International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 25 No. 4 Mar. 2019, pp. 1181-1188

http://www.ijias.issr-journals.org/

Impact of Harshaw 6600 Plus Reader's Electronic Parameter Stability on Precision Dose Measurements of Workers Exposed to Ionizing Radiation in Côte d'Ivoire

Omer KOUAKOU[1], Georges Alain MONNEHAN[1-2], and Gogon B.D.L. HUBERSON[1]

[1]Laboratoire de physique nucléaire et radioprotection, Unité de Formation et Recherche, Sciences des Structures de la Matière et Technologie, université Félix Houphouët Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire

[2]Laboratoire National de la Santé Publique, Ministère de la Santé et de l'Hygiène Publique, 18 BP 2403 Abidjan 18, Côte d'Ivoire

ABSTRACT: This work focuses on evaluation the electronic stability of the Harshaw 6600 Plus reader. For this evaluation, a control procedure of electronic components of the reader was developed to quantify normal ranges of variation and annual average trends. These are: the temperature of the nitrogen regulator thermocouple, the high voltage, the reference light, and the background noise of the photomultiplier tubes. The results show that the optimal operating values specific to our working conditions were respectively for pellet ii of 23.460C - 31.98oC; 797.1V - 798.8V; 73.10 nC - 90.29 nC; 0.037 nC - 0.44 nC; respectively for pellet (iii) of 23.680C-32.230C; 810.8V-811.6V; 78.14nC-97.95 nC. ; 0.07nC-0.31 nC; an evolution rates, not significant below 0.5% and 1% for the background of the photomultiplier tubes and the temperature of the thermocouple; constant 0.05% of the high voltage; not significant above 2% for the reference light parameter for positions (ii) and (iii) were respectively observed between years.
The high voltage and the photomultiplier exhibited stability during all the time of our study, on the other hand certain parameters like the temperature of the thermocouple, the reference light sometimes presented instabilities. Overall, the current state of our system is satisfactory for its continued use.

KEYWORDS: Stability, Electronic parameters, Pellet, Optimization condition.

RÉSUMÉ: Ce travail porte sur l'évaluation de la stabilité des paramètres électronique du lecteur Harshaw 6600 Plus .Pour cette évaluation, une procédure de contrôle qualité des composantes électroniques du lecteur a été mise au point pour quantifier les fourchettes normales de variation et les tendances moyennes annuelles. Il s'agit de : la température du thermocouple du régulateur d'azote, la haute tension, la lumière de référence, le bruit de fond des tubes photomultiplicateur. Les résultats montrent que les valeurs de fonctionnement optimales spécifique à nos conditions de travail ont été respectivement pour la pastille ii de 23,46^{0}C - 31,98 °C ; 797,1V - 798,8V ; 73,10 nC - 90,29 nC ; 0,037 nC - 0,44 nC ; respectivement pour la pastille (iii) de 23,68^{0}C-32,23^{0}C ; 810,8V-811,6V ; 78,14nC-97,95 nC. ; 0,07nC-0,31 nC ; Des taux d'evolutions, non significatif en dessous 0,5% et 1% pour le bruit de fond des tubes photomultiplicateurs et la temperature du thermocouple ; constant de 0,05% de la haute tension ; peu significatif en dessus de 2% pour le paramètre de la lumière de référence pour les positions (ii) et (iii) ont été respectivement constaté entre les années.
La haute tension et le photomultiplicateur ont présenté une stabilité pendant tout le temps de notre étude par contre certains paramètres comme la température du thermocouple, la lumière de référence ont présenté parfois des instabilités. Dans l'ensemble, L'état actuel de notre système est satisfaisant pour son utilisation continue.

MOTS-CLEFS: Stabilité, Paramètres électroniques, optimisation du fonctionnement.

1 INTRODUCTION

Individual radiological monitoring of workers under ionizing radiation is a regulatory requirement of a radiological protection program [1] that respects the optimization principle [2, 3, 4]. Since 1999 the National Laboratory of Public Health (LNSP), created by the decree n °91-605 of October 09, 1991,through its Ionizing Radiation Protection Sub-Directorate (SDPRI), monitors radiation exposed workers in Côte d'Ivoire [5] using thermoluminescence dosimetry. The new Harshaw 6600 Plus model dosimetry system offered in 2014 by the International Atomic Energy Agency (IAEA) is based on the phenomenon of thermoluminescence. From 2017, the new Radiation and Nuclear Surety Authority (ARSN) was created to replace LNSP. ARSN to decide to join a quality approach to verify the performance of its measurement system. Dose measurements in terms of quality require a good knowledge of the dosimetric and electronic performances of the system [6, 7]. The electronic performance of the reader object of this article through the electronic quality control test presents in the course of its use drifts vis-à-vis the data of the manufacturer. Long-term use of the TLD system without a complete verification of the stability of critical parameters could lead to underestimation or overestimation of doses that could compromise the protection and safety of exposed workers [8]. These problems are solved by expanding the tolerance range of our working conditions so that measurements continue without critical evaluation of the reasons for the failure. It is imperative in this work to check the current state of the electronic components, to evaluate the stability and to define new optimal operating ranges for continued use of the Harshaw TLD Model 6600 Plus Reader for personal monitoring in Cote d'Ivoire.

2 MATERIALS AND METHODS

2.1 MATERIALS

The TLD system used for individual monitoring at the SDPRI is used to measure thermoluminescence (TL) from the temperature of liquid nitrogen. It is composed of a Harshaw 6600 Plus automatic reader connected to a computer, a printer and TLD-100 type dosimeters each consisting of two rows of LiF: Mg, Ti pellets in position (ii) and (iii) of dimensions 3.2x3.2x0.38 mm3 and 3.2x3.2x0.15 mm3 protected by a case in rubber. The bottle of nitrogen gas is used to cool the reader for its operation. Positions (ii) and (iii) on the TLD map allow the evaluation of Hp (10) and Hp (0.07), respectively [9].

2.1.1 DESCRIPTION OF THE READER

The reader is composed of electronic circuits that can read up to 200 maximum cards in a single load. During the reading, periodic checks of the intensity of the internal source, the reference light (RL) and the noise of the two photomultiplier tubes (PMT) are taken at the beginning and at the end of each new dosimeter group. . The reader was calibrated in physical unit (mSv) by irradiating the dosimeters "gold" of calibrations at the Secondary Laboratory of Dosimetry Calibration (LSED) of the Nuclear Research Center of Algiers (CRNA, Algeria), compared to Hp (10) and Hp (0.07). After irradiation, these "gold" dosimeters from Algeria were read two months after sending in order to have similar fadings [10]. At the start of the reader, an electronic quality control procedure is carried out by carrying out tests. On-line observation to test that the various critical operating parameters remain within the permissible limits during the normal course of operations. This procedure controls certain critical and sensitive subsystems so regular monitoring is recommended to help understand the reader's problems [11]. The quality control self-test report generates and displays the results of the parameters such as the temperature of the nitrogen regulator thermocouple, the high voltage, the reference light, the background of the photomultiplier tubes, the Ground, -15V, + 15V and the analog-to-digital converter on each card position to check the ability of the 6600 Plus model reader to accurately read the pellets in position (ii) and (iii) on the map and compare the results internal firmware standards. All lines and columns must read "PASS". A reading indication '' FAIL '' indicates that an electronic card or assembly must be verified calibrated or replaced [12].

2.2 METHODS

We have identified at each quality control test four electronic parameters of the reader that exhibit fluctuations. So, we decided to collect historical experimental data from these quality control tests during the period from February 2014 to December 2016. The data unavailability of 2017 and 2018 was due to the inactivity of the SDPRI for reasons for changing legal status. Next, we have grouped and calculated the annual averages (equation 1), the standard deviations of the annual mean (See Eq.1) and the annual evolution rates (See Eq.2), relative to the four (4) critical parameters of the reader in position (ii) and (iii) TLD card patches.

$$m = \frac{1}{N}\sum_{i}^{N} x_i \ (1)$$

m is the mean value best estimate of the variable x, N is the number of measurements, i represents the number of series of any measurement and x the measured parameter

$$\sigma = \sqrt{\frac{1}{N(N-1)}\sum_{1}^{N} x_i - m^2} \ (2)$$

σ is the standard deviation of the mean, m is the mean value best estimate of the variable x, N is the number of measurements, i represents the number of series of any measurement and x the measured parameter

$$t = \frac{y_2 - y_1}{y_1} \ (3)$$

t is the rate of evolution, y1 is the value of one magnitude at a time and y2 is the value of the same magnitude at another time.

The study of the stability and the optimal conditions of operation of our system were finally determined by the retrospective analysis of the temporal evolution of these tests of starting of the parameters of electronic quality. The analysis quantified the normal range of variation and the annual average trend. The results were compared with those of the literature and the manufacturer's specifications [12].

3 Results And Discussion

3.1 Temporal Evolution Of Thermocouple Temperature

During the heating of termoluminesscents dosimeters, the phenomenon of appearance of micro-dust can become incandescent to disturb the measurements of doses [13]. To limit this, the flow of nitrogen makes it possible to avoid the presence of oxygen in contact with the TLD material. The temperature of the nitrogen is regulated by a thermocouple that must operate in the temperature range to be measured with the optimum thermocouple usage range defined by the manufacturer in order to have reliable doses. Figure 1 shows the evolution of the temperature of the hot nitrogen regulator thermocouple pellets in position (ii) and (iii) depending on the day of operation of the reader. Pellet temperatures in positions (ii) and (iii) ranged from 23.460C to 31.980C and from 23.68^{0}C to 32.23^{0}C in 2014, respectively; from 24.63^{0}C to 31.49^{0}C and from 24.90^{0}C to 31.74^{0}C in 2015; from 23,46^{0}C to 30,27^{0}C and from 23,68 to 30,52 ^{0}C in 2016. The temperature range of the thermocouple of our use medium was in the range of 23.460C to 31.98oC for the pellet (ii) and from 23.680C to 32.230C for the pellet (iii). We observe that 8% of the data in the graph in Figure 1 showed temperatures slightly above 30 ° C, which is higher than the range of use defined by the manufacturer. This is probably due to our working environment. However a low evolution rate below 1% of the average annual temperature for both positions was found between years. During the period of our investigation, the average ambient temperature of the laboratory room was around 24°C, while the average annual temperature trend was 27°C for both positions. This value of 27 °is a little upwards since it had to be at working ambient temperature after a two-hour stabilization period of the reader [] Therefore, the climatic conditions of our laboratory have to be improved. The average annual temperature has been within 10-30, so the thermocouple is in good condition and has a stable response despite some derivatives

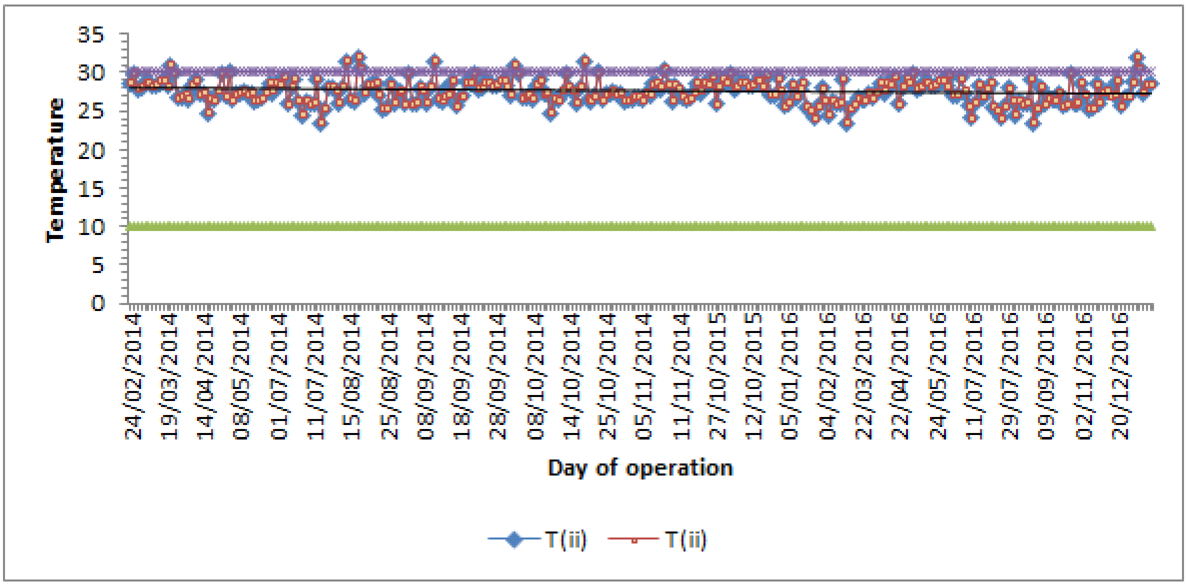

Fig. 1. ***Evolution of the temperature of the hot nitrogen regulator thermocouple pellets in position (ii) and (iii) depending on the day of operation of the reader***

3.2 Temporal Evolution Of PMT Noise

The photomultiplier is the electronic component that captures the thermoluminescent emissions of the TLD and delivers an electrical signal. It is therefore very important to continuously measure the electronic background noise in the system. This noise comes from light leaks and the dark current of the PMT. Figure 2 shows the evolution of the PMT noise of the pellets in positions (ii) and (iii) according to the day of operation of the reader. The electronic background of the pellets at positions (ii) and (iii) ranged from 0.0390 nC to 0.1034 nC and from 0.5525 nC to 0.15088 nC in 2014, respectively; from 0.0401 nC to 0.2404 nC and from 0.0802 nC to 0.3117 nC in 2015; from 0.037 nC to 0.445 nC and from 0.0749 nC to 0.2474 nC in 2016. The range of variation was in the range 0.037 to 0.44 nC for pellet (ii) and 0.05 nC to 0.31 nC for pellet (iii). We find that the ranges of variations of the pellets (ii) and (iii) agree with that of the manufacturer. But they are below the value 2, the operating range defined by Alves. And al. [14]. The average annual trend of PMT noise over the years of study in Table 1 is substantially equal to 5% and 10% for pellet (ii) and (iii) respectively [15]. These differences in ranges of variation and annual mean values were probably due to the meteorological condition of our middle of use of the reader or reader model. In addition, a very insignificant rate of change below 0.5% of the mean annual PMT noise for both positions was observed between years. The PMT daily reading values plotted in Figure 2 show stable over the study period. The few cases of exceeding the manufacturer's defined range of use observed in Figure 2 were due to a small contribution from another deferred light such as the natural background signal [9]. However, this signal of the natural background noises at a relatively low weight and very little influence the measurement. The photomultiplication behaves well

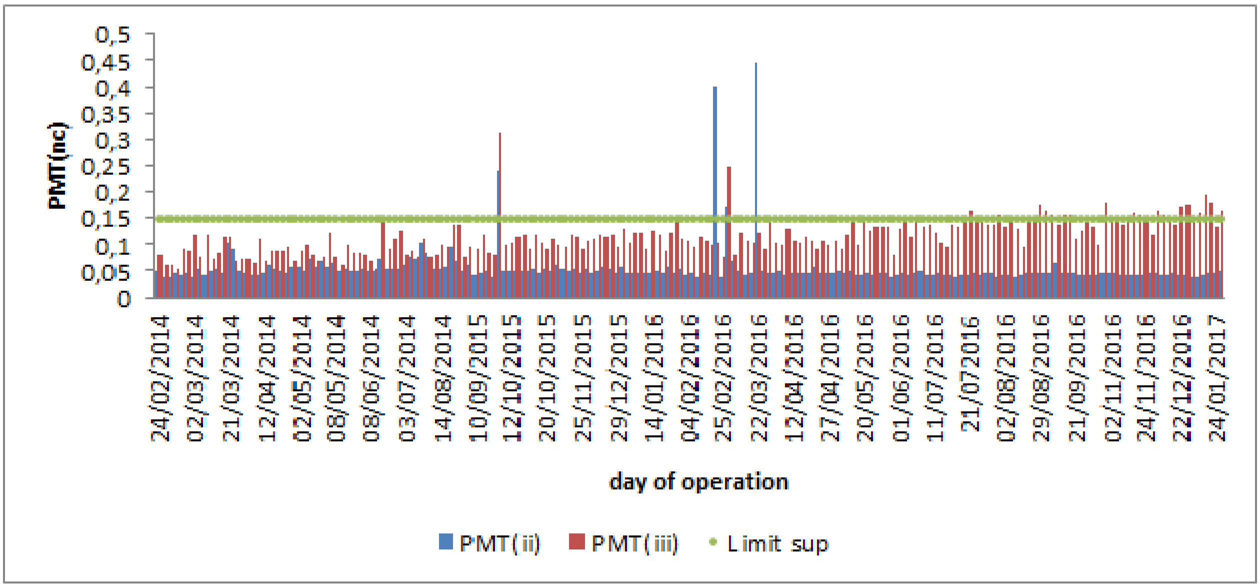

Fig. 2. Evolution of the PMT noise of the pellets in positions (ii) and (iii) according to the day of operation of the reader

3.3 TEMPORAL EVOLUTION OF THE HIGH VOLTAGE (HT)

The high voltage measures the supply voltage of each photomultiplier tube. It requires careful examination because it may affect the light collection system, and therefore the results of the TL dose Figure 3 shows the evolution of the values of daily readings of the high voltage (HT) positions (ii) and (iii) of the pellets as a function of the day of operation of the reader. The values of positions (ii) and (iii) of pellets ranged from 798.1V to 798.8V and from 810.8V to 811.6V, respectively, in 2014; from 798.2V to 798.8V and from 810.8V to 811.6V in 2015; from 797.1V to 798.8V and from 810.8V to 811.6V in 2016. The range of variation of high voltage during normal operation of the device of this work was respectively in the range of 797.1V-798, 8V for the pellet (ii) and 810.8V-811.6V the pellet (iii). The variation ranges for pellet (ii) and (iii) respectively were below 860-880 V and 855-875V [14]. a constant rate of change of 0.05% of the high voltage for both positions was observed between years. The mean annual trend of HT over the years of study for pellet (ii) and pellet (iii) was 798V and 811V, respectively. These annual mean values trends in Table 1 are very low between years, very insignificant compared to reference levels of ± 5V standard deviation of the manufacturer's tolerance and are less than 804 for pellet (ii) and greater than 796 for lozenge (iii) [15]. These differences in ranges of variation and annual average values could have their origins in this work, either in the difference of the model of manufacture of the reader [15] or in the meteorological conditions of functioning of the readers. The daily values traced in Figure 3 pellets (ii) and lozenge (iii) show standard deviations of less than 5V, suggesting that HT show stable behavior over the study period and make the reader calibration factor stable. Some short-term variations were observed, which is probably due to the different latency times before starting the test. High voltage did not affect the light collection system (photomultiplier) and therefore the results of daily readings of termoluminescence. it is in good condition. We do not need to do a manual correction.

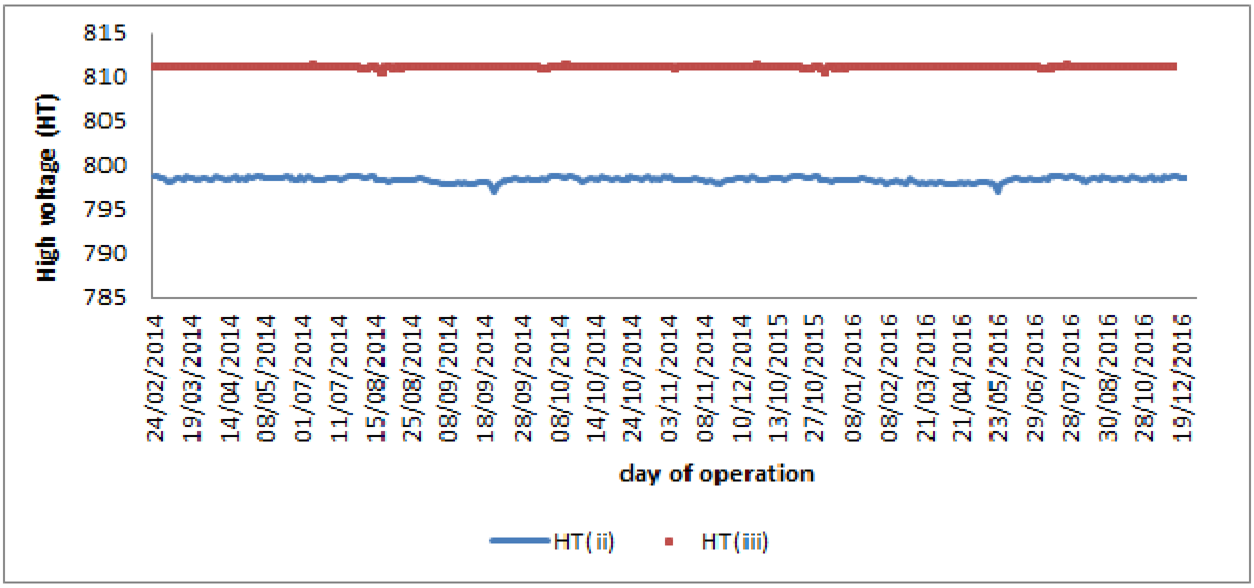

Fig. 3. The Evolution of the values of daily readings of the high voltage (HT) positions (ii) and (iii) of the pellets as a function of the day of operation of the reader

3.4 Temporal Evolution Of Reference Light

This parameter measures the light delivered by two diodes. These reference lights are located in the PMT device. Reference readings are taken at the beginning and at the end of each new dosimeter group. Figure 4 shows the evolution of the values of daily readings of the reference light (RL) of the positions (ii) and (iii) of the pellets as a function of the day of operation of the reader. The values of positions (ii) and (iii) of pellets ranged from 73.10 nC to 90.29 nC and from 78.14 nC to 97.95 nC in 2014, respectively; from 80.46 nC to 88.24 nC and from 79.18 nC to 87.37 nC in 2015; from 81 nC to 89.43 nC and from 81.04 nC to 90.62 nC in 2016. The range of variation of the reference light (RL) during normal operation of the device was respectively in the range of 73.10 -90.29 nC for the pellet (ii) and 78.14-97.95nC the pellet (iii). However, they are below 400-485 nC and 580-700 nC, the operating range defined by Alves. et al. [14] respectively for pellet (ii) and (iii). An evolution rate above 2% of the average annual reference light for both positions has been observed between years. The long-term trends in the standard deviations of these mean annual values over the years of study in Table 1 are significant compared to the reference levels of 10% standard deviation of the manufacturer's tolerance. Moreover, these mean annual values are below 1479.7 1303.0, values recommended by Schandof and Al [15] respectively for pellet (ii) and (iii). These differences in ranges of variation and trends in mean annual values may be due to the duration of data collection or in the difference of the reader's manufacturing model [10]. The daily values plotted in Figure 4 of pellets (ii) and (iii) show dispersions greater than 10% of the standard deviation, which suggests that the reference light source has not been constant over the period of time. 'study. The cause of this dispersion, which was suggested by the manufacturer of the instrument, is probably due to some foreign matter such as dust that could accumulate on PMT lenses [17]. For this, regular maintenance of the PMT lens must be carried out. The reference light must now be monitored with great care.

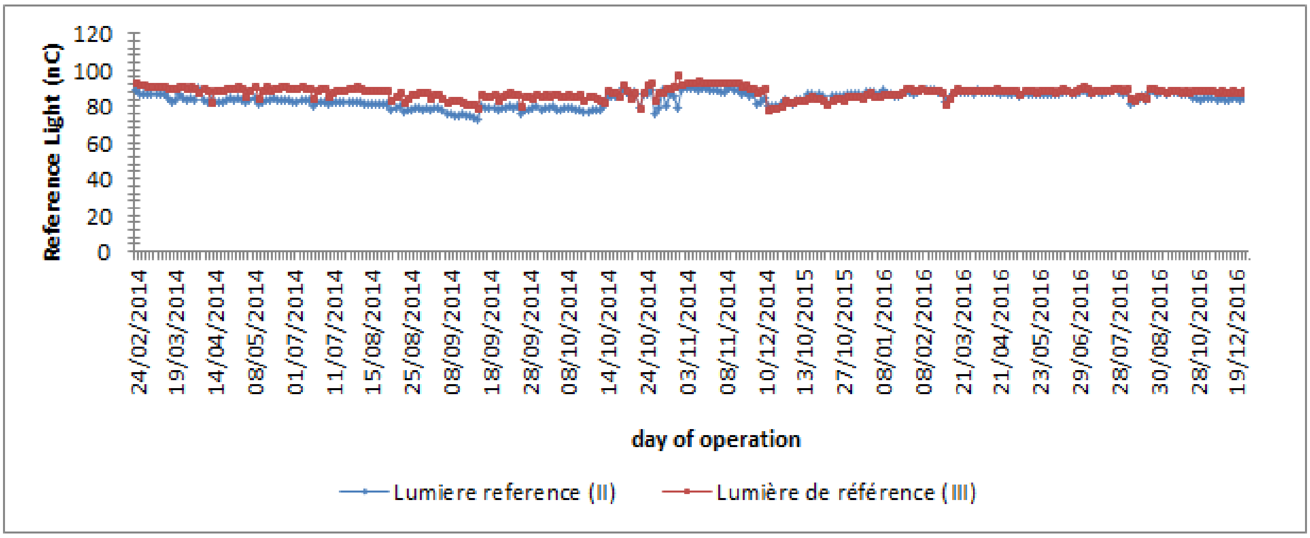

Fig. 4. ***Evolution of the values of daily readings of the reference light (RL) of the positions (ii) and (iii) of the pellets as a function of the day of operation of the reader***

Table 1. ***Annual average and standard deviation of the 2014-2016 reader's electronic parameters***

Parameter	Estimate of value						
	Position ii			Position iii			Acceptable criterion [12]
	2014	2015	2016	2014	2015	2016	
T (°C)	27,64±1.4	27,7±1.6	27,43±1,4	27,84±1.4	27,9±1,7	27,4±1,4	0-30
HV (Volts)	798±0,26	798±0,18	798,4±0,31	811,4±0,10	811,±0,19	811,4±0,07	$\overline{X} \mp 5$
RL (nC)	82,40±4,5	84,75±2,26	86,47±2,07	88,21±3,43	88,8±2,06	88,28±1,49	$\overline{X} \mp 10\%$
PMT (nC)	0,05±1%	0,05±3%	0,05±6%	0,10±2%	0,11±4%	0,13±2%	$\overline{X} \mp 10\%$

4 CONCLUSION

This work evaluated the stability to electronic parameters of our Harshaw 6600 Plus reader as part of our technical quality assurance program. The monitoring and analysis of readings of the daily values of the self-tests of the electronic quality control parameters made it possible to check the current state of the electronic components and to redefine new ranges of variation specific to our working condition. These new ranges of variation will now serve as a reference indicator for responding to maintenance needs in a timely manner. The annual average trends will also make it possible to evaluate, in the medium and long term, the upward or downward trends in the parameters between years.

The results also revealed that parameters such as high voltage and photomultiplier are stable, but some parameters such as thermocouple temperature and reference light need to be monitored with special attention in order to take timely maintenance decisions for avoid for a long time to immobilize the reader.

REFERENCES

[1] International commission on radiological protection, “1990 Recommendations of the International Commission on Radiological Protection”, Publication No.60, Pergamon Press, Oxford and New York, 1991.

[2] CIPR 26, “Recommandations 1977 de la Commission Internationale de Protection Radiologique”, Pergamon Press, Oxford, 1977.

[3] CIPR 60, “Recommandations 1990 de la Commission Internationale de Protection Radiologique”, Pergamon Press, Oxford, 1993.

[4] CIPR 73, “Protection et sûreté radiologiques en médecine”, Nucléon, 1997.

[5] Arrêté n° 32/MSPS/MEFP du 17 février 1992, Fixant les modalités de contrôle des activités liées à l'utilisation de sources de rayonnements ionisants et de radioéléments artificiels en côte d'ivoire, 1992.

[6] L. Z. Luo, K. J. Velbeck, J. E. Rotunda, "Experience of type testing Harshaw advanced TLD system to new IEC- 61066 standard"; Radiat. Meas., vol. 43, pp. 594 – 598, 2008.

[7] M. Malek Mohammadi, S. M. Hosseini Pooya, B. Firoozi, A. Nabipour Chakoli, "Performance Characteristics Of A Home-Made Tld Reader, Preliminary Results";. Vol. 1, No 3, pp. 233 – 235, 2016.

[8] Available from the University of Ghana, School of Nuclear and Allied Sciences, Department of Nuclear Safety and Security, P. O. Box Box AE1, Atomic, Legon, Ghana; 2 tabs. 26 figs., 21 refs; 76 p; Thesis (M.Phil) Jul 2013 (Junuary 29, 2019)

[9] ICRU. "Determination of dose equivalents résulting from external Radiation sources". Report 39 (bethesda),MD ICRU Publications,1985.

[10] Rizk, and F. Vanhavere, "A study on the uncertainty for the routine dosimetry service at the lebanese atomic energy commission using harshaw 8814 dosemeters". Radiat. Prot. Dosim. pp. 1–5 doi:10.1093/rpd/ncv426, 2016.

[11] Weinstein M., Shemesh Y., Abraham A., GermanU, "Use of statistical checks as maintenance tools for TLD readers". *Radiation Protection Dosimetry* 125 (1-4):109-112. 2007.

[12] Bicron, "Model 6600 Automated TLD Reader with WinREMS^{TM} Operator's Manual". Publication No. 6600-W-O-0602-005. Bicron, Saint-Gobain/Norton Industrial Ceramics Corporation. Solon (OH), USA, 2002.

[13] David blanchet, "Développements méthodologiques et qualification de schémas de calcul pour la modélisation des échauffements photoniques dans les dispositifs expérimentaux du futur réacteur d'irradiation technologique jules Horowitz) (RJH)". Thèse de Doctorat de l'École doctorale des sciences fondamentales n° 178, université blaise pascal Numéro d'ordre DU 1651 EDSF : n°485, 2006.

[14] Alves. J. G., Montezuma, R., Margo, O. and Santos, L, "Study on quality control parameters of a TLD system for individual monitoring". Radiat. Prot. Dosim. 111(1) 21-25 Radiat. Prot. Dosim. pp. 1–5, doi:10.1093/rpd/ncv426,2004.

[15] C. Schandof, A. D Asiamah and S. Anim-Sampong, "Performance of Harshaw 6600 thermoluminescent dosimeter (TLD), Système for personal Monitoring"; Journal of Applied Science and Technology (JAST), vol. 7, N0 1 et 2, pp37-43,2002.

[16] K. J. Velbeck, L.Z. Luo, K.L. Streetz, "Type testing the model 6600 plus automatic TLD reader". Radiat. Prot. Dosim., vol.120, no.1-4, pp. 303-306, 2006.

[17] German, M. Weinstein and O. Pelle, "Determination of quality parameters from statistical analysis of routine TLD dosimetry data". Radiation Protection Dosimetry Vol. 119, No. 1–4, pp. 306–309, doi:10.1093/rpd/nci514,2006.

[18] Environmental Instruments 26400 Broadway Avenue Oakwood OH (440) 439-202044146 (440) 439-9856 fax ,2014. [Online] Available: http://www.thermo.com/, (July, 2014)