P-3b-167

A New PC Based Semi-Automatic TLD Badge Reader System For Personnel Monitoring

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INTRODUCTION

Personnel monitoring of more than 40,000 radiation workers in India is being carried out routinely using a Bhabha Atomic Research Centre (BARC) made thermoluminescent dosimeter (TLD) badge based on $CaSO_4$:Dy phosphor embedded in Teflon discs [1], and a photographic film badge. Till recently the TLD badges were read using the manual type TLD badge reader system with an external interface unit for connection to a PC for glow curve storage and dose evaluation [2]. The film badge is being replaced by the TLD due to the operational convenience and the low cost of the latter resulting in a very significant increase in the number of persons being monitored using TLD. A new PC based semiautomatic TLD badge reader system with a number of design improvements for faster processing of the TLD badges with reduced man power has been developed. The new reader has features such as non contact N_2 gas heating, reproducible temperature profile of the gas, built-in safeguards against gas flow, heater and EHT failures, dark current compensation, background subtraction, auto ranging, automatic switching of EHT to a lower value when high TL output is encountered to enable a wide range of measurement with high sensitivity to lower levels of TL, etc. An elaborate software is written in 'C' language for storage and recall of glow curves, evaluation of doses and printout of dose reports.

INSTRUMENT DESCRIPTION

The semiautomatic TLD badge reader system is based on a Personnel Computer with all the front end functions in the reader controlled by an Atmel 89C51 microcontroller which is connected to PC through an RS-232 serial interface. Fig. 1 shows the functional block diagram of the reader. The reader comprises of a microcontroller based electronic control circuits, TLD card transport mechanism for moving the TLD badges to the reading position, PMT housing, gas heater & an on-off proportional temperature control circuit and a solenoid for switching the gas flow on & off. The entire operation of the reader is controlled by a menu driven, user friendly, software residing in the PC. An assembly language software in the 89C51 microcontroller controls the various motorized movements, monitoring of various circuits, generation of EHT for the photo-multiplier tube (PMT), measurement of PMT anode current, etc., on command from the PC.

The movement and the positioning of TLD cards inside the reader is achieved using three compact DC motors and the positioning is accurately sensed using opto-electronic sensors. The circuits are opto-isolated from the rest of the circuit to prevent motor driver noise from affecting the rest of the circuit. The motors are driven in both forward and reverse direction by a software controlled pulse width modulated outputs from the microcontroller for achieving precise positioning. A anodized aluminum magazine (maximum capacity of 50 TLD cards) loaded with the TLD cards is moved in a 'U' channel into the reader by a 'Y' motor which also raises the card for pickup and placement. A motor 'X' is used to move the TLD badge to the reading position. Sensing of the different motor positions is done using opto-interrupters and the presence / absence of the dosimeter card in the magazine is sensed by using an opto-reflector. Another DC motor 'Z' is used for moving a shutter to prevent infra-red and stray light from reaching the photo cathode of the PMT, when the TLD card is not in the reading position. This dc motor is also used for bringing a built-in check light source (in ^{63}Ni incorporated in a plastic scintillator) to the reading position for checking the PMT sensitivity.

A high stability temperature compensated photo multiplier tube type EMI 9125B is used for light detection. A software controlled high voltage power supply (EHT, -200V to –1200V) with a load regulation and stability better than 0.05% is designed for the PMT. A control circuit is used to switch this EHT from a high to a low value automatically, under the software control, when the dosimeter reading exceeds 200,000 counts (equal to 0.2Sv of Cs^{137} gamma dose) such that the gain of the PMT is reduced by a factor of 100. This is done to safeguard the PMT from exceeding the recommended maximum anode current of 50 µA under high radiation dose condition and to cover a range of 1 µSv to 10 Sv. A current – to – frequency (I-F) converter is used to convert the PMT anode current into a train of pulses whose frequency is proportional to the current. The I-F converter has a linearity of ±1% from 1nA to 10 µA (10Hz to 100 KHz).

A dual on/off proportional temperature controller is designed for uniform and rapid heating of the TLD badges. Cold N_2 gas is forced through a Nichrome coil heater at a flow rate of 5LPM to get the hot gas at the outlet of the heater. The heater is maintained at 300°C using feedback from a thermocouple located inside the heater during the idling period when readout of TLD cards is not in progress. The temperature of the hot gas is raised to 280 °C within 5 seconds and clamped at 280 °C till the end of the readout time, using feedback from a second thermocouple located in the hot gas stream below the exit nozzle. A solenoid valve is used to switch the gas supply 'On' & 'Off' at the cold end of the heater. The glow curves obtained are uniform. A typical glow curve recorded for a TLD badge along with temperature–time profile is shown in fig.2. As can be seen from the glow curve a read out time of 30 seconds is adequate. The left over TL is found to be less than 10% by the second readout of the dosimeter cards. The read out time per badge (containing three 0.8mm thick TL dosimeters) is 90 secs and 50 badges are read in less than 90 minutes.

SOFTWARE

A user-friendly menu driven software package has been developed for the semiautomatic TLD badge reader system. The package has features like creating data files for storing glow curve data, generation of the personnel & institution data files, data analysis, recall of glow curves, dose evaluation, printout of dose reports, record-keeping, etc. A 16 digit identification code is assigned for each user. This code contains entire information of the person wearing the TLD badge, which includes the institution number to which the user belongs and his personal number, service year and service month, frequency of service, nature of radiation environment in which the user is working (eg. gamma, beta/gamma, X/gamma, X-ray, etc), and the location code (indicating where the TLD badge is worn). The dose evaluation is carried out using empirical relations depending upon the code entered and a printout of dose report can be obtained.

Once all the TLD cards are loaded in the magazine (maximum 50 cards), the 'start' reading cycle can be invoked. This prompts the entry of the dose data file name and the 16 digit identification numbers serially in the same order in which the badges are loaded in the magazine. After this code is entered the reading cycle begins and the solenoid valve opens at the inlet of the gas and the heating process starts. The gas temperature is continuously monitored and displayed on-line on the screen along with the glow curve and temperature profile. The entire glow curve data is stored in the hard disc at the end of the reading cycle.

The reader is calibrated either by changing the EHT through the software (which in turn varies the gain of the PMT), or by entering the calibration factor for fine adjustment. The calibration factor is obtained using a set of dosimeter cards exposed to a known dose and reading them in the reader. An optimum EHT (900 – 1200V) is usually selected for the PMT to obtain the best signal to noise ratio. After the readout is over, the readings are normalized and mean dose and standard deviation is calculated using the software option. The calibration factor is then the ratio of the actual dose given to the TLD badges to the mean dose.

DETECTION THRESHOLD & LINEARITY

The detection threshold the lowest dose that can be measured with the reader system (also defined as 2.26 times the standard deviation (σ) of the annealed dosimeter readings as per the latest International Electro – technical Commission draft [4] is improved in the reader by increasing the readout resolution to 1µSv, minimizing the infrared background using a infrared filter, reducing non-radiation induced background by using N_2 gas for heating. A high stability, temperature compensated, low dark current (0.1nA) PMT tube is used in the reader system. Before the readout of each dosimeter badge the dark current is measured and stored in the PC and subtracted from subsequent dosimeter readings. The EHT is switched from a high to a low value automatically when the dosimeter reading exceeds 200,000 counts (approximately 0.2Sv of ^{137}Cs gamma dose) so as to reduce the gain of the PMT by a factor of 100. This is done to safeguard the PMT from the fatigue when dosimeters of high radiation dose are read. A range of 1 µSv to 10 Sv for the reader system is thus achieved. To determine the detection threshold, a set of 30 randomly selected TL dosimeter badges (used regularly for personnel monitoring) were annealed and read in the reader for three times. A mean background reading of 63.17 µSv ± 22.07 µSv (mean σ) equivalent was obtained from these readings. The observations are shown in the table1. However, when the same experiment was done with the fresh TLD badges having minimum sensitivity variation, a mean background of 17.5 µSv with a std. deviation of 10 µSv was found, indicating the minimum detection threshold can be improved to 1mR using the TLD badge reader system. Table 1 also shows the reader response for a test dose of 5 mSv and the standard deviation and residual TL which is well within 10%.

Cycle Number	Average dose(µSv) for annealed badges	Standard Deviation	Test Dose	Average dose(µSv) of test badges	Standard Deviation	Residue
1	63.26	22.13	5mSv	5505	405.12	8.9%
2	63.34	21.90	5mSv	5506	404.91	8.8%
3	62.92	22.19	5mSv	5511	405.01	8.7%

Table 1: Background reading and standard deviation of the routinely used TLD badges indicating the minimum measurable dose and the reader response for a test dose of 5 mSv along with the std. deviation and residual TL.

A stable and reproducible built-in light source made up of ^{63}Ni coupled to a plastic scintillator [5] is used to check the performance of the light detection system. To check the linearity of response of the TL dosimeter output with respect to dose, the TLD badges were exposed to the different levels of gamma dose from ^{60}Co radiation field. The dose (in Sv) verses the TL output is found to be linear from 50 µSv to 10Sv. Table 2. shows the response of TL dosimeters read in the reader system for various doses. The results were found to be reproducible in the various personnel monitoring centers using the above PC based semiautomatic TLD badge reader system. A study was made to find the reusability of TLD badges with the new reader system. For this, a fresh set of TLD badges were subjected to more than 50 cycles of anneal, exposure and readout in the reader system. It was found that there is no significant change in the sensitivity and shape of the TLD badges even after 50 cycles (table 3). These studies were repeated by the other groups working on these TLD reader system, and the results were found to be similar.

Dose Level	50 µSv	500 µSv	1 mSv	100 mSv	1 Sv	10 Sv
Response	49.22	518.28	965.45	97885	998664	9648780

Table 2. Response of TL dosimeters read in the reader system for various doses.

Cycle Number	1	10	20	30	40	50
Sensitivity	1.01	1.05	1.055	1.04	1.042	1.041
Residue	8.1%	7.98%	7.79%	7.70%	8.32%	8.01%

Table 3. Sensitivity of TLD badges used with the reader system

RESULTS & CONCLUSION

The new PC based semiautomatic TLD badge reader system facilitates a fast readout of TLD badges with a resolution of 1µSv and covers a large dose range of 50µSv to 10 Sv without any range switching. The detection threshold is reduced to 50 µSv for the routine personnel monitoring badges. The genuineness of the dose can be readily verified using the glow curve recall facility. The hot N2 heating of the TLD badges results in the reduction in readout time for 0.8 mm thick TL dosimeter to 30 sec and 0.4 mm thick dosimeters to less than 20 secs and increases the life span of the dosimeters. Operator related errors are completely eliminated due to direct transfer of data to the PC. Glow curve with the temperature profile for any dosimeter can be readily recalled when required for analysis.

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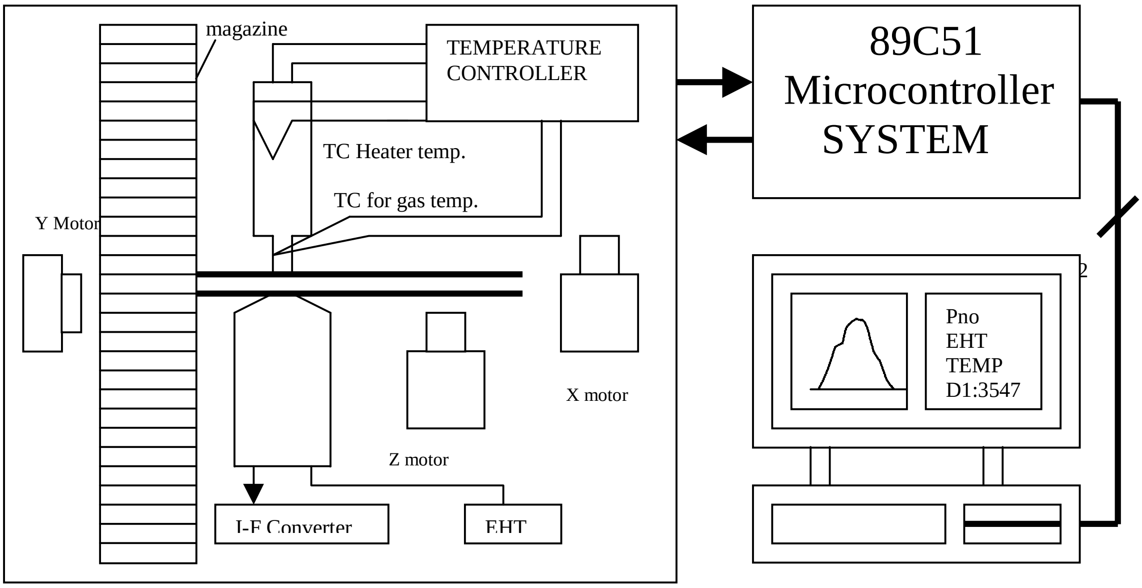

Fig.1 BLOCK DIAGRAM OF THE PC BASED TLD BADGE READER SYSTEM

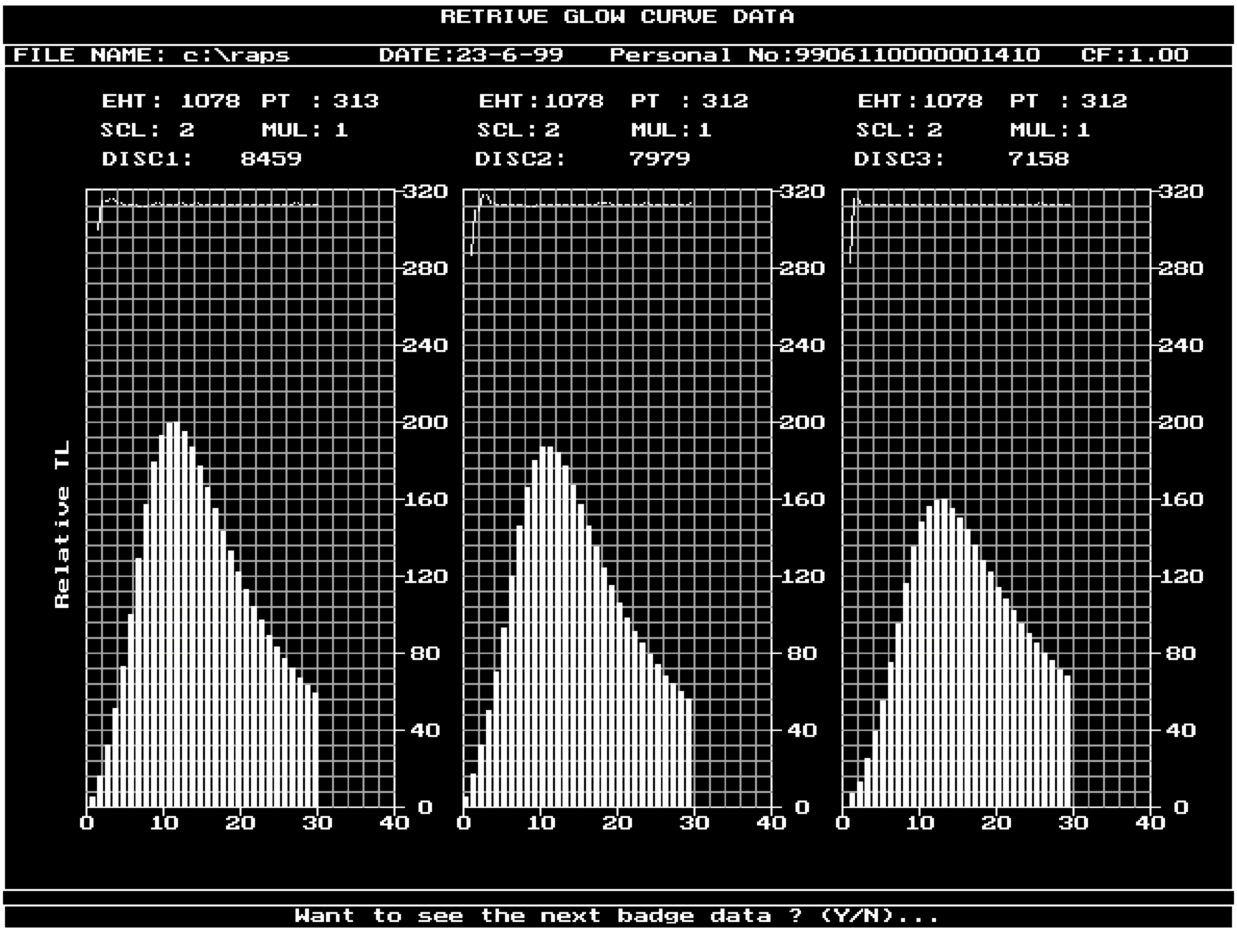

Fig.2 A typical glow curve recorded for a TLD badge along with temperature–time profile