DESIGN AND IMPLEMENTATION OF A NEW DEVICE FOR THE INTEGRAL MEASUREMENT OF TOTAL SOURCE-ON TIME FOR A HIGH DOSE RATE (HDR) REMOTE AFTER LOADING TREATMENT UNIT

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Abstract— **Most treatment units that utilize a radioactive source are equipped with a timer that measures the source-on interval; however, independent verification of the accuracy of this internal timer for each treatment is part of a comprehensive QA program. Design and implementation of a new device used to automatically measure the total integral time that a radioactive source spends outside the safe will be presented. Most radiation therapy rooms have installed a radiation detector unit operating independent of the radiation producing device. One wall mounted sample of such device is a simple Geiger Muller (GM) counter known as the "PrimAlert-35" made by Nuclear AssociatesTM that will illuminate when placed in radiation field. Using a digital timer known as "Veeder Root TimerTM" connected to the auxiliary output of a PrimAlert-35, we were able to visualize the signal on an oscilloscope screen and determine that is was a step function. We also found that auxiliary output is a 200 millisecond pulse when in alarm condition, and the timer could not track the pulse because of the oscillation of the signal. A circuit was then designed and added to the PrimAlert-35 unit to stretch the 200 ms pulse so that it appears to be a non-pulsing signal at a constant DC level. This allowed us to measure the time interval for as long as the PrimAlert-35 was active. This is an equivalent time for the source being out of the safe. Our timer can be utilized to enhance the quality assurance program necessary for the safe implementation of an HDR brachytherapy or Co-60 teletherapy program.**

Keywords— **Quality Assurance, Teletherapy, Brachytherapy, Radioactive Sources.**

I. INTRODUCTION

In the past few decades high dose rate (HDR) brachytherapy has become a significant modality in the treatment of cancer. HDR sources are capable of delivering high doses of radiation in very short time and hence, from the radiation safety point of view, are a cause of concern for radiation oncologists, physicists and staff. The high activity of the source requires a very precise timing system for accurate dose delivery.

Dose is delivered to the patient by dwelling the source at set locations for specific amounts of time. Dwell times are calculated by complex radiation treatment planning systems (TPS) for a set number of dwell positions determined from 3-dimensional imaging. For the accurate delivery of treatment, the HDR is equipped with a redundant set of timers that measure and monitor the total time that the radiation source sits in each of the dwell positions, as well as the total treatment time. The HDR room is also equipped with a Gamma area monitor, which alerts staff if radiation level exceeds a certain limit. This function is very important since it assists in identifying the status of source position: whether the source is in or out of the safe. A comprehensive HDR quality assurance program necessarily must establish and follow proper definitions of clinical and machine parameters [1,2], one of the most important being the accuracy of the total treatment time. Yet most clinics will verify the timer accuracy by hand with a stopwatch, a method prone to subjective error. In this article, we present the design and implementation of a timer device that gives the integral “source-on-time” and its implementation as part of our HDR QA program. This device when added to the Gamma monitor “PrimAlert-35”, measures the time for which the source of radiation is outside the shielded area, hence providing an independent method to monitor the active “source-on-time”. This additional measurement will also serves as a double check on the total treatment time given by the HDR planning system. Such a timing system can also be used to verify the source-on-time for Co-60 teletherapy systems in developing countries or utilized in new emerging technologies, such as MR-RT machines.

II. METHODS AND MATERIALS

Measurements were made using our Varian HDR unit (iX) and a commercial simple Geiger Muller (GM) counter (Figure 1) known as the "PrimAlert-35" manufactured by Fluke BiomedicalTM. The PrimAlert-35 is a compact G-M counter monitor that responds to scatter radiation and can be mounted anywhere inside of the treatment vault. It is implemented in high radiation areas as an independent monitor of ambient radiation levels. A visual indicator light illuminates when the measured radiation level reaches a certain threshold. It has a range indicator at 1, 2, 4, 8, 16, and 32 mR/hr that allows an immediate assessment of the radiation risk. The light for each level goes on when the radiation intensity reaches that level, and goes out when the rate drops below the level. If the alarm threshold is set to the highest sensitivity, it will trigger the indicators at radiation levels of about 5 times the background level, approximately 0.02 mR/hr.

The circuit diagram of the PrimAlert-35 is relatively simple and operates using a 12VDC power supply. The timer's input signal can easily be taken from the output of this detector unit.

Figure 1. Sample image of a PrimAlert-35 G-M Radiation Detector

For the purpose of this project, we designed a circuit diagram depicted in Figure 2 with simple plug-in at the output of the PrimAlert-35 device, to start a timer exactly concurrent with the triggering of the PrimAlert-35. Of all radiation detector types, the G-M counter produces signals of the same amplitude as soon as finds radiation present, regardless of strength of radiation source in the area. At the instant the detector is activated via presence of a source, the timer turns on and remains on as long as the detector remains active. Because of the high activity of the source, this means that the timer activates almost immediately after it has been deployed from the safe, and measures the time it takes for the source to return.

The total time the source was out of the safe was measured manually with a stopwatch and with the automated timer circuit. The stopwatch was activated as close as possible to when the PrimeAlert alarm was activated. The dwell position was set to 100 cm from the afterloader and the dwell times were set to span the range of clinically relevant treatment dwell times.

III. Results

A series of measurements (Table 1) were made using the new PrimAlert-35 device with the additional timer circuit attached. These measurements were checked against the internal timer of the HDR unit, a manual stop watch used to measure the radiation on-time from the control console, and the auto timer from the circuit diagram shown in figure 2 located in the patient treatment room. The dwell location was 100 cm from the afterloader. The contribution from transit time has been subtracted from both measurements

IV. Discussion

As shown in Table 1, the ability of the timer circuit to accurately measure the dwell time is comparable to manual timing. The timing circuit averages a higher deviation by approximately 0.2 seconds, which may be caused by the configuration of the pulsed circuit as it operates on a 0.2 s period step-function. The anticipated transit time effect does not appear to have a large influence on the timing results. The manufacturer cites the transit speed of the source between 50-60 cm/s, with an average of 55 cm/s [3]. This should introduce ~3.8 – 4 s worth of transit time exposure over the course of 100 cm from the safe to target and back to safe. The timing circuit is also accurate over the relevant clinical ranges and shows a high degree of reproducibility

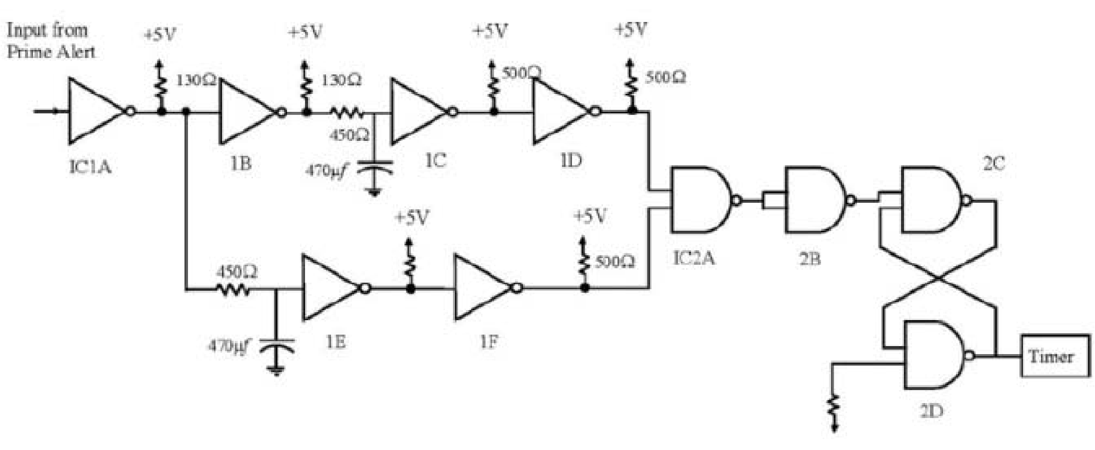

Figure 2. Diagram of automated timing circuit

The timer can also be used as an independent verification of the total source exposure time for patients treated with HDR brachytherapy or Co-60 teletherapy. The transit time for each patient's HDR plan can be quickly subtracted off with minimal effort. Obviously, teletherapy treatments will not have the added complexity of incorporating transit time.

The automated timer can also be used for efficient and objective daily and monthly timer tests, simplifying the process of these QA tests.

V. Conclusions

We developed a method to obtain automatically the period of radiation on-time for the HDR I-192 source using a specially designed timer circuit. By this method, we could quantitatively measure the total time the source is out of the safe. This timer can be implemented as part of a rigorous QA program for HDR brachytherapy or Co-60 teletherapy units in an effort to reduce the susceptibility of measurement bias introduced by human involvement. The timer results can also be utilized as an independent validation of each patient treatment. This circuit can be integrated into the in-room radiation monitor. Our timer circuit is a simple and cost-effective method to provide independent verification of timer systems utilized in modern radiation therapy.

Table 1 Comparison of manually measured and automatically measured time of source exposure. Manual measurements were performed using a stopwatch for total source-out time. Automated timer measurements were generated by the PrimAlert timer circuit. Transit time was subtracted assuming 50 cm/s transit speed to a dwell position at 100 cm. All units are in seconds.

Computed Dwell Time	Manual Timer	Automated Timer with Transit Time	Automated Timer without Transit Time
10	11.5	13.3	9.6
30	31.6	36.0	32
50	52.4	55.5	51.5
70	71.2	76.1	72.1
90	90.6	95.8	91.8
120	120.2	125.1	121.1
150	151.0	155.9	150.9
200	201.1	204.8	200.8

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