CALIBRATION OF A TLD SYSTEM FOR PERSONNEL AND ENVIRONMENTAL MONITORING

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ABSTRACT

The different aspects of calibration of a TLD reader system will be discussed based on the results of an intercomparison experiment performed at the Centro de Estudios Nucleares, UNAM.

RESUMEN

Los diferentes aspectos de la calibración de un equipo de lectura para dosimetría termoluminiscente se discuten en base a los resultados obtenidos en el experimento de intercomparación efectuado en el Centro de Estudios Nucleares de la UNAM.

1. INTRODUCTION

For the application of a thermoluminiscence dosimetry system in personnel dosimetry three different TLD-Harshaw readers of the type 2000

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were calibrated. During this study the change of the dosimeter response after repeated use of the dosimeters were investigated taking into account the influence of a post- and pre-irradiation annealing, of the reader instability and of a change of the exposure conditions.

2. EVALUATION TECHNIQUE

The dosimeters used were LiF(TLD-700) and CaF_2: Dy(TLD-200) ribbons of the size 1/8" x 1/8" x 0.35"; each dosimeter had been previously calibrated several times at 2.5R, and its relative response monitored and recorder for purpose of normalizing the readings of all TLD's in this experiment to a uniform sensitivity. After cleaning in methanol all dosimeters were annealed as follows: 400°C for 1.5h, 100°C for 15 min, room temperature for 7 min, and finally 100°C for 2h.

Two hundred thirty annealed TLD-700 dosimeters were divided as follows:

A set of 150 was irradiated to 2.9R and stored as reference dosimeters ("daily reading first day exposures") storage I. Another set of 50 TLD-700 dosimeters was stored without any irradiation, storage II and the remaining 30 TLD-700 annealed dosimeters were divided into 3 set of 10 dosimeter each ("daily dosimeters"). See Figure A.

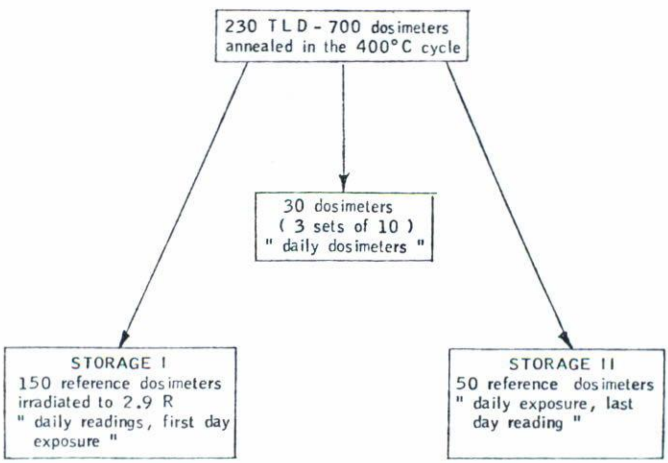

Fig. A. Treatment of 230 TLD-700 dosimeters

The TLD's from storage I, from storage II and the "daily dosimeters" were then introduced into the following cycle (see Figure B).

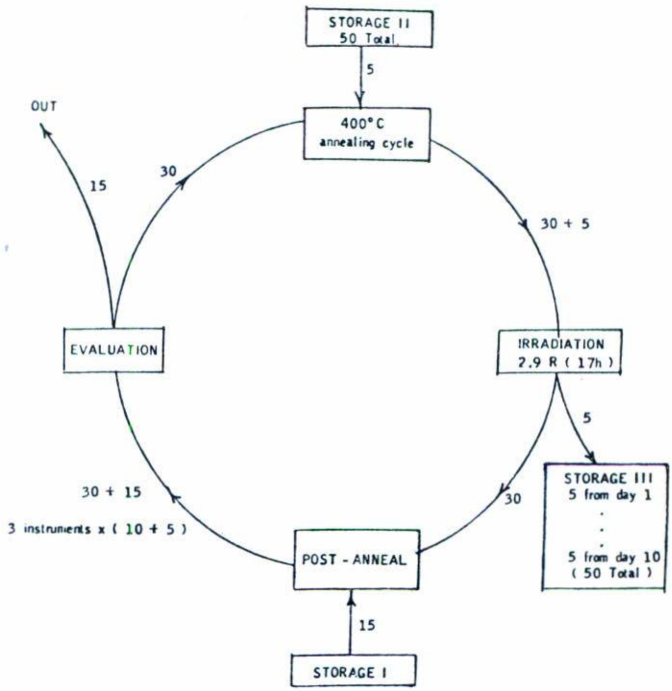

Fig. B. Every day evaluation cycle

Every day the three sets of 10 dosimeters together with five coming from storage II were annealed and irradiated during a 17 hour period to 2.9R. After irradiation the five dosimeters coming from storage II were transferred to storage III to be read on the last working day ("daily exposure, last day reading").

The three sets of 10 irradiated dosimeters were post-annealed together with fifteen dosimeters coming from storage I. The post-annealed treatment consisted of washing in methanol followed by a heating period of 20 min, at 100°C.

After the post-annealing treatment, the 45 dosimeters were divided into three sets of 10 "daily dosimeters" plus 5 "storage I dosimeters"; each set was then evaluated in a given reader. Each day the same ten "daily dosimeters" were read in the same reader.

Every day the fifteen evaluated dosimeters coming from storage I were taken out of the cycle and the remaining 30 "daily dosimeters" began the cycle again.

The last working day all the dosimeters from storage III were post-annealed and evaluated in the UNAM reader (reference dosimeters "every day exposure, last day reading"). See Fig. B.

The annealed CaF_2:Dy dosimeters were distributed as follows:

Five were irradiated at 6.7 mR from a ^{227}Ra source. Each of them were placed in a spherical capsule paired with a non irradiated CaF_2:Dy dosimeter and irradiated at different locations of Mexico City.

Another set of the annealed CaF_2:Dy dosimeters were irradiated with a ^{137}Cs source at different doses ranging from 1 to 10 mR.

Evaluation of these dosimeters gave the calibration curve where each point represents the mean value of then dosimeters readings.

A calibration factor for the available equipment in Mexico was obtained from two sets of LiF dosimeters (irradiated and non-irradiated) provided by the Karlsruhe Nuclear Research Centre.

For the evaluation of the LiF dosimeters three different Harshaw readers from the type 2000 have been used; one reader from the UNAM; one from the INEN and one reader from the Hospital General de la Secretaría de Salubridad y Asistencia.

3. INSTABILITY OF THE TL DOSIMETER SYSTEM

3.1 Annealing and Re - use of the dosimeter

The mean value reading of every set of 10 dosimeters per reader, annealed, irradiated to 2.9 R and evaluated every day (daily dosimeters) is shown in Fig. 1.

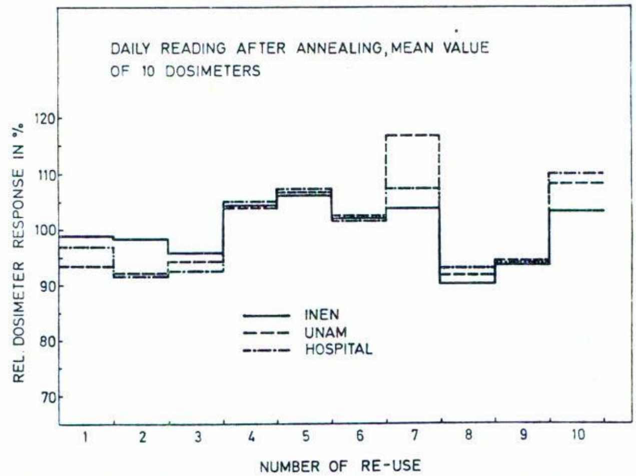

Fig. 1. Mean value of test dosimeters after daily irradiation reading and annealing.

It can be seen, that the daily deviation of the dosimeter reading of the order of ±10% is mainly due to the influence of the annealing technique or the irradiation, because all the three readers have shown the same change. Fig. 2 shows the standard deviation for the three readers.

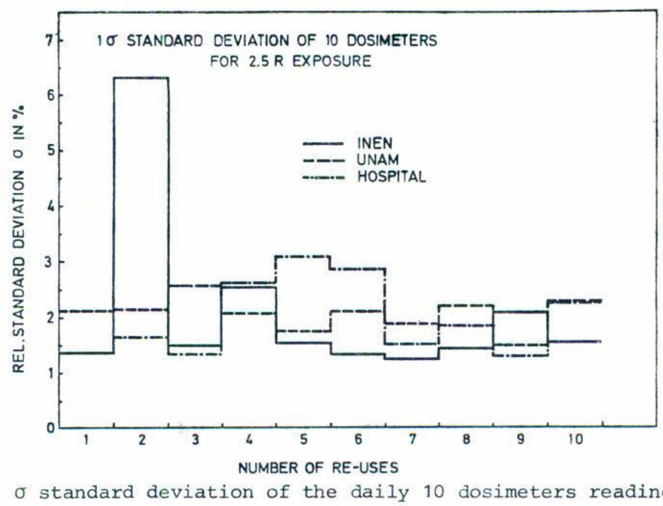

Fig. 2. σ standard deviation of the daily 10 dosimeters reading.

Excluding the abnormal values for the second day the relative standard deviation of the 10 dosimeters was found to be between 1.5% and 3%, approximately.

3.2 Reference Dosimeters

Two sets of reference dosimeters were used to control the daily exposures and the influence of the pre-irradiation annealing.

From one set 15 dosimeters were daily annealed, irradiated and stored, perfomed the evaluation of all dosimeters the last working day. With this set the influence of the daily annealing and irradiation can be point out. The mean values of these reference dosimeter readings is shown in Fig. 3. Compared to the results in Fig. 1. it can be seen from table 1 that the change of the dosimeter response is of the same order. All dosimeters from the second set were annealed and irradiated at the first day. The valuation of 15 dosimeters (five dosimeters per reader) was performed every day. In Fig. 4 the daily change of the mean value of reference dosimeters is shown. Because of a ±2% reproducibility of the daily irradiations and a reader stability of ±2% (see Fig. 4) the main influence on the daily dosimeter reading is due to the pre-annealing technique.

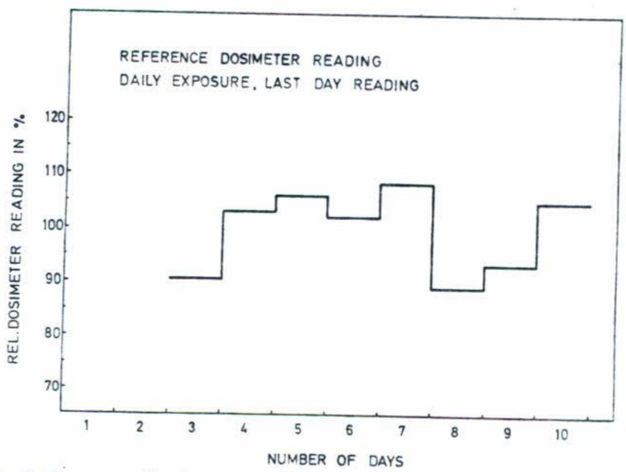

Fig. 3. Reference dosimeter reading on the last day after daily annealing and exposure.

TABLE 1

COMPARISON OF REFERENCE DOSIMETER READING AND DAILY READING OF 10 DOSIMETERS AFTER ANNEALING AND EXPOSURE WITH 3 READERS

Day	REL. DOSIMETER READING IN %x)			
No.	REFER. DOS.	UNAM	INEN	HOSPITAL
1	- - - -	93.01	99.47	98.59
2	- - - -	94.59	99.08	90.40
3	90.64	96.05	95.44	93.20
4	103.98	103.57	103.71	106.51
5	106.30	102.65	107.12	103.58
6	102.44	102.17	101.64	100.78
7	108.63	112.37	106.16	103.65
8	89.10	90.92	91.57	95.18
9	93.59	95.32	93.92	93.61
10	105.28	109.83	102.23	110.20
MEAN nC	54.26	54.55	8.07	1.46

x) Mean value 100%

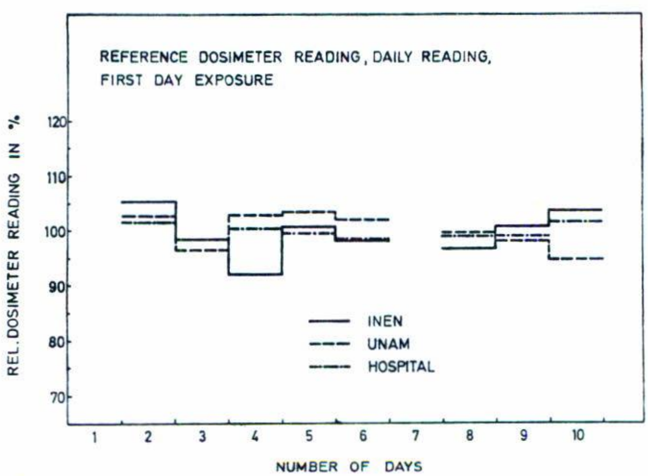

Fig. 4. Daily reference dosimeter reading after first day exposure

3.3 *Light Source*

The daily light source check of the three readers is shown in Fig. 5 (mean value of 10 readings). Except the results from the eighth day, the change of the light source reading was ±2%. Fig. 6 shows the relative standard deviation 1σ of 10 readings per day. The value is (0.54 - 0.96)% for the INEN reader, (0.59 - 1.54)% for the UNAM reader and (0.61 - 0.99)% for the reader of the Hospital General.

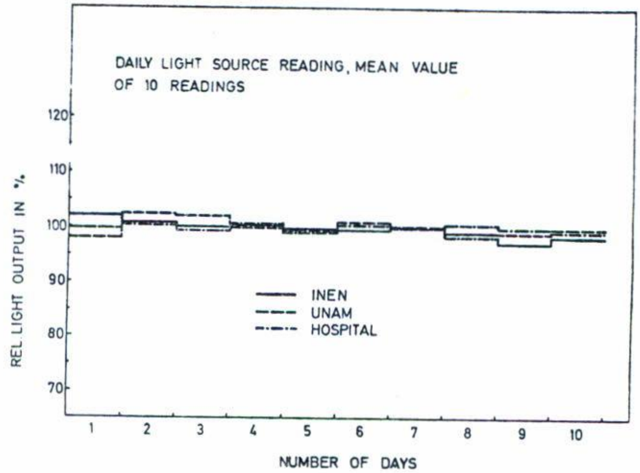

Fig. 5. Mean value of the daily light source reading

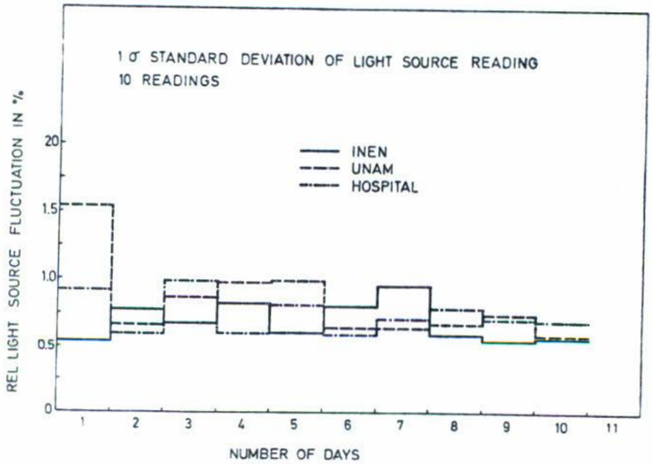

Fig. 6. σ standard deviation of 10 light source readings

3.4 *Dark Current*

The daily change of the dark current is presented in Fig. 7 (mean value of 10 measurements).

Corresponding to the different multiplier sensitivity of the readers (see Fig. 11) the maximum change per day was ±28%, ±23% and ±9% for the UNAM, INEN and Hospital General readers, respectively. It should be pointed out that the suppression of the dark current from the first day was not changed during the experiments.

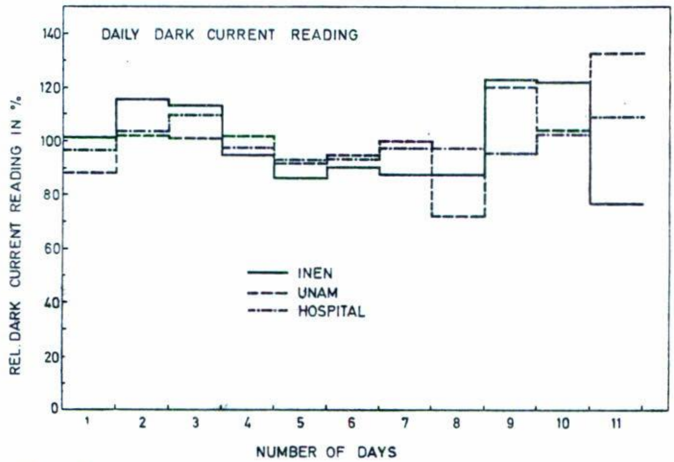

Fig. 7. Mean value of the daily dark current reading

The relative standard deviation for 1σ is given in Fig. 8 for 10 reading per day and was found to be 6 - 16%(UNAM), 3 - 6%(INEN) and 0.5 - 3%(Hospital General).

The lower detection limit of the LiF dosimeter system based on the standard deviation can be presented only if a minimum of 10 dosimeters is used for the irradiation.

The lower detection limit for a single measurement is given by the maximum deviation of the dark current (see paragraph 5).

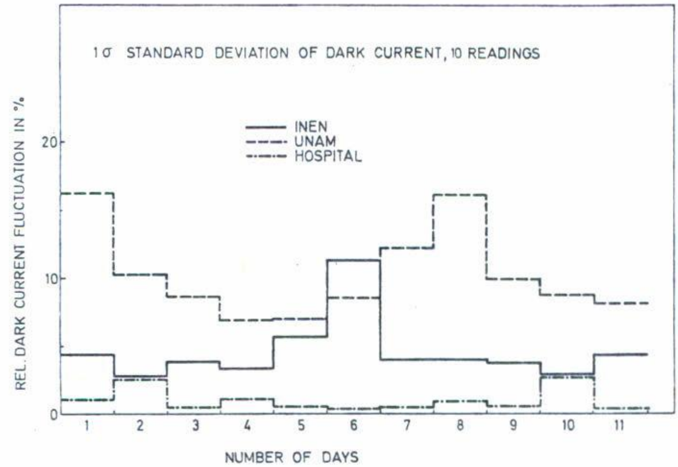

Fig. 8 σ standard deviation of 10 dark current readings

4. CALIBRATION

For the calibration of the TLD two ^{137}Cs source of 200 mCi and 10 mCi were used. The dosimeters were exposed at the same distance from the source (70 cm). The dose rate at these positions were 171.18 mR/h (source I), and 6.72 mR/h (source II).

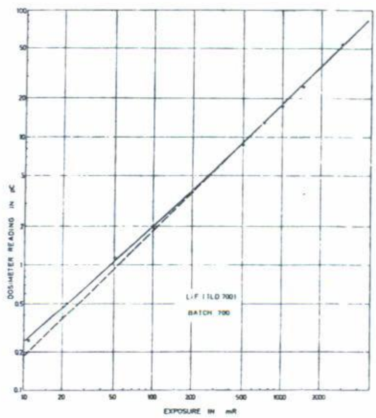

Fig. 9. Calibration curve of LiF (TLD-700)

The calibration curves for LiF and CaF_2:Dy obtained by changing the exposure period from 5 min up to 17 h and 90 min, respectively, are presented in Fig. 9 and Fig. 10 for the UNAM reader.

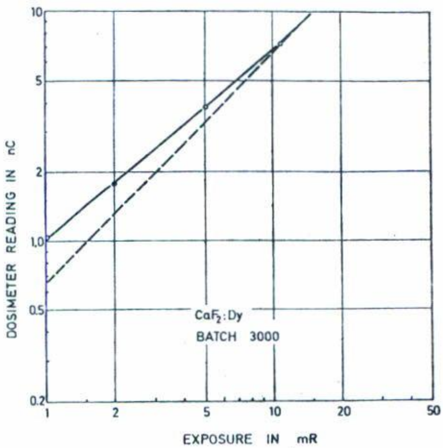

Fig. 10 Calibration curve CaF_2:Dy(TLD-200) found for two different batches

It can be seen from the figures that there is a relatively high divergence from the linearity due to the individual reader adjustment.

From the dosimeter reading only the dark current was substracted which was found during the heating cycle without using a dosimeter. Table 2 shows the corresponding reader sensitivity.

TABLE 2

DOSIMETER RESPONSE FOUND WITH THE UNAM READER

DOSIMETER	nC/R
TLD - 700	18.75
TLD - 100	13.64
TLD - 200 UNAM	670
TLD - 200 - GFK	470

5. LOWER DETECTION LIMIT

The lower detection limit of the LiF dosimeter system found with the different readers is presented in Fig. 11.

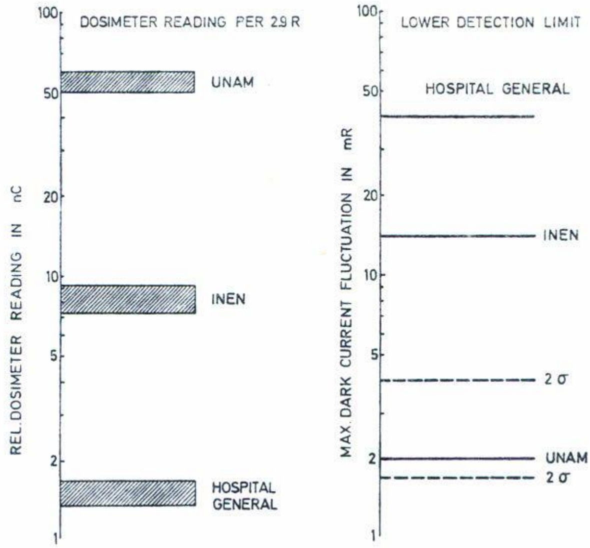

Fig. 11. Dosimeter reading and lower detection limit found for the three TLD readers

Taking into account the different reader sensitivity for a 2.9 R exposure which gives 54.5 nC (UNAM) compared to 8 nC (INEN) and 1.46 nC (Hospital General) and the maximum dark current fluctuation found in Fig. 8, the lower detection limit is given by a measuring error of 2 mR (UNAM), 14 mR (INEN) and 40 mR (Hospital General).

For the application of LiF dosimeters to environmental monitoring, and accumulated dose of (10 ± 2) mR can be measured with the UNAM reader, which corresponds to an accumulation period of the order of 5 weeks.

6. NATURAL BACKGROUND

CaF_2:Dy dosimeters were exposed at different locations free in air at the Salazar Center, at the UNAM and outside of two private buildings in Mexico City.

Because of the short accumulation period of 1 week and the relatively high fluctuation of the dark current (in the order of factor 2) during the evaluation of the dosimeters, the accuracy of the results found is not reliable enough. Taking into account the calibration curve in Fig. 10 the natural background level found was in the range of 11.6 μR/h.

A linear dose characteristic would give a value of 101 mR/y.

Careful calibration of the dosimeter batch in the low energy range and longer exposure periods up to 3 months should improve this results.

7. DISCUSSION OF THE RESULTS

The results found for the three TLD readers are summarized in table 3. Here the maximum deviation of the LiF dosimeter system is presented which was found for the different test runs, and which can be explained by error influences and instabilities of the dosimeter system due to the pre- and post-irradiation annealing at different days as well as due to the readers instability and the conditions of the daily irradiations.

The individual dosimeter response found for the 30 dosimeters which were annealed every day was within ±2.5%.

The reproducibility of the irradiation performed every day was within ±2%. A similar reproducibility of the reader sensitivity was found with the light source check.

The reference dosimeter set No. 2 which was exposed at the first day and read daily, reflects the influence of post-irradiation annealing and reader inestability. A comparison of the reference dosimeter set No. 1 and of the 10 test dosimeters which were annealed daily before irradiation, shows that the influence of the pre-irradiation annealing yields to a maximum daily deviation of the dosimeter reading of ±10%.

TABLE 3

MAXIMUM DEVIATION OF THE TLD SYSTEM

ERROR INFLUENCE x)	TEST	MAX. DEVIATION %
Pre + Post + reader	Annealing and re-use	
+ irradiation	INEN	± 10
	UNAM	± 8.5
	HOSPITAL	± 7.5
Pre + irradiation	Reference dosimeter daily annealing last day reading	± 10
Post + reader	Reference dosimeters daily reading first day exposure	
	INEN	± 8
	UNAM	± 5
Reader	Dark current	
	INEN	± 23
	UNAM	± 28
	HOSPITAL	± 8
Reader	Light source	
	INEN	± 2.5
	UNAM	± 2
	HOSPITAL	± 1
Dosimeter	Individual dosimeter response	± 2.5

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x) due to the instability of pre- and post-annealing, of the reader and irradiation.

These large deviation of the dosimeter response was incorporated by the annealing technique. The control of the ovens temperature at 400°C and 100°C was not sufficient and temperature changes during the annealing technique of more than 5% was observed. The uncontroled change of the temperature during a pre- and post-irradiation period of 2 hours yields to a deviation of the dosimeter reading in the order of ±10%.

For a rutine use of thermoluminiscence dosimeter the long term stability of the annealing technique is of most interest. To improve the relative high inaccuracy of the dosimeter system ovens with a better temperature control should be used. In this case the overall accuracy of the dosimeter system should be in the order of ±3%, taking into account individual correction factors for the dosimeter response.

During the investigations it was found out that two Harshaw readers give inaccurate readings, when the evaluation was performed in different ranges of the pico amperemeter. This was found mainly if the dosimeter reading was low (difference up to factor 2 between the two scale readings).

The relative high non-linearity in the lower dose range and the dark current reading fluctuation in the reader of the UNAM should be therefore investigated bery carefully.

ACKNOWLEDGMENTS

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