

Objective Monitoring Program

The general objectives of the monitoring program are to assess the conditions in the workplace, to determine the individual exposure and to ensure the safety of which can still be tolerated. Dose monitoring of radiation worker is a regular basis of an integral part of the radiation protection program. The radiation dose from external radiation can be estimated from the monitoring in the workplace for assessable individual dose. However, the results of the individual monitoring is required for those people who work routinely in controlled areas such as interventional radiology, nuclear medicine, beam port, glove box application and cardiology due to external radiation hazard. Individual monitoring program for external radiation exposure is aimed to optimize protection, to indicate that the exposure of workers do not exceed dose limits, and to verify the adequacy of the monitoring in the workplace. For that every worker must be equipped with integrating dosimeters that can detect Hp(10), Hp(0.07) and Hp(3) with sufficient accuracy for the relevant type of radiation. Hp(3) is the equivalent dose to the lens of the eye, a depth of 3 mm. To achieve sufficient accuracy in dose evaluation services, processing laboratory requires trained personnel, processing equipment other relevant facilities, and the implementation of quality assurance.

Eye-Llens Dose Monitoring

The eye lens dosimetry has become increasingly important with the changes recommended by the ICRP No.103 (Statement on Tissue Reaction). The ICRP issued new recommended limits for radiation dose to the eye lens dose, Hp(3), due to concerns over cataracts in April 2011 [3,6]. This reduction of annual dose limits to the eye lens from 150 to 20 mSv (2 rem) has created the need for enhanced monitoring using dosimeter as close as possible to the eye. These documents indicated that the threshold dose for effects on the eye lens is now considered to be 0.5 Gy (ICRP, 2012).

Dose monitoring of workers in interventional radiology, nuclear medicine, beam ports, glove box and cardiology application needs to be addressed. Large extremities doses of the Hp (3) received by radiation workers that reached almost equal to the whole body dose, Hp (10) (Domienik J., et.al, 2011) are presented in Table 1.

Table 1. Ratio of Eye-lens dose against Equivalent Dose (Domienik J., et.al, 2011)

Kind of work	Hp(3)*/Hp(10)
Technicians	1,1 ± 0,2
Operator	0,7 ± 0,1
Nurse	0,7 ± 0,2
Doctor	0,8 ± 0,3

*) Data in Europe in 2011 (Interventional Procedures)

Based on the Regulation of BAPETEN Head No. 4/2013, the CTRSM studies the characteristic of TLD-700H in order to prepare eye-lens dose evaluation service. Characteristic of Extrad Harshaw Dosimeter (TLD-700H) to be used as a eye-lens dosimeter, Hp (3) is presented in Table 2. Characteristic of TLD-700H compared with TLD-700, is presented in Table 3. Test Method/calibration standard is based on ISO 12794 (Ciraj-Bjelac et.al., 2010), are presented in Table 4. The dosimeter consists of the following components:

- Chipstrate (consisting of Kapton-base and elements TL).
- TL dosimeter material element (in the form of powder/chip) together with the materials used in the personnel dosimeters, can monitor beta ray, gamma ray/neutron.
- Elements TL whether LiF: Mg, Ti or LiF: Mg, Cu, P (Table 2), or CaF_2: Mn (TLD-400 in the form of chips), all the elements supported in inert substrate (Kapton-base).
- Shield filter
- Identification
- Attachment device

Table 2 . Characteristics of Extrad Harshaw Dosimeter (TLD-700H)

Radiation Type	γ, β, dan X-ray
Dose range	0.15 mSv - 10 Sv
Energy range (photon)	16 keV to 662 keV
Beta Energi range (E_{max})	>70 keV to 3.5 MeV
Angle of radiation incidence	0° - 45° (normal)

Table 3. Characteristics of TLD-700 compared with TLD-700H

LiF: Mg, Ti (TLD-700)	LiF: Mg, Cu, P (TLD-700H)
Repeatability : < 2% (1 stdev) from10 measurements with ^{137}Cs (1 mGy)	
uniformity : ± 30% from every batch	
Sensitivity changes < 5% from 50 x use	
dose range: linear (10 μGy-1 Gy)	dose range: linear (1μGy-10 Gy)
Supra linear : > 1 Gy	Supra linear : > 10 Gy
Fading : < 5%/3 months	Fading : negligible
Residual TL signal : <0,2 %	Residual TL signal : <1 %

Table 4. Calibration Standard based on ISO 12794 (2000)

Parameter	ISO 12794 (2000)
Type of detector / dosimeter	Extremity and eye-lens Dosimeter
Radiation Energy	15 keV to 3 MeV, (0,5 ≤ response 1,5)
Angle	$0^o – 60^o$ on 60 ± 5 keV, (0,85 ≤ response ≤ 1,1)
Linearity	1 mSv -1 Sv, (0,9 ≤ respose ≤ 1,1)
Coefficient Variation	Repeatability: 10%, uniformity: 15%
Environmental	Temperature up-to +40° C & humidity up-to 90% (0,9 ≤ response ≤ 1,1)

Objectives, Goals, and Benefit of Assessment of TLD-700H

The objectives of the assessment of TLD-700H are to get the uniformity, the response at various angles of radiation incidence and calibration curve for some energy X-rays, to obtain traceability to the international system through the national reference. The calibration curve will be used to evaluate accepted dose of radiation worker in interventional radiology, nuclear medicine, beam ports, glove box application and cardiology.

The Goals of the assessment of TLD-700H are to get calibrated dosimeter traceable to the international system through the national reference and to be used as an accurate eye-lens dosimeter.

The benefits from the assessment of TLD-700H is the CTRSM-BATAN can serve eye-lens dose evaluation using the TLD-700H dosimeters.

Materials and Method

TLD-700H made in Harshaw is made from Lithium Fluoride (Li Natural), LiF; Mg, Cu, P. It has Z_{eff} : 8.3, a main peak at 210°C, maximum emission of 400 nm, and relative sensitivity of 25% and fading of 5%/year at 25°C. It also can monitor beta and gamma radiation. Chip strate for TLD-700H is the TLD-707H having a density of 7 mg/cm^2. Figure 1 represents system of TLD-700 H.

Figure 1. System of TLD-700H

Preparation

Before use, TLD-700H Harshaw was annealed using a Harshaw TLD Reader 6600 to clean its background radiation, then was tested its uniformity by irradiating the dosimeter using ^{90}Sr beta source with the dose of 0.34 mSv. After irradiation these TLDs were kept for 24 hours and then they were read using Harshaw TLD reader type of 6600 that can be seen in Figure 2.

Figure 2. Harshaw TLD Reader Type of 6600 used to read TLD-700H

Radiation Angle Dependency

The characteristics of TLD-700H dosimeter was tested its angle dependency. The Harshaw TLD-700H was put on a cylinder water phantom at an angle of 0° and was irradiated with X-ray W (80) for a dose of 10 mSv.The same step was done for angles of ±20°; ±40°; and ±60°. After 24 hours the irradiated TLDs were read using Harshaw TLD reader. The lay out of TLD-700H irradiation using X-ray can be seen in Figure 3.

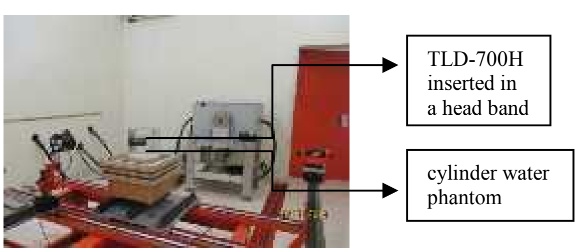


Figure 3. Lay out of TLD-700H irradiation by using X-Ray

Dosimeter Calibration

Prior to calibration TLD-700H were annealed and recorded on the data form. The dosimeters were inserted in the pouch chipstrate available in headband, attached to a cylinder water phantom, and placed at the SDD (Source Detector Distance) of 200 cm from the center of the X-ray source. The Dosimeters were irradiated by X-ray of YXLON/325 X-ray machine using N(120) or 1.75 mmCu HVL at the Secondary Standard Dosimetry Laboratory (LDSS)–CTRSM BATAN. Figure 4 represents TLD-700H and headband.

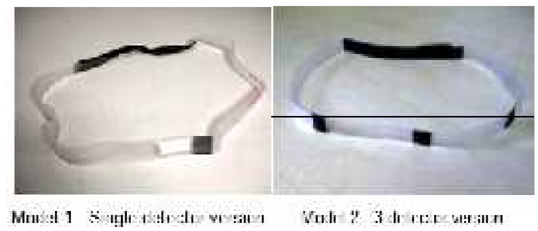


Figure 4. TLD-700H and Headband

The TLD-700H were irradiated for 7 doses of 0.1; 0.5; 1; 5; 10; 15; 20 mSv. After being stored for 24 hours, the dosimeters were inserted into carrier card which contains 2 pieces of dosimeters and were read by using TLD Reader type 6600 Using the same steps, TLD-700H were irradiated by X-ray using N(100) or 1.13 mmCu HVL, N(80) or 0.59 mmCu HVL.

Results and Discussion

Uniformity Test for 30 dosimeters of TLD-700H was performed by irradiating the dosimeter with ^{90}Sr beta source. The results were fairly uniform, with a standard deviation of 1.6% and 1.7%, at the 67% confidence level as seen in Figure 5. The standard deviation of this will contribute to the evaluation of the dose.

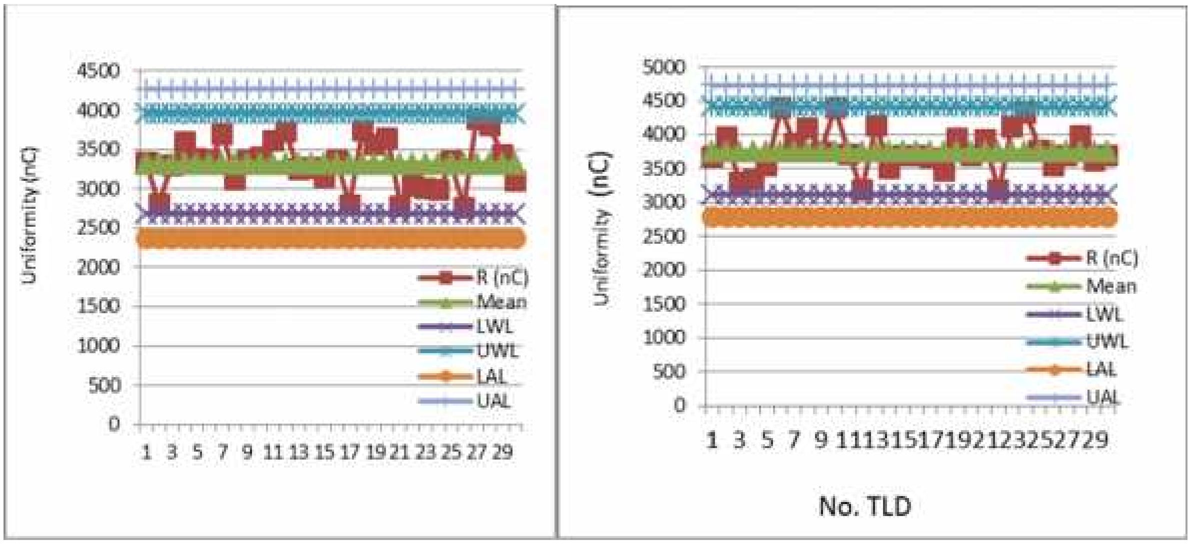


Figure 5. Uniformity of TLD-700H

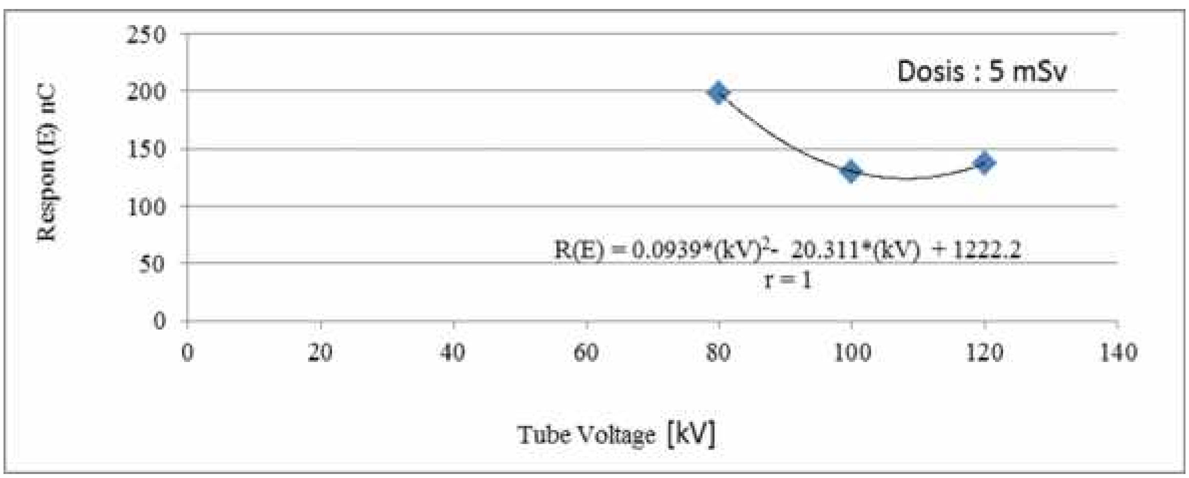


Figure 6. Energy dependence of TLD-700H for X-ray

For calibration curve of TLD-700H at x ray energies of N(80), N(100) and N(120) were obtained D_m=0.0289 R+0.0082, r=0.9993, D_m=0.0404 R-0.0303, r=0.9998 and D_m=0.0357 R+0.1706, r=0.9987 respectively.

At each calibration curve there is uncertainty that will contribute to the evaluation of the dose. By obtaining the above equation, the dependence of the dosimeter response against X-ray energy is presented in Figure 6. This is consistent with the theory of the interaction of radiation photons/x-rays with matter, namely in the area of the photoelectric effect, where response rises an energy below 100 kV and above 120 kV. To prove this, the study should be continued with radiation dosimeters with X-rays at energy under 80 kV and irradiation with gamma rays ^{137}Cs (661 kev).

The angle response of TLD-700H against the W(80) X-ray was R (Θ) = $-0.0943\Theta^2 + 0.4583\Theta + 326.2$ with r = 0.914 and was presented in Figure 7.

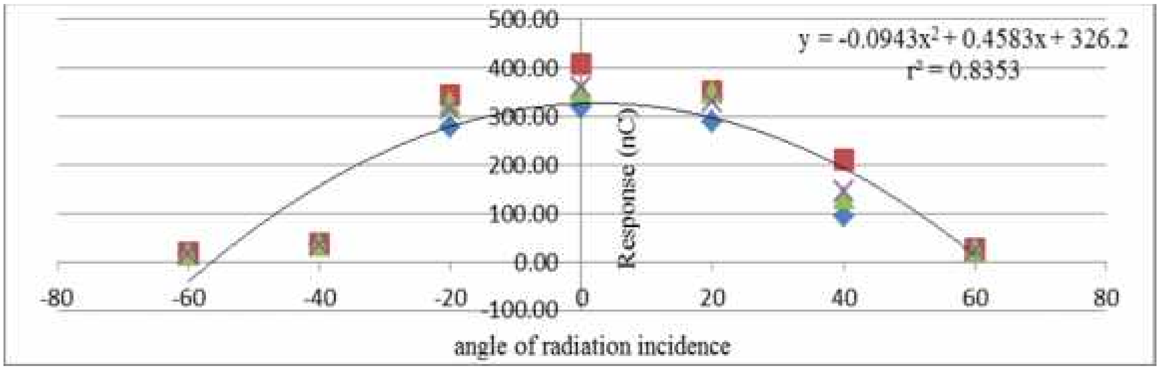


Figure 7. Radiation angle dependency of TLD-700H against W(80) x-ray

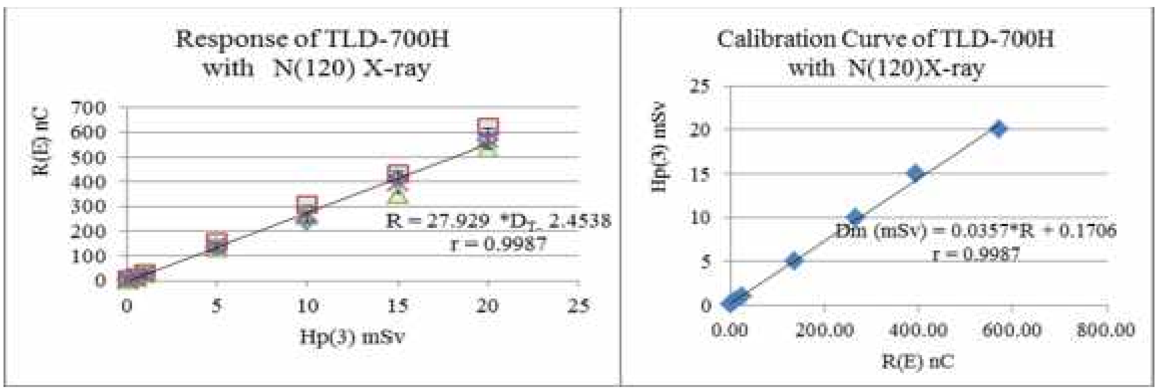
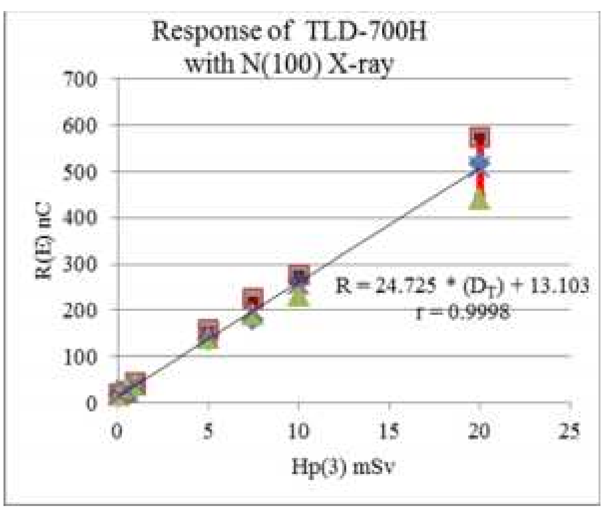


Figure 8. Response and Calibration Curve of TLD-700H with N(120) X-ray



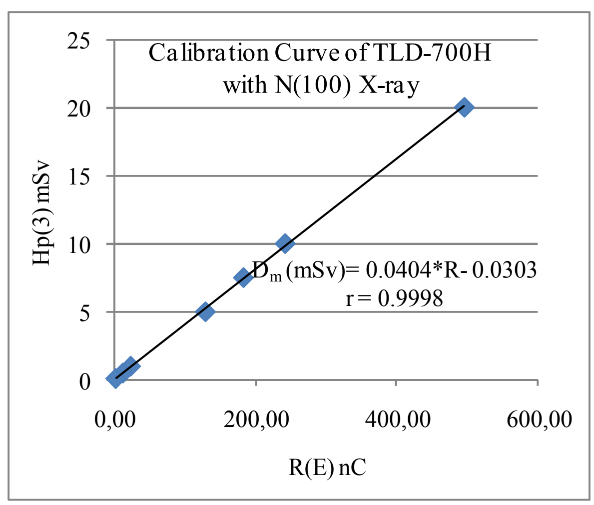


Figure 9. Response and Calibration Curve of TLD-700H with N(100) X-ray

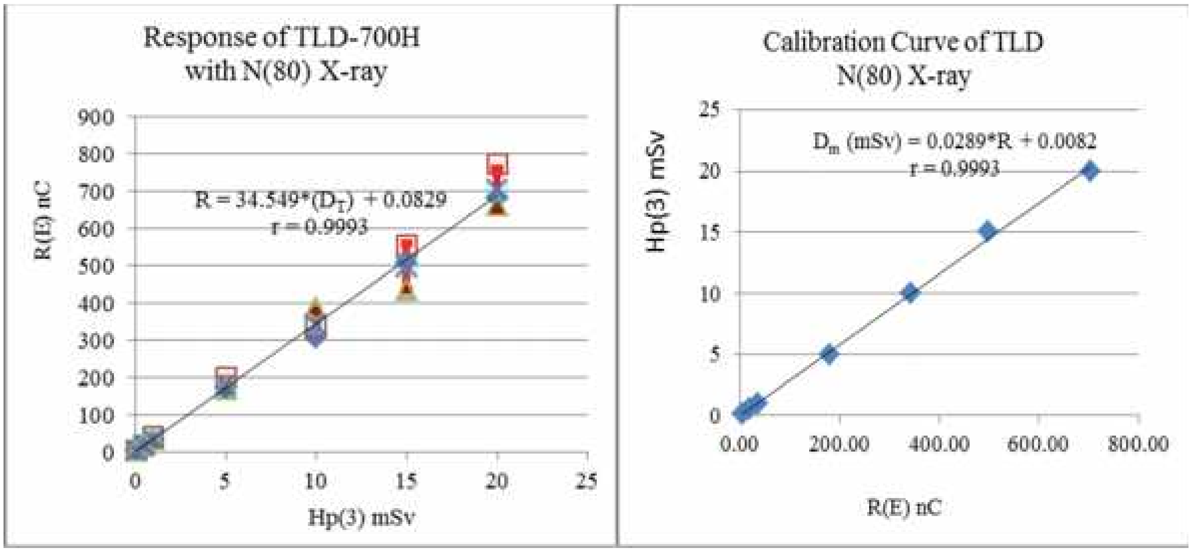


Figure 10. Response and Calibration Curve of TLD-700H with N(80) X-ray

The calibration curve of TLD-700H with N(120), N(100) and N(80) X-rays were presented in Figure 8, 9 and 10.

Conclusion

From the research result TLD-700H is fairly uniform, with a standard deviation of 1.65% (CL: 67%). Meanwhile, the response of TLD-700H to the X-ray at W (80) with the variation of angle of incidence was $R(\Theta) = -0.0943\Theta^2 + 0.4583\Theta + 326.2$; r = 0.914. Calibration curves of TLD-700H for X-ray at N(80) , N(100) and N(120) are D_m (mSv) = 0.0289 R+ 0.0082 with r = 0.9993, D_m(mSv) = 0.0404 R - 0.0303 with r= 0.9998, and D_m (mSv) = 0.0357 R+ 0.1706 with r = 0.9987 consecutively. The Energy response, R, of TLD-700H at the range of (80, 100 and 120) kV x-ray energy was R = $0.093*(kV)^2$-20,311 (kV)+ 1222.2 with r = 0.914. So it can be concluded that by knowing the characteristics of TLD-700H eye-lens dose, TLD-700 H can be used as eye lens dosimeter and the evaluation method of eye lens obtained can be implemented to evaluate the eye lens dose, Hp(3), of radiation workers who work in special places such as interventional radiology, nuclear medicine, beam ports, glove box and cardiology.

Acknowledgment

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