The determination of timer error and its role in the administration of specified doses

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In its most recent Code of Practice, the International Atomic Energy Agency (IAEA) has recommended that timer error of a ^{60}Co teletherapy unit should be taken into account. In the present paper it is shown that the measured timer error for this unit is very reproducible over a long period of time and for different dosimeter set-ups. When a correction for this error is performed, the uncertainty in the dose due to timer error is found to be reduced by a factor of 7.5.

I. INTRODUCTION

Since 1987, the IAEA has published several reports concerning standards in dosimetry and radiotherapy. In two International Codes of Practice for the determination of the absorbed dose to water in a Co-60 beam, namely TRS 277 (1987) [1] and IAEA TRS 277 (1997) [2], there is no mention of timer error, although it is a topic with a long history. More recently, in a series of quality control tests for a Co-60 teletherapy unit recommended by the IAEA [3], the timer error has been identified as one of the parameters that must be determined. The IAEA has further outlined a tolerance value of 1% that must be met if the unit is to pass the test.

In the most recent of the International Codes of Practice for the determination of the absorbed dose to water in a Co-60 beam, namely IAEA TRS 398 (2000) [4], the need for the timer error correction is again emphasised and its use is demonstrated in a worksheet. The worksheet in TRS 398 gives an equation from which dosimeter reading rate, corrected for timer error, can be obtained. Out of the four well-documented [5-12] timer error determination methods, namely two-exposure method, single/double exposure method, single/multiple exposure method and graphical method, this Code of Practice [4] has used the third method to derive the correction. The recent inclusion of the timer error and its determination into a Code of Practice suggests that a further consideration of this topic would be timely.

This paper describes the use of the graphical method for timer error determination of a Co-60 teletherapy unit, of type Eldorado 8(#104), in a secondary standard dosimetry laboratory (SSDL). Measurements were made over a period of 9 months from June 1999 to March 2000, using seven dosimeter set-ups. Previously reported values of timer error for the ^{60}Co teletherapy machine were the order of ±1 s [5] and 1 or 2 s [8]. In this graphical method, if values of exposure X (R) are plotted as ordinates against corresponding values of timer reading t (s) as abscissae, a straight line with an equation of $X = mt + c$ should result, where m is slope of the line and c is the intercept on the ordinate axis. The timer error T_e is obtained when $X = 0$, i.e. $T_e = -c/m$. The graphical method was chosen in the present work for the following three important features:

(1) It offers the simplest procedure to get the sign and magnitude of T_e as nowadays any commercially available personal computer is fitted with software capable of plotting the straight line $X = mt + c$ and yielding the values of m, c and the correlation coefficient r^2 values.
(2) The yielded r^2 values can give a check on the linearity of the dosimeter, $r^2 = 1$ being the ideal value.
(3) The plotted graph offers clarity *without* the possibility of confusion [13] on how to apply T_e to the indicated irradiation time so that the correct dosimeter reading rate is obtained. In another words, the incorrect treatment of the timer error, which may lead to incorrect value of the dosimeter reading rate, can be avoided.

II. MATERIALS AND METHOD

Five ionisation chambers and three electrometers were used, as identified in Table I. Only seven pairings of chamber and electrometer are compatible, and exposure measurements were therefore made with the seven possible set-ups, made up as shown in Table II.

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TABLE I. Identification of the ionisation chambers and electrometers used in the present work. The combinations used are given in Table II.

Dosimeter component	Identification	Type
Ionisation chambers	c_1	NE 2571 (#1028)
	c_2	NE 2571A (#3002)
	c_3	N 34001 (#0124)
	c_4	NE 2561 (#267)
	c_5	NE 2581 (#334)
Electrometers	e_1	PTW-UNIDOS 10005 (#50013)
	e_2	Farmer Dosimeter NE 2570A (#535)
	e_3	NE 2560 (#151)

TABLE II. A summary of timer error measurements made with the different dosimeter set-ups. For each graph, the correlation coefficient was exactly 1. "Duration" refers to the time that elapsed between the first and last measurements of a set.

Dosimeter set-up		Duration	No. of	Timer error (s)		
No.	Combination	(days)	graphs	individual	s.d.	averaged
1	c_1+e_1	193	3	1.1749	0.1606	1.2325 ± 0.0927
				1.1086		
				1.4139		
2	c_1+e_2	80	3	1.6758	0.2951	1.3353 ± 0.1704
				1.1761		
				1.1539		
3	c_2+e_1	82	3	1.5946	0.1670	1.4028 ± 0.0964
				1.2897		
				1.3241		
4	c_2+e_2	82	3	1.4678	0.1608	1.2846 ± 0.0928
				1.1670		
				1.2191		
5	c_3+e_1	245	3	1.3112	0.0456	1.3178 ± 0.0263
				1.2758		
				1.3663		
6	c_4+e_3	225	2	1.1001	0.0018	1.0989 ± 0.0013
				1.0976		
7	c_5+e_1	27	2	1.0808	0.1690	1.2003 ± 0.1195
				1.3198		
All above	All above	275	All above (19)	All above	0.1683	1.2799 ± 0.0386

Fig. 1 shows the procedures that have been performed after a single experiment ($N = 1$) with the dosimeter set-up 1 has been carried out, for the purpose of getting an *individual* timer error. It can be seen that the timer error value calculated in this figure, i.e. 1.1749 s, is also mentioned as the first timer error value in column 5 of Table II. For the purpose of accuracy and precision in getting this timer error value, in this work:

(1) At least two experiments ($N \geq 2$) were carried out for each set-up, so that the averaged value can be obtained. It can be seen in Table 2 that all together N = 19 experiments were carried out for the 7 dosimeter set-ups.

(2) On average each graph has 6 points, and most of these points were the average of 5 readings. All the readings are actually the corrected readings, i.e. have been corrected for temperature and pressure influences.

For each dosimeter set-up, a chamber was placed in air along the beam at SCD = 100 cm with the field size (at 100 cm) set to 10×10 cm^2. The figure for this experimental set-up, and the methods used to calculate the individual corrected reading, averaged reading, uncertainty in the averaged reading and standard deviation; have been described elsewhere [14].

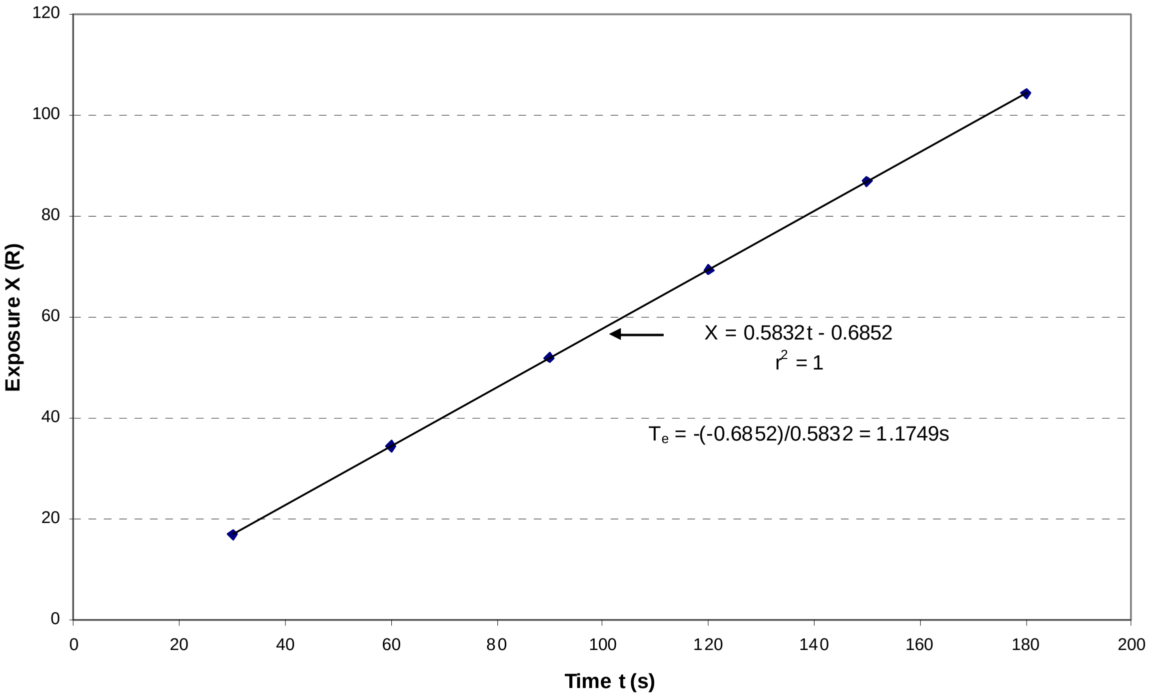

FIG. 1. Exposure versus irradiation time obtained when dosimeter set-up no. 1 is used. The excessive precision in the calculated parameters will be adjusted when the results of all 19 similar graphs are compared.

III. RESULTS AND DISCUSSION

19 graphs were plotted for the 7 dosimeter set-ups, to yield 19 *individual* timer error values as shown in Table II. From the individual timer error values of each dosimeter set-up, the averaged timer error, its standard deviation (s.d.) and its standard uncertainty (in the average) were calculated. This calculation yielded 7 averaged timer error values, 7 s.d. and 7 standard uncertainty (in the average) for the 7 dosimeter set-ups, as shown in Table II. Upon examining these results, it clearly shows that the 7 average timer error values obtained from the 7 dosimeter set-ups are consistent with each other.

All the 19 *individual* timer error values were tested to verify whether they belonged to a single sample. Repeating the same calculation procedures, this sample yielded the overall average of 1.2799 ±0.0386 s and the overall standard deviation 0.1683 s, as shown in the bottom row of Table II. Upon examining all the results now, it clearly shows that the 7 average timer error values (obtained from the 7 dosimeter set-ups) are also consistent with the overall average and the overall standard deviation.

The above results were displayed graphically in Fig. 2 so that: (1) the consistency of the 7 average timer error values among themselves, and (2) the consistency of the 7 average timer error values with the overall average; could be checked easily. It can also be seen in this figure that all the experimentally obtained values are about the same order as previously reported values [8].

The need for the IAEA 1% tolerance value is justified by the fact that the knowledge of timer error value, be it its magnitude or its sign, when applied, will contribute to the achievement of accurate patient irradiation times, and henceforth accurate patient doses (or, in the SSDL environment, accurate calibration doses). Therefore there are two ways in which we can use this result in the administration of dose:

(1) Ignore the timing error. Since there is a very small chance of the timing error (in a single measurement) being greater than the 3-s.d. value, i.e. 1.8 s (= 1.2799 s + 3×0.1683 s), we should ensure that any irradiation times are greater than 180 s, thus satisfying the IAEA recommendation that the dose uncertainty should be less than 1%.

(2) Correct for the timing error. This means that for a prescribed time *T*, the timer must be set to *T* + 1.28 s. The dose uncertainty is then determined only by the uncertainty in a single determination of the timer error, which is the s.d., i.e. 0.17 s, and is therefore much less than 1% for irradiations of duration ≥ 17 s.

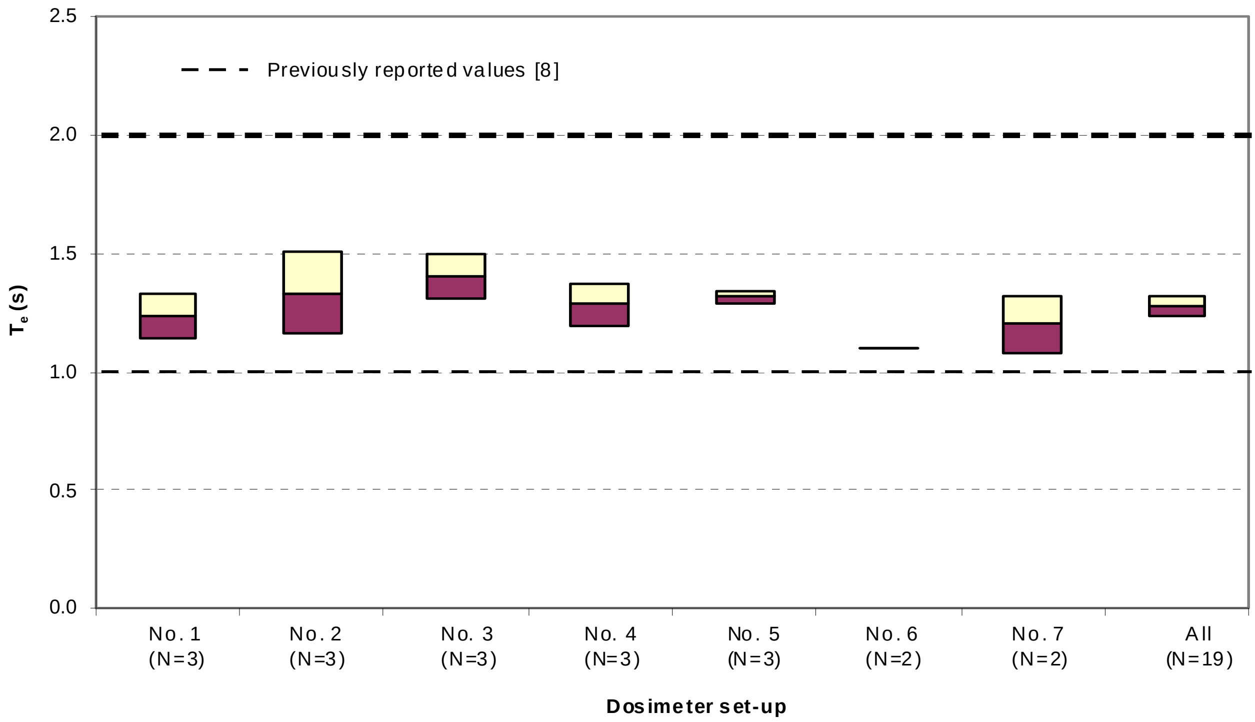

FIG. 2. Experimentally obtained timer error T_e with standard uncertainty, for a Co-60 teletherapy unit in comparison with the previously reported values.

It should be noted that when the timer setting is greater than the actual exposure time, as it is here, then the graphical method gives a positive timer error. If the timer is regarded as a pre-set adjustment, however, then it is logical to think of a negative error occurring when the actual time is less than the pre-set value, and this usage is in accordance with the most recent IAEA recommendations. Both sign conventions are found in the literature, and some authors have made confusing statements perhaps through not realising that there are two possible conventions. This point has been discussed more fully elsewhere [13].

It is also useful to mention here three important points pertaining to this work:

(1) Motions of the shutter or the source have been identified as the two possible causes for timer error of a ^{60}Co teletherapy unit [8,9,15]. The latter is relevant for this Eldorado 8(#104) unit. If a particular radiation facility adopts the recommendation to correct for timer error, then they should monitor the timer error at regular intervals. This will check for malfunction problems such as lack of lubrication (for the source movement), or a failure in the source-driving mechanism [10]. As the measured timer error value in the present work is very reproducible over a long period of time and for different dosimeter set-ups (and agrees with the previously reported values), we conclude that this unit is free from malfunctions of this type.

(2) Although the teletherapy unit investigated here is set up in a standards laboratory, a similar method may be followed for the determination of timer error for (clinical) units belonging to hospitals and radiotherapy centres.

(3) The method described here may also be used for x-ray machines [10]. In this case, a slightly higher tolerance value of 2% has been reported [16]. The most usual cause of timer error for this machine is that the timer starts before the full potential is applied to the tube [9]. A measured timer error value of 1.9 s has been reported [17], however it is interesting to learn from another report [11] that a timer error value of −15 s is not impossible for this type of machine.

IV. CONCLUSION

If the present Co-60 unit is used clinically, for each single patient irradiation subsequently carried out, a timing correction of 1.28 s should be added to the prescribed time. We anticipate that the irradiation time would then lie within an interval of ±0.17 s of the correct time with a probability of 68%. For this particular series of investigations, allowing for timer error decreases the dose uncertainty (arising from the timer) by the ratio 1.28/0.17 = 7.5.

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