

Calibration of the Harshaw 6600 Plus Tld Readers and Thermoluminescent Dosimeter (Tld-100) Cards at the Personal Dosimetry Laboratory

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CALIBRATION OF THE HARSHAW 6600 PLUS TLD READERS AND THERMOLUMINESCENT DOSIMETER (TLD-100) CARDS AT THE PERSONAL DOSIMETRY LABORATORY

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Abstract

This study gives a detail activities of the calibration of Dosimeters in the Personal Dosimetry Laboratory which was carried out in the Radiation Protection Institute in Ghana Atomic Energy Commission. The calibration was done to establish the quantitative relationship between a dosimeter's readout signal using their traceable, and the physical quantity of ionizing radiation to reduce measure uncertainty. The activity was carried out in the Secondary Standard Dosimetry Laboratory (SSDL) of Ghana Atomic Energy Commission where a calibration source was use to establish a reliable response function traceable to national or international reference standards (e.g., IAEA or ISO guidelines). Which helps to ensure accurate radiation dosimetry such regulatory compliance, safety and therapeutic efficacy in Industries, Research, and Medical Facilities. Because Dosimeters response depends on environmental and beam parameters, the following

physical and Environmental parameters were also considered such as humidity, temperature, dose rate during/after irradiation. energy spectrum and radiation type during the activity.

The Dosimeters were exposed using an Irradiation Setup and they were exposed under standardized reference conditions. Phantoms such as water or slab phantoms were used for backscatter on appropriate phantoms ray/beta/neutron fields. The reader output to the reference dose for a specific dosimeter was done by use a mathematical model (linear or non-linear regression equation) which was finally fitted to map.

KEYWORDS: Dosimeters, Calibration, Occupational Exposure, Equivalent Dose and Element Correction Coefficient

1.0 INTRODUCTION

The Personnel Dosimetry Laboratory is a Service provider that provide monitoring services to different categories of Occupational Exposed Workers who were registered as our clients. These clients are Professionals who uses radiation or radioactive source their field of work. Doses are evaluated from the TLD Thermoluminescent Dosimeter by using the Dose Management System (DMS) and WinRems provided by the International Atomic Energy Agency (IAEA) [1]

Occupational exposure is the exposure workers incurred in the course of their work regardless of the situation of the exposure. To control this exposure, it is important to access the magnitude of the radiation doses they are exposed to and this calls for radiation dosimetry. Radiation dosimetry is defined as the measurement, usually, of the absorbed dose, or other relevant quantities like KERMA, exposure or equivalent dose, which is produced due to the interaction of the ionizing radiation with a material. That measurement can be achieved using a dosimeter. A dosimeter with its reader is called a dosimetry system [2].

The TLD reader system is used to process a worn TLD dosimeter. The reader automatically heats the TL material. A photo multiplier measures the TL-light released during the heating of the material from room temperature up to a maximum of (250-400°C) depending on the system.

Personal dosimeters should be calibrated in terms of operational quantities for individual monitoring of external exposure (i.e. the personal dose equivalent $H_p(10)$ for strongly penetrating radiation and $H_p(0.07)$ for weakly penetrating radiation).

The purpose for calibrating TLD Cards is to ensure that all cards in a system will give virtually the same response to a given radiation exposure. Because of natural variations in TL material

responsiveness and the physical mass of manufactured TL chips, there is a variation in response of as much as 30% (based on 3 sigma) from the mean in a population of dosimeters. The calibration factor for dosimeters is called the Element Correction Coefficient (ECC). The ECC is used as a multiplier with the Reader output (in nanoCoulombs) to make the response of each dosimeter comparable to the average response of a designated group of dosimeters maintained as Calibration Dosimeters [3]

The purpose of Reader calibration is to maintain a consistent output from the Reader over a period of time based on a convenient local source. Such a source might be a ^{90}Sr source built into the Reader or a ^{137}Cs source in a Model 6600 Irradiator. By using a set of Calibration Dosimeters and a consistent local source, the Reader's performance can be kept at a constant level in spite of high voltage changes, repairs, dirt accumulation, or long-term drift. The calibration factor for Readers is known as the RCF. This factor converts the raw charge data from the Photomultiplier Tubes (in nanocoulombs) to dosimetric units (rems, for example) or to generic units (gU) for input to an algorithm [4]

Internal irradiator of strontium-90 (^{90}Sr) source was employed for this work. Strontium-90 (^{90}Sr) is a radioactive isotope of strontium produced by nuclear fission, with a half-life of 28.8 years. ^{90}Sr undergoes β^- decay into yttrium-90, with a decay energy of 0.546 MeV.

2.0 MATERIALS AND METHODS

2.1 MATERIALS

2.1.1 Harshaw 6600 Plus TLD Reader

For this project, two Harshaw TLD (Model 6600 plus) located at the Radiation Protection Institute were the readers used for estimating whole body and extremity effective doses recorded by the TLDs. One of the readers was refurbished by Radiation Protection Institute with the following specifications: Model Number- 1808490, Strontium-90 (^{90}Sr) internal source and Activity of 0.5 mCi. The other one was acquired through the assistance of International Atomic Energy Commission and bears the following specifications: Model Number- 9805167, Strontium-90 (^{90}Sr) internal source and activity of 0.5 mCi. The Model 6600 Plus TLD Card Reader is a fully automated, state-of-the-art instrument used for extremity, environmental, and whole body thermoluminescence dosimetry (TLD) measurement. It combines a medium capacity (200 TLD Cards or Carrier Cards) transport system. A non-contact heating system is used which utilizes a stream of hot nitrogen gas. The Reader is interfaced to a computer where all measured data can also be displayed, stored and printed [5].

2.1.2 Strontium - 90 Internal source

Strontium - 90 internal source was employed for this work. The activity of the source is 0.5 mCi and the half-life is 28.8 years.

The internal Irradiator is shielded and contains a radioactive source/holder which is pre-installed at Bitcron. The ^{90}Sr Irradiator Assembly is shipped as separate component from the Reader.

2.1.3 Thermoluminescent Dosimeter (TLD)

The most widely used material is the LiF with added magnesium and titanium. TLD-100 is LiF:Mg,Ti which consists of 92.5% of Li-7 and 7.5% of Li-6. Each card consists of four/two chips. In this project, two hundred (200) new two elements TLD 100 were used. One hundred (100) for each of the TLD readers. The TLD cards are fixed in their holders which consist of two aluminium filters of different thicknesses; 0.07mm (for skin dose measurements) and 10mm (for deep dose measurements). One corner of the TLD card is notched to make sure it is placed correctly in the Reader holder system. The Reader holder system protects the cards from the environment and keeps the filtration media which attenuate different types of radiation in order to ensure selective entrapments of the TLD-100. Apart from the chips, each card has a unique barcode. [6].

2.2 METHODOLOGY

2.2.1 Calibration of Harshaw TLD Reader 6600 Plus

Full calibration of the Harshaw Model 6600 plus required calibrating both the Reader and all the TLD cards used in the system. Before setting up the system it was important that the following directions and steps were carefully followed;

- (i) Dosimeter Preparation
- (ii) Generation of Calibration Dosimeters
- (iii) Calibration of Reader
- (iv) Calibration of new TLD Field cards

i. Dosimeter Preparation

Before beginning any calibration procedures, a fixed fade time for your operations for each of the calibration procedures should be established. It is important that the time between irradiation and readout for all dosimeters be consistent in order to keep fading the same from one calibration to the next. The specific length of this time is not as important as is its consistency. It is recommended that the fade time be 24 to 48 hours, and never less than thirty minutes. Otherwise, any length of time that suits your operations is acceptable, but it must be consistent from one time to the next. If the dosimeters are not irradiated simultaneously, they should be read in the sequence in which they were irradiated. The Procedure was as follows:

- a. The Reader annealed the Dosimeters to clear them of all residual exposure
- b. After annealing, the dosimeters were stored in a shield enclosure for one hour at a temperature below 30°C before irradiation.
- c. The dosimeters were then exposed to a known internal radiation source (^{90}Sr) within two hours after annealing.
- d. The dosimeters were again stored in a shielded enclosure for one hour at a temperature below 30°C.
- e. The dosimeters were read for calibration purposes

ii. Generation of Calibration Dosimeters

This procedure established the Element Correction Co-efficient (ECC) of these cards without reference to the Reader. These cards were retained for subsequent re-calibration of the Reader. Below were the procedures in generating Calibration Dosimeters:

1. The cards were loaded into the reader and set the Reader function on the Result Screen to a “Remote Operation”.
2. From the WIN REMS main menu on PC, “Data Acquisition” was selected. From the Data Acquisition Menu, “Time Temperature Profile (TTP)” was also selected
3. The TTP was set to the required condition and return to the Data Acquisition Menu.
4. From the Data Acquisition Menu, “Acquisition setup” was selected. The Acquisition setup was set to the required conditions.
5. “Read Cards” was selected and then “Enter”, this brought up the Read Cards Screen. A unique group Number and the appropriate TTP number was entered.
6. “Function Field” was selected. From the pop-up menu “Generate Cal. Dosimeters” was selected.
7. “Start Reading” was selected and the comment prompt was responded, then “Start”. The Reader began to read the Cards and display the data in accordance with both the setting in the TTP and Acquisition setup screen.
8. After completing the Reading process, “QA Procedure” was selected from the Main Menu; then “Generate Calibration Cards” was selected. Then the same Group number assigned earlier on and an acceptable ECC range for each position (ii and iii for a two-element position cards) were entered and the ECC calculations was initiated
9. When the calculation process was completed, the report was printed to obtain a list of calibration cards.

iii. Calibration of TLD Reader

The calibration Dosimeters generated were used to establish the Reader Calibration Factor (RCF) for each Time-Temperature Profile (TTP) through the procedures below:

1. Eight (8) of the calibration cards were annealed and exposed as before to 2000 gU of Strontum-90 source to the required conditions and were loaded into the Reader.
2. The Function Field was set to “Remote Operation” on the Reader Results Screen which transferred control of Reader to the REMS PC.

3. From the WinREMS Main Menu on the Screen “Data Acquisition” was selected from the Data Acquisition Menu, then, “Acquisition Setup” Screen. The Acquisition setup screen was set to the required conditions before returning to the Data Acquisition Menu.

4. A unique Group Number was entered and the number of the TTP being calibrated which has been set to the required conditions and the cards were read.

5. On the Reader Calibration Screen, the Nominal Irradiation Value (2000 gU) to which the cards were exposed was set. Also enter the TTP number, the Group number and the Calibration Units (gU).

6. “Start Reader Calibration” was selected to bring the “Calibrate Reader” Statistics Screen into view. The new RCFs were applied and a report with the new calibration values was generated.

iv. Calibration of new field TLD cards

Below are the procedures for generating ECCs for the field TLD cards:

1. The cards were prepared and exposed to 408.9 gU of Strontium-90 source approximately equivalent to 2 mSv. The cards were loaded into the reader and read after entering a unique group Number and the TTP number previously selected.

2. On the Card Calibration screen, the following data was entered; the acceptable ECC Range for each element position (0.77; 1.43), recommended for field cards the nominal irradiation value to which the dosimeters were exposed.

3. “Start Card Calibration” was entered and the ECCs were calculated and the results stored in the ECC Database to be used anytime the dosimeters are read.

3.0 RESULTS AND DISCUSSION

3.1 Selection of Calibration Dosimeters

The reader automatically selects the TLD cards that are within the set selection limits. Initially the selection limit was set to 0.77-1.43. As all golden cards fell within this limit, the limit was reduced and the Calibration Dosimeters were selected as those within the range of 0.9-1.1 ($\pm 10\%$).

The readings for the golden cards are given in Table 1 and 2 below. Eight (8) TLDs were within the selection limits for both TLD readers and designated automatically by the reader as the Calibration Dosimeters. [7].

3.2 Calculation of Reader Calibration Factor (RCF)

The RCFs for the refurbished TLD reader for elements ii and iii were established as 0.0139 and 0.0158 (no units) whilst the new reader acquired through the assistance of IAEA were established as 0.0369 and 0.0326 (no units). Two different RCFs were calculated as each card consists of 2 TL elements. Thus the first RCF is for the TLD in position ii and the second one for position iii. The RCF of this reader changes by 1.3% over 5.5 years proving that its system is reliable and stable [5]. Using the RCF, a measurement of the charge is automatically converted into dose by the reader (see equation 1). [8].

3.3 Calculation of Element Correction Coefficients (ECCs) and Selection of Field Dosimeters (FDs)

For selecting the Field dosimeters to be used for the energy and angular dependence of the TL response a range of 0.77-1.43 ($\pm 30\%$) of the normalized mean value of the response was chosen. For the TLD element falling in this range their ECCs were calculated (a different one for each TLD element). Those falling outside this range were rejected (asterisked). These ECCs are used by the Reader to multiply automatically each charge measurement in order to have a similar sensitivity (efficiency). ECCs follow a Gaussian distribution with mean value equal to 1. As ECCs are correction factors given by the Reader, it was assumed that they do not have an error. [9].

The calibration factor for dosimeters called Element Correction Coefficient (ECC) is used as a multiplier with the reader output (charge in nanocoulombs) to make the response of each dosimeter comparable to the average response of a group of calibration dosimeters. The Reader Calibration Factor (RCF) is then used to convert the raw charge data from the Photomultiplier Tubes (in nanocoulombs) to the Dose (D) on the TLD Card.

The two factors are applied according to the following formula to evaluate the Dose (D);

$$D_j = \frac{q_j \times ECC_j}{RCF \times K} \quad (1)$$

where

q_j = the charge measured by the Reader from a Field Dosimeter j
 ECC_j and RCF are as defined above
 and K is expressed by:

$$K = \frac{L}{D}$$

where

L is a radiation quantity expressed in generic units (gU). 1 gU is the radiation delivered in 1 second at a specific geometry by a specific source at a constant distance from the source.

D is defined above.

K is measured in gU/Gy

From equation (1) the quantity $RCF \cdot K$ is measured in nC/gU and shows a relation between the dose and the internal units of the Reader. The time between irradiation and read-out or irradiation and preparation is not important but it should remain constant. Using the RCF an accurate conversion from charge to dosimetric units is achieved [10].

The tables below show the reader calibration report for the two TLD Readers

Table 3.1 Reader Calibration Report for the New IAEA TLD Reader

Dosimeter ID	ECC (II)	ECC (III)
900301	0.9668	1.022
900181	1.002	0.9643
900225	1.017	1.011
900227	0.9539	0.9859
900233	1.006	1.008
900176	1.04	0.9585
900242	1.027	1.021
900290	0.9916	1.017

RCF value established

(II) 0.0369

(III) 0.0326

Table 3.2 Reader Calibration Report for the Refurbished TLD Reader

Dosimeter ID	ECC (II)	ECC (III)
700172	0.9418	0.965
700111	1.038	0.9601
700339	1.025	0.9994
700366	1.039	1.016
700084	1.007	1.005
700221	1.014	1.065
700405	0.9595	0.9464
700028	0.9851	1.056

RCF value established

(II) 0.0139

(III) 0.0158

The tables below show the dosimeter calibration report for the two TLD readers

Table 3.3 Dosimeter Calibration Report for the New IAEA TLD Reader

Dosimeter ID	ECC (II)	ECC (III)
900261	0.8906	1.252
900298	1.063	1.127
900297	1.073	1.002
900205	0.9371	1.061
900203	0.9532	0.9468
900208	0.9573	0.9904
900201	1.02	1.023
900284	1.013	1.137
900283	0.9486	1.103
900282	0.9583	1.012
900307	0.8767	0.9859
900204	0.9497	1.043
900396	1.095	1.011
900074	0.9275	0.9667
900130	0.865	1.005
900279	1.009	1.043
900128	0.9109	0.919
900305	1.209	0.9999
900207	0.9552	0.9953

900287	0.9644	1.09
900289	1.061	1.047
900397	1.039	1.261
900280	0.9165	0.8667
900126	0.9551	0.8713
900076	0.9485	0.9705
900206	0.9833	0.971
900202	1.068	1.145
900075	1.071	0.9462
900004	0.8929	0.9674
900288	0.9116	1.048
900002	1.059	0.9422
900018	0.9907	0.9943
900125	0.9063	0.9257
900003	0.9545	0.9306
900086	1.006	0.9656
900035	0.9544	0.9982
900308	0.9709	1.012
900129	0.9612	0.9346
900124	0.9384	0.8513
900100	1.003	0.9868
900398	0.9526	1.163
900399	1.158	1.041
900285	0.9549	1.019
900281	0.9969	1.153
900098	1.013	0.9795
900127	0.9728	0.9697
900286	1.074	1.055
900099	0.8952	0.9372
900072	0.8861	0.8919
900175	0.9269	0.8923
900307	0.9883	1.113
900124	1.016	0.8929
900202	1.187	1.258
900283	1.04	1.204
900289	1.164	1.167
900130	0.9517	1.115
900305	1.333	1.099
900074	1.022	1.061
900396	1.207	1.113

900288	1.012	1.139
900298	1.14	1.207
900098	1.129	1.072
900126	1.028	0.9812
900281	1.066	1.215
900125	1.012	1.02
900128	1.019	1.001
900204	1.03	1.128
900127	1.103	1.115
900282	1.054	1.103
900279	1.094	1.144
900397	1.136	1.332
900004	0.9657	1.074
900076	1.052	1.077
900285	1.046	1.101
900206	1.089	1.065
900002	1.164	1.055
900018	1.099	1.084
900003	1.079	1.043
900207	1.083	1.1
900280	1.046	0.942
600144	1.046	1.134
600407	0.856	1.118
600134	1.033	1.126
700240	1.075	1.21
700047	0.9957	1.389
700953	1.123	1.269
700173	1.061	1.199
700680	1.166	1.344
700925	1.135	1.383
700146	1.22	1.188
700299	1.1	1.198
701018	1.096	1.367
700882	1.117	1.392
700295	1.049	1.077
700438	1.044	1.267
700850	1.107	1.286
701153	1.007	1.397
700823	1.037	1.378
700701	1.186	1.295

*700648	1.117	1.47
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*Rejected TLDs

Table 3.4 Dosimeter Calibration Report for the Refurbished TLD Reader

Dosimeter ID	ECC (II)	ECC (III)
700510	1.073	1.046
700865	0.9178	1.119
700349	0.9048	1.157
700634	0.9519	1.034
700060	1.029	0.9523
700317	1.05	0.9464
701185	0.899	1.113
700065	0.9931	1.027
700764	1.007	1.099
700315	1.031	1.182
701008	1.169	1.24
701089	0.9987	1.007
700197	0.891	0.9941
701174	0.9106	1.058
700784	0.8681	1.019
700638	0.9637	0.8694
701140	0.9393	1.029
701112	0.9696	1.153
700936	0.9596	1.064
700799	0.9616	1
700754	1.006	1.012
700755	0.9226	1.175
700303	0.9712	0.8926
701196	0.9518	1.052
700262	0.9033	1.032
700653	0.9284	1.003
700990	0.984	0.9291
700070	1.086	1.119
700158	0.9536	0.84
700782	0.9756	0.9821
700956	0.9123	1.075
700919	0.981	1.018

700962	0.9766	1.139
701132	0.9287	1.036
701132	1.07	1.252
700642	1.195	1.334
700990	1.171	1.098
700262	1.054	1.234
700611	0.9968	1.367
700110	1.09	1.349
700936	1.114	1.223
700669	0.9412	1.188
700913	1.155	1.308
700779	1.092	1.187
700241	1.23	1.29
700278	1.132	1.378
701079	1.254	1.358
700237	1.112	1.24
700260	1.109	1.231
700290	1.179	1.34
700282	1.034	1.206
700956	1.104	1.312
700919	1.153	1.22
700962	1.145	1.394
700251	1.133	0.957
700324	1.152	1.221
700006	0.9317	1.258
700303	1.142	1.072
701196	1.103	1.246
700233	1.082	1.342
700174	1.176	1.273
700814	1.217	1.308
700183	1.256	1.244
700319	1.258	1.232
700189	1.35	1.266
701080	1.327	1.409
700754	1.147	1.224
700975	1.169	1.31
700426	1.188	1.222
700297	1.385	1.328
700321	1.235	1.309
700410	1.088	0.9728

700746	1.239	1.301
700256	1.031	1.05
700977	1.159	1.396
701030	1.131	1.188
700832	1.239	1.41
700160	1.027	1.173
700670	0.9526	1.138
700326	1.283	1.393
700799	1.13	1.228
700653	1.104	1.216
700158	1.116	1.044
700841	1.157	1.311
701207	1.265	1.32
700070	1.292	1.358
700782	1.15	1.179
700966	1.082	1.337
700755	1.104	1.438
958	0.9217	1.051
460	1.246	1.176
368	1.194	1.154
*30	0.7636	1.231
600293	1.306	1.229
700664	1.093	1.275
700715	0.9772	1.223
700054	1.144	1.156
900289	0.9055	0.9596

* Rejected TLDs

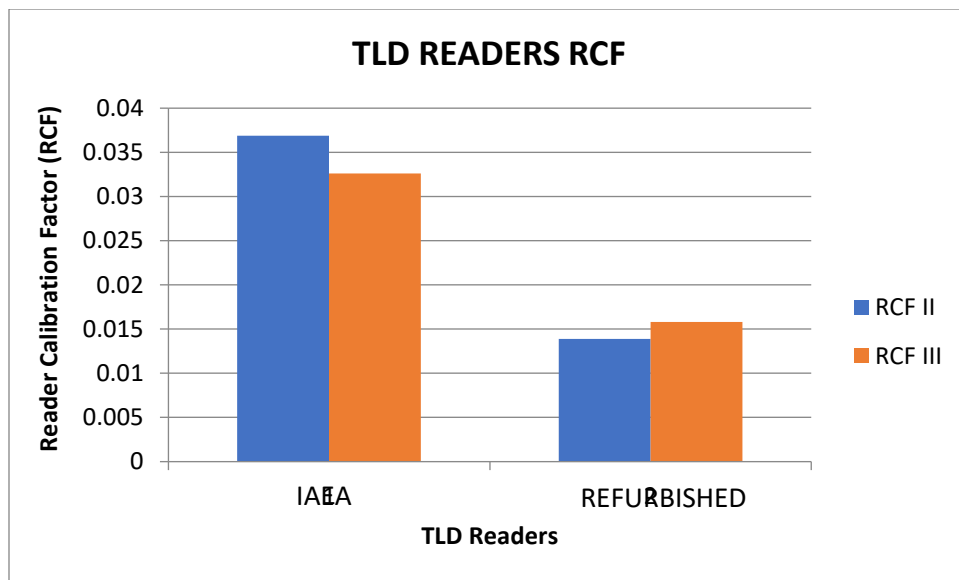


Fig. 1 RCFs of the two (2) Harshaw TLD Readers

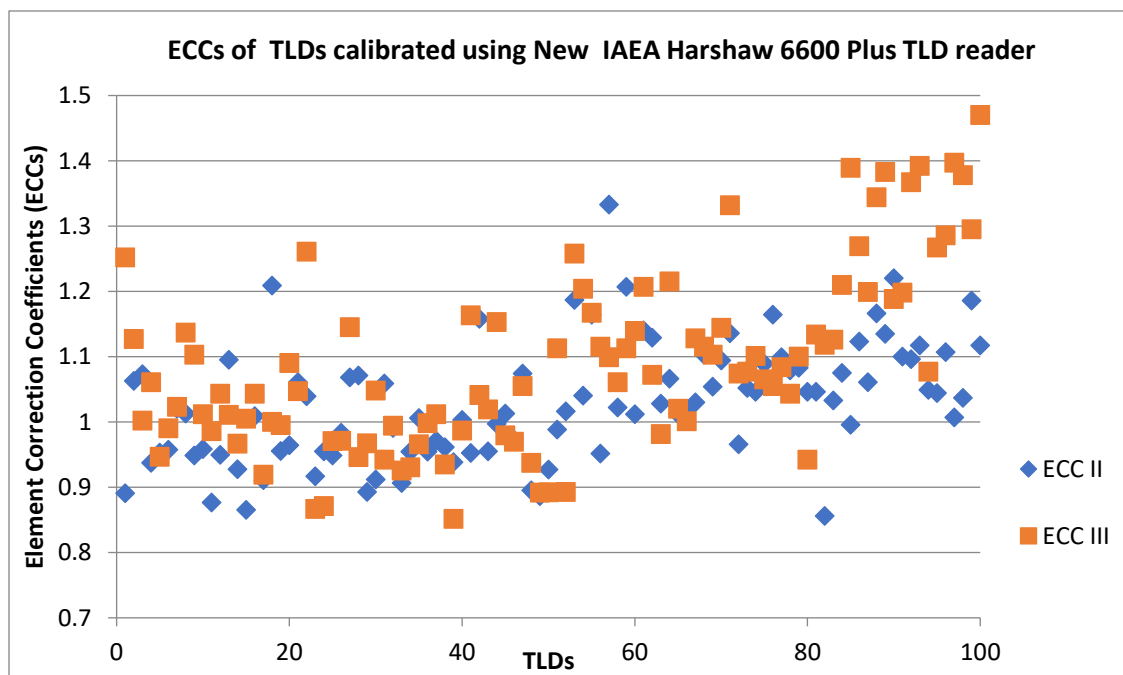


Fig. 2: ECCs of TLDs calibrated using\\New IAEA Harshaw 6600 Plus TLD reader

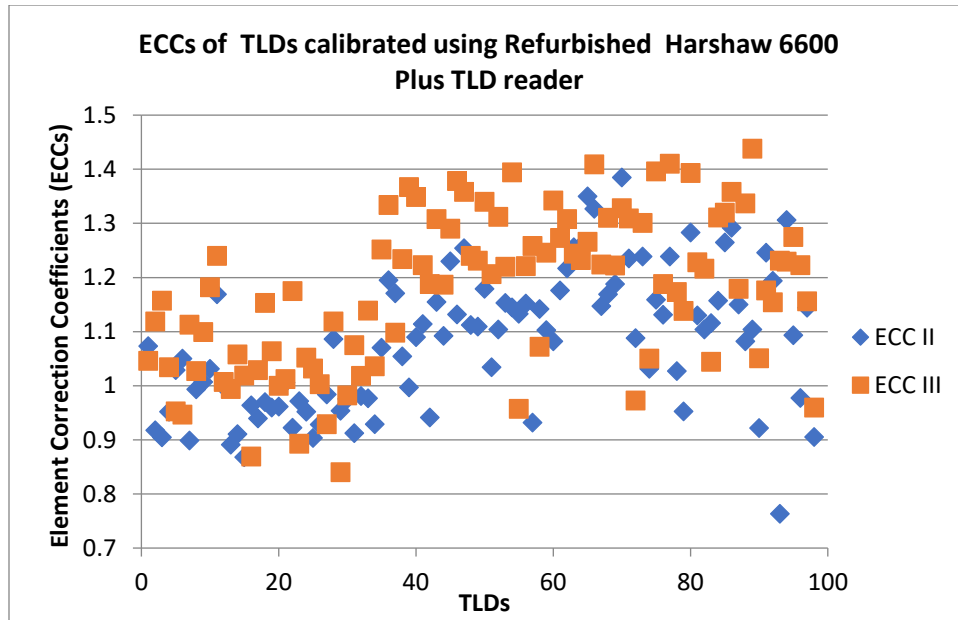


Fig. 3: ECCs of TLDs calibrated using Refurbished Harshaw 6600 Plus TLD reader

4.0 CONCLUSION

From Fig 1. The RCF values for the new IAEA TLD reader, 0.0369 and 0.0326 (no units) were almost thrice more than that of the refurbished TLD reader, 0.0139 and 0.0158 (no units). Further work will be carried out to ascertain the cause of this observation.

From Fig 2. Almost seventy percent (70%) of the One hundred (100) TLDs calibrated had acceptable ECCs of greater than 1, that is, the positive deviation of +30 % with the remaining having -30% deviation from 1. From Fig 3. Almost sixty-five percent (65%) of the One hundred (100) TLDs calibrated had acceptable ECCs of greater than 1, that is, the positive deviation of +30 % with the remaining having -30% deviation from 1. These cards were designated as field cards to be issued out to the Occupationally Exposed Workers (OEWs) in the various facilities being monitored by the Radiation Protection Institute. It was observed that the rejected cards had been used for more than ten (10) years. This could be due to loss of sensitivity as they have been used over a number of cycles. [11].

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