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HAND BOOK ON THE USE OF TLD BADGE BASED ON $CaSO_4$: Dy TEFLON TLD DISCS FOR INDIVIDUAL MONITORING

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Abstract

Individual monitoring is one of the most important aspects of a radiation protection programme. In India, an official and centralized personnel monitoring service to radiation workers started in 1952. With the indigenous development of a Thermoluminescence dosimeter (TLD) badge system in 1975 at Bhabha Atomic Research Centre, decentralization of monitoring service was initiated. At present, about 40,000 radiation workers are monitored using this system through twelve TLD units located in different parts of the country, including a private accredited laboratory. Regulatory and other inspecting bodies have often asked outstation TLD units to produce a duly approved document on the procedures being practiced for the assessment of personal doses. A need for such a document has also been felt to ensure the uniformity in processing of dosimeters, recording and reporting of doses by different TLD units and to provide guidelines regarding the infrastructure requirement. This document in the form of a handbook has been prepared to cater to the above needs. The handbook is expected to provide necessary guidelines not only to the newcomers / forthcoming units and the existing laboratories but also to help the regulators, inspectors and assessors.

PREFACE

Individual monitoring has always played a very important role in radiological protection. A substantial amount of effort has been devoted to the development of dosimetry systems and many changes have taken place in the past 35 years the world over. Thermoluminiscence dosimeters (TLDs) based on solid state techniques have emerged as one of the best alternatives to provide the required accuracy, reliability, ruggedness and possibility of automation for handling large number of dosimeters.

Indigenous development of TLD personnel monitoring system in India has been one more step in the direction of making country self-reliant in the technological advancement. Transfer of technology to private sector and accreditation of laboratories by Bhabha Atomic Research Centre, made the TLD badge system commercially viable and has helped in enhancing the infrastructure. The expansion of services through Accredited Laboratories has helped to cater to the increasing need for personnel monitoring services to radiation workers and in disseminating the technical know- how developed through the years.

Harmonization of procedures in such a widespread programme becomes utmost important and is a key factor in ensuring the reliability of the service. Documented procedures to be followed by the processing laboratories are needed for ensuring the compliance of the guidelines and uniformity in all aspects of the service. This handbook has been prepared to cater to the above long felt need and covers all aspects of routine TLD monitoring such as infrastructure facilities, responsibilities of the staff members of the TLD unit, procedures to be followed for the processing of the TLD cards, dose recording & reporting, technical details of the dosimeters & equipments along with the list of the suppliers etc. The handbook is expected to provide necessary guidelines not only to the existing laboratories and forthcoming units, but also to help the experts and assessors for the evaluation of the performance. As this field continues to grow and the requirement may change from time to time, the revision of this handbook would be taken up as and when necessary. Suggestions and comments to make the handbook more comprehensive and useful, are welcome.

1. INRODUCTION

The Department of Atomic Energy (DAE), since its inception has accorded high priority to safety in activities dealing with radiation and radiation sources. This is evident from the emphasis given to health and safety aspects in the Atomic Energy Act, 1962 enacted by the Government to provide basic regulatory frame work, promulgation of Radiation Protection Rule-1971 (RPR-71), and setting up an apex regulatory body - the Atomic Energy Regulatory Board (AERB).

Individual monitoring constitutes an integral part of radiation protection programme and as per RPR-71, all radiation workers have to be covered by individual monitoring as specified by the competent authority. Bhabha Atomic Research Centre (BARC) started providing personnel monitoring services to radiation workers since 1952 using film badge system. With the indigenous development of a TLD badge system based on $CaSO_4$:Dy Teflon TLD disc offering better dosimetric characteristics, process of replacing the prevalent film badge by the TLD system was initiated in 1975. Standardization of production procedures of TLD badges and dosimetric procedures paved the way to the transfer of technology to the private sector. This made the decentralization of the personnel monitoring services feasible and economically viable. At present there are twelve TLD units (including one private accredited laboratory) located in different parts of the country to provide TLD monitoring service. With increasing use of ionising radiation and enforcement of regulation by competent authority (AERB), a large number of radiation workers would have to be monitored in the near future, requiring many more new processing laboratories/units. Although all the processing laboratories/units will work under the supervision of BARC, it is essential to have an approved document giving the necessary procedures to be followed by all the laboratories for ready reference.

Personal dosimetry enables individual control of exposure in order to make sure that the stipulated dose limits for occupational workers are not exceeded and supports the measures to be taken for further reduction of doses to as low as reasonably achievable (ALARA). The philosophy of radiation protection has considerably changed during the last century and so are the requirements and expectations. While the radiation protection was initially concerned chiefly with limiting exposure to a level, where direct harmful effects (mainly non-stochastic) could be excluded, the assessment of radiation doses became more important when the risk due to radiation doses to produce stochastic effects such as radiation induced carcinogenesis was observed to have no threshold value. At present, the recommended annual dose limit is mainly based on the results of the radiobiological & epidemiological investigations of health risks due to exposure to ionizing radiation and opinions on additional health risk, which might be acceptable to workers and public. With the increasing knowledge in the field, the limits have been gradually reduced and the last revision in 1990, International Commission on Radiological Protection (ICRP-60) has reduced the limit from 50 mSv to 20 mSv per year averaged over 5 years for occupational exposure and from 5 mSv to 1 mSv for the public. The reduced limits have obviously increased the demands on the requirement of individual monitoring in terms of accuracy, performance and recording level. As per ICRP, the recording level value for a monthly service has been reduced from 0.42 mSv of ICRP-26 (1977) to 0.17 mSv of ICRP-35 (1982) and now to 0.085 mSv of ICRP-75 (1999) for occupational exposure. Consequently, the requirements of type testing of dosimeters, performance testing, and aspects of management, record keeping and quality assurance have become more and more stringent.

2. SCOPE OF THIS HAND BOOK

The scope of this handbook is limited to the use of the prevalent official TLD badge system in India. The present TLD badge is designed to asses the doses incurred by workers in the radiation fields of X rays, high & low energy gamma rays, beta rays, mixed fields of X-rays and gamma rays and mixed fields of beta rays & high energy gamma rays. This badge is not intended for mixed fields of beta rays and low energy X-rays and to measure neutron doses. However its response is adequate to measure gamma ray doses in the mixed fields of gamma ray and neutrons. Other personnel dosimeters such as pocket dosimeters, film badges, neutron dosimeters, criticality accident dosimeters and customized extremity dosimeters etc. are beyond the scope of this handbook.

The purpose of this hand book is to provide the details of the infrastructure requirements and the procedures to be followed by the processing laboratories / TLD units for carrying out the individual monitoring using TLD system based on $CaSO_4$:Dy Teflon TLD discs (Appendix-A).The specimen formats provided in the appendices are for general guidelines and the exact format / specification would vary depending upon the local requirement of a TLD unit. The handbook is aimed at providing a ready reference material to the new entrants / forthcoming units and existing laboratories / units.

3. INFRASTRUCTURAL REQUIREMENTS FOR A TLD PERSONNEL MONITORING LABORATORY

For monitoring of 2000 radiation workers in a month or 6000 radiation workers in a quarter, each processing unit should have the following infrastructure facilities. The infrastructure facilities should be increased in proportion with the number of radiation workers to be monitored.

3.1. Technical Manpower

3.1.1. Senior Scientific Staff (e.g. Scientific Officer SO): Minimum one

3.1.1.1. Qualification: M. Sc. (Physics) and either one year Post-graduate Diploma in Radiological Physics or equivalent course conducted by recognized university / institution or five years working experience in the field of radiation dosimetry in a recognized institute preferably with some published work on personnel dosimetry. Lower educational qualification (B. Sc.) could also be considered for the candidates having long experience (more than 10 years) in personnel monitoring.

3.1.1.2. Responsibilities: He will be the overall in-charge of the laboratory/unit. His responsibility includes all the technical aspects of the TLD unit, supervision of the work carried out by other staff members of the TLD unit and ensuring the availability of necessary infrastructure. He should arrange for the preparation of dose reports in time and all the dose reports should be approved by him before sending to user institutions and the concerned authorities. He will arrange written recommendations to the head of his institution sufficiently in advance from time to time to ensure the availability of necessary funds etc. He has to arrange for testing and selection of the TLD cards and other equipment. He has to ensure the proper setting and functioning of all TLD readers and use of proper calibration factor for dose evaluation. He has to conduct the internal quality assurance tests, arrange to participate in external quality assurance programme conducted by BARC, attend to any abnormal TL readings / glow curves and conduct experiments for the improvement of the system or if required for reconciling the doses. He has to

keep track of the sensitivity of the TLD cards, take decision for replacing the batch of TLD cards in service, arrange for the blind test (in case of power station) / spot test, conduct the swipe test of radioactive source periodically, request BARC for calibration of the radiation source and survey instruments so as to keep the traceability to the national standards and act as a member of concerned committees such as TLD - DRD discrepancy committee at power stations/ local committee. In case of any doubt, he would consult concerned unit at BARC and follow the advice. He will also make the arrangements for inspection of regulatory / concerned authorities. He will submit a written report about the status of work, recommendations and future requirements every month to immediate superior or concerned authority of BARC. He will investigate if any significant difference between the readouts of control cards kept at TLD unit and those returned after field use is noted. He is expected to keep himself upto date with the recent development in the field and arrange regular technical meeting (every month), training courses for the staff of the laboratory as and when needed. This will include periodic reviews of the work.

3.1.2 Technical Person (e.g. Scientific Assistant SA): Minimum one

3.1.2.1. Qualification: B.Sc. (Physics as main subject) and a training in radiation safety at BARC.

3.1.2.2. Responsibilities: Scientific Assistant will assist Scientific Officer in all operational aspects and work as acting Scientific Officer in his absence. He will ensure working of TLD readers, annealing ovens, computers and will co-operate in day- to - day work including update of the master file and TLD-5 form, calibration of the TLD reader and readout of TLD cards, preparation of dose reports. He will expose TLD cards for calibration purpose. He will also maintain separate logbooks for the performance and use of each equipment etc. He would check the contamination of TLD cards as soon as they are received after the field use and in case of unusual observation, he will initiate necessary action in consultation with senior person. In case of manual reader without interface facility (TLD BR-3A type), the relevant dose data should be entered into the computer by him for preparing the dose reports. In case of automatic readers (BR 7B type), the badge data of cards to be loaded in the magazine will be entered by him. He will involve the technical staff in the routine work.

3.1.3. Assistants (e.g. Tradesman B or C): Two for the above workload. For monitoring of additional workers, number would increase at the rate of one assistant per 1000 radiation workers per month or 3000 radiation workers per quarter.

3.1.3.1. Qualification: 12^{th} standard (Science discipline) passed and a practical training in TLD processing at BARC or in-house training by senior staff.

3.1.3.2. Responsibilities: He would take directions from Scientific Officer/Scientific Assistant for carrying out his routine job. He will assist SA in all day-to-day work. He shall keep his seniors informed about the difficulties and requirements. His main responsibilities will include the work associated with readouts, annealing and numbering of TLD cards, preparation of TLD cards and badges for dispatch and receipt of TLD cards/badges. He would ensure that the wrappers and TLD cards are arranged in proper order. To replace the missing/spoiled wrapper and card, he would arrange wrapper with personnel number written on it and freshly annealed TLD card in advance. He would load the card with wrapper in the polythene pouch and seal it before the dispatch. He will follow all the procedures for calibration of reader and processing of TLD cards. He will read all the cards (used and unused) on TLD reader. In case of semiautomatic TLD reader, he will monitor the readout procedure during the processing of TLD cards. He will also keep constant vigil on the oven temperature during annealing of TLD cards. He will keep control cards from each

lot of annealed TLD cards issued by the unit/laboratory. He will report immediately all the cases of unusual pattern and high TL readouts of used cards/unused cards/control cards.

3.1.4. Helper: one (optional)

3.1.4.1. Qualification: 10^{th} standard passed or as per government rules or as applicable.

3.1.4.2. Responsibilities: Cleaning of the laboratory, movement of equipment (e.g. nitrogen cylinder), carrying TLD cards and TLD readers from place to place, helping in receipt & dispatch and other related works as decided by the in-charge.

3.2. Space: Adequate space to be provided for following activities of the laboratory / unit and basic amenities for the staff.

3.2.1. TLD Processing Room: Two air-conditioned rooms each of total area about 30 sq. m. are required for the processing, handling, receipt & dispatch of the TLD cards. For processing of additional TLD cards, floor area of air conditioned rooms at a rate of 10 sq. m. per 1000 radiation workers should be added.

3.2.2. Oven Room: An oven room of area 10 sq. m for annealing of the TLD card is required. The room should have a platform to accommodate at least two electric ovens for annealing of TLD cards and washbasin for cleaning of trays, cards etc.

3.2.3. Calibration/Source Room: A source cum calibration room of size 5 m x 4 m x 3 m is required to carry out exposure of TLD cards for calibration purpose and storage of radioactive source. The source room should have appropriate design and wall thickness in order to provide adequate radiation shielding. Facility for storage of source in an appropriate pit (in a lead container of appropriate wall thickness) with lock and key should be provided at one corner of the room.

3.3. Equipment and Materials: Following equipments are required at each unit.

3.3.1. TLD Cards: (Appendix –B) Sufficient number of TLD cards of the order of three to four times of radiation workers to be monitored, should be available depending upon whether the service is conducted in-house as at power stations or service is conducted through post.

3.3.2. TLD Cassettes: (Appendix-C) Number of TLD cassettes available should be at least one and half times the number of radiation workers; one cassette for each card in use and remaining to provide the replacement for the broken / damaged / lost cassettes.

3.3.3. TLD Readers: Three manual TLD badge readers (BR-3A/ BR-3B type) or two semiautomatic N_2 gas readers (BR-7B type) with an additional standby manual TLD reader are required for the above workload. For monitoring of additional 2000 workers in a month, two more manual readers or a semiautomatic reader will be required. Specifications of manual TLD badge reader BR-3A/BR-3B and semiautomatic TLD badge reader BR-7B type are given in Appendix-D and Appendix-E respectively.

3.3.4. UPS/ Voltage Stabiliser: An UPS (uninterrupted power supply)/Voltage Stabiliser of about 3-5 KW capacity is necessary to take care of fluctuations in electric supply and power failure.

3.3.5. Check Light Source: ^{63}Ni beta ray source incorporated with plastic scintillator in the card form is required to check sensitivity of PMT of TLD reader BR-3A /BR-3B type.

3.3.6. Wrappers & Polythene Pouches: (Appendix-F) A minimum requirement for one year in advance of paper wrappers and polythene pouches should be made available. Paper wrappers of different colours (dark) should be used.

3.3.7. Air Circulating Ovens: (Appendix-G) Minimum two air circulating ovens having maximum temperature up to 450 °C with an accuracy of ± 2 °C in the range from 200 °C to 400 °C are required for annealing of TLD cards.

3.3.8. Radiation Source: A standard radioactive source Cs-137 (~10-37 GBq) is required for calibration purpose. Calibration must be traceable to national standards.

3.3.9. Contamination Monitor: (Appendix-H) One Contamination Monitor is required to check the radioactive contamination of TLD cards received from the user institutions.

3.3.10. Gamma Zone Monitor/Area Monitor: (Appendix-I) One Area Monitor / Gamma Zone Monitor, capable of measuring low level (<10mR/hr) radiation field is required to check the radiation level at the calibration / source room entrance.

3.3.11. Calibration Ring/Table: (Appendix-J) A Perspex calibration ring/wooden table is required for exposure of TLD badges / TLD cards.

3.3.12. Computer: A personal computer along with the other related accessories is required for data entry, dose analysis and for dose record maintenance. Additional computers may be required depending upon the type of TLD reader to be used and workload of radiation workers with the laboratory. Computer should have facility to connect reader through interface for direct TLD reading transfer while using manual TLD reader (BR -3A or BR- 3B).

3.3.13. Glow Curve Recorder: Normally, the PC based TLD Readers have the facility to record the glow curve. In case of manual TLD reader without any PC interface, a two-pen glow curve recorder, having scale in the range 1 mV to 10 V and speed of 2.5 - 25 cm per min is recommended for recording of glow curves.

3.3.14. Annealing / Drying Trays: Sufficient number of steel trays (~20), preferably with cover, of size 25 cm length x 4 cm height x 3.5 cm width and thickness less than 1 mm are required for annealing of TLD cards. Minimum two trays of size 30x30x5 cm^3 are required for drying the TLD cards after cleaning with acetone.

3.3.15. Forms: Sufficient stock of TLD-5, TLD-4 and TLD-2 forms should be ensured for at least one year. Specimen format for TLD-5, TLD-4 and TLD-2 forms are given in Appendix - K, Appendix – L and Appendix – M, respectively.

3.3.16. Number Punching Machine: Number Punching Machine is required for engraving the individual card number on the TLD cards.

3.3.17. Sealing Machine: A heat-sealing machine is required for sealing TLD card in polythene pouch before despatch.

3.3.18. Thermometer & Thermocouple: An additional thermometer with thermocouple is required to verify the temperature of the oven.

3.3.19. Gadget: A suitable electrical gadget (could be made locally, also available from the supplier of Manual TLD Reader, Appendix-U, Kaustabh Industrial Engineers) having indicator light facility to detect the fault with the TLD card is preferred to check the physical dimension of the card and the appropriateness of clipping and centering of TLD discs on the card. This gadget is more relevant for the TLD cards to be used in manual reader.

3.3.20. Vernier Calliper: A Vernier calliper is required for measuring the dimension of TLD cards, filters in the cassette etc.

3.3.21. View Box: Commercially available view box is required to check spots and presence of voids and foreign particles in the TLD discs.

3.3.22. Stop Watch: A stop watch is required to set exact time in terms of hour, min and sec with alarm for irradiation of TLD cards.

3.3.23. Air Blower: An air blower is required for drying / evaporating acetone from the TLD card after cleaning.

3.3.24. Nitrogen Cylinder and accessories: Sufficient number of nitrogen cylinders is required for auto TLD reader along with accessories such as gas regulator, rubber tube, spanner, key and trolley. Safe storage and proper immobilization of nitrogen cylinders during use should be ensured.

3.3.25. Long forceps: One or two stainless steel forceps of length 45-60 cm are required to handle radiation source.

3.3.26. Acetone: Sufficient stock of analytical grade (AR) acetone is required for cleaning the TLD cards on receipt from the supplier and during the field use.

3.4. Utility Services and other Materials

3.4.1. Boxes: Sufficient number of cardboard and plastic boxes of various sizes for despatch and storage of TLD badges / cards should be stocked to last for at least six months.

3.4.2. Stationery: Sufficient stationery items such as computer printing paper, note books / registers for log books for keeping and maintaining various records should be made available.

3.4.3. Furniture: Adequate furniture for the staff as well as for the equipment should be provided.

3.4.4. Communication facilities: Laboratory should have an arrangement for the required communication such as telephone, fax, email, internet etc.

3.4.5. Fire Protection: Provision should be made for protection of laboratory from hazards arising out of fire, electricity, fumes etc.

3.4.6. Water and Electricity: Provision should be made for adequate number of power points for TLD readers, ovens & other equipment and tap water facility in laboratory.

4. TLD BADGE

TLD badge is based on $CaSO_4$:Dy thermoluminescent phosphor as a radiation detector. The concentration of Dy dopant to the extent of 0.05 mol.% in $CaSO_4$ makes it highly sensitive thermoluminescent (TL) phosphor (about 40 times that of the most popular LiF TLD-100). The response to neutrons remains negligible (only 3.8 mGy equivalent Co-60 gamma ray response per 10^{10} thermal neutron cm^{-2}). The phosphor exhibits a main TL glow peak at about 220°C (TL peak of $CaSO_4$: Dy Teflon Disc occurs at about 240 °C) with very small satellite glow peaks on higher and lower temperature sides of the main peak. The TL response is linear and glow curve structure remains stable for both low and high LET radiation in the dose range of interest in radiation protection. The response and the chemical form are highly stable to the climatic variations. Though the TL signal fades faster when exposed to bright sunlight, exposure to normal room light does not affect the response. However, the response of TLDs contained in paper wrapper and

polythene pouches, is not affected by exposure to sunlight. In order to obtain large number of integrated dosimeters having the same TL sensitivity, $CaSO_4$:Dy phosphor was embedded in Teflon (polytetrafluoroethylene PTFE) to make TLD discs. Teflon is a plastic which can withstand temperatures necessary for TL readout and annealing process for repeated use and thus provides rugged and handy dosimeter suitable for field use. Some of the characteristics of the $CaSO_4$:Dy Teflon embedded TLD discs are given in Appendix -A.

The TLD badge comprises of a TLD card and plastic cassette / holder. TLD card has three Teflon TLD discs (13.3 mm dia. and 0.8 mm thick) that are mechanically clipped onto circular holes (12.0 mm diameter) punched in an aluminium plate of size 52.5 x 30 x 1 mm^3. An asymmetric "V" cut is provided in the card to ensure its orientation. Specification of TLD card is given in Appendix-B. The card wrapped in a thin paper wrapper (thickness 10 mg/cm^2) containing printed information regarding the user, service period and type of radiation etc. is put in a thin plastic pouch (thickness 3-4 mg/cm^2) before loading it in the plastic cassette. The paper wrapper protects the TLD discs from exposure to light whereas plastic pouch prevents contamination of the TLD card. Specifications of TLD cassette are given in Appendix-C. Specifications of paper wrapper and plastic pouch are given in Appendix-F. There are three well-defined regions in the plastic cassette / holder corresponding to three TLD discs of the TLD card. The asymmetric "V" cut of the card permits its loading in the plastic cassette in only one orientation and ensures proper positioning of three discs as follows: (i) Disc D1- sandwiched between a pair of filter combination of 1.0 mm thick Al and 1.0 mm thick Cu (Copper filter nearer to the disc), (ii) Disc D2- sandwiched between a pair of 1.6 mm thick (180 mg/cm^2) plastic filters and (iii) Disc D3- under a circular open window. For identification purposes, photograph of the user could also be permanently fixed on the central transparent region of the badge.

There are three types of TLD badges / cassettes in use namely, 1- Chest Badge, 2- Wrist Badge and 3- Head Badge. Though the dosimeter and design of all the three types of TLD badges are same, they have different attachment (clip/strap) for wearing purpose depending on their use.

5. TLD BADGE READER

5.1. <u>Manual TLD Reader (Model BR-3A and BR-3B):</u> The TLD badge reader model BR-3A, utilizes the integral method of TL measurement as it involves less stringent requirements on heating rate. Contact heating using kanthal strip is used to quickly attain the required temperature, which is maintained for the duration to cover the main TL glow peak. The reader basically provides a programmed heating cycle to the TL dosimeter and senses the instantaneous light emitted by the dosimeter (glow curve signal), displays the total integrated light in terms of mSv. A common display (3½ digit DPM) is provided which on selection, indicates the instantaneous temperature of the heater (°C), EHT supply to photomultiplier tube (volts), integrated output (EXP) of the sample or calibration (CAL) light source. A timer controls the duration of the heating/integrating cycle. Background suppression is provided so as to subtract the spurious counts (dark current) from the TL reading. Heater raising control knob is provided on the front panel, which raises the heater to make the contact with the TL discs. The other controls provided on the panel include "EHT ADJ" for adjusting the voltage to the photomultipliertube (PMT) for calibration of the reader, "STOP" to terminate the reading cycle during measurement, if required and "RESET" to bring the display (either in "EXP" or "CAL" mode of operation) to zero. The reader specifications are given in Appendix- D.

Heater Drawer System consists of a gear controlled metal cassette, in which the card is loaded. Micro switches are provided to indicate the respective TL discs in reading position, by

panel lamps. The kanthal strip heater element placed below disc position is required to be raised at each TL disc position before timer/heater cycle is initiated. Heater is raised by rotating knob provided on the front panel. A chromel-alumel thermocouple is welded beneath the heater to sense the heater temperature and the temperature is displayed on the panel. Any of the discs (D1, D2 & D3) can be placed above the heater by rotating the knob provided on the right side of the reader. After readout of one disc, the card is moved to position the next disc on the heater manually by advancing the card holder. For readout of a TLD card, it takes about 4 minutes.

A new microprocessor controlled manual TLD reader (model BR-3B) also became available. This TLD reader is having facility for on - line glow curve recording and can store dose data & glow curves for large number of dosimeters. The display of the reader are through liquid crystal display (LCD). It can be operated both manually as well as through PC. In addition to the Normal and LS mode for the measurement of TL output and LS reading respectively, it has a Test mode for testing the PMT performance by taking the readout of ^{63}Ni light source. Rocker switches are provided on the front panel of the reader to change the values of cycle time, EHT to PMT, and type of operating mode. Other features of the reader are same as that of BR-3A.

5.2. Semiautomatic N_2 Gas Heating TLD Reader (Model BR-7B): Recently a semiautomatic TLD reader has become very popular. The TLD badge reader (model BR-7B) is capable of automatically reading 50 TLD cards in 100 min. The reader specifications are given in Appendix-E. The main features of this reader are - measurement of doses from few μSv to 1 Sv without any range switching, hot gas (air or N_2) heating of TLD discs, auto dark current subtraction, PC based operation (AT 386 or advance versions) and built-in data base management software. The TLD badge reader consists of microprocessor based electronic control circuits, the PMT housing, card transport system for moving the TLD card to the reading position, gas heater and temperature control unit, cooling fans and a solenoid for switching the gas flow on/off. Entire operation of the reader is PC controlled. Once the cards are loaded in the magazine and inserted into the reader, with all corresponding badge numbers and other relevant data entered manually in the same sequence in which the cards are loaded, the reader automatically reads the 50 cards loaded in the magazine. It prints the TL readings as and when each card is read in order to provide a hard copy and stores the glow curve & the TL readings in a floppy/hard disk. Elaborate self-diagnostic software keeps an eye on the vital circuits of the reader such as EHT applied to the PMT, temperature, gas flow etc. In case of fault detection, the readout process is terminated automatically with a message displayed on the PC monitor to alert the user.

6. TESTING OF TLD BADGE READER

Specifications of TLD Badge reader should be ensured prior to their procurement which should be as given in Appendix D & E for manual and semiautomatic N_2 gas TLD readers, respectively. The following tests should be carried out and recorded before acceptance of the reader.

6.1. Mechanical: Overall mechanical finish and proper fitting of the TLD card in the drawer/magazine of the TLD reader and smooth movement of the magazine should be ensured. Compatibility of the reader drawer/magazine for the cards received from different suppliers should be ensured.

6.2. Light Leakage: There should not be any light leakage in the reader. This could be confirmed by comparing the readout of freshly annealed card in bright room light and with all lights switched off in the room.

6.3. Timer: The timer should reproduce the cycle time with an accuracy of ±1 s. This should be verified by an external timer for minimum 20 readings.

6.4. EHT to PM Tube: After warm up time of 30 minutes, EHT should not vary by more than ±1 V throughout the readout process.

6.5. Integrated Dark Current: In case of manual TLD reader the integrated dark current for the reading cycle with the heater off position should be set to display zero by adjusting the background suppression knob. Once this position is set, dark current should not vary by more than 4-5 counts for any disc reading position at the set operating voltage.

6.6. Light Source Reading: Performance of PMT stability can be checked by taking repeated readouts of light source (LS). In case of manual reader, an in-built light source (LED) is provided and LS readings can be taken in CAL position at a fixed disc position (as mentioned in the manual) without inserting the TLD card. This can also be checked by taking repeated readouts using an external ^{63}Ni light source. The LS readings should be taken at room temperature and the heater should be kept in OFF position. However, in case of semiautomatic TLD reader, an in-built ^{63}Ni source is provided as the light source and repeated LS reading can be taken in the 'Reader Test' mode. The light source reading should not vary by more than 2% throughout the day.

6.7. Readout Temperature: Clamping of readout temperature should be checked. It should be around 280°C ± 2°C and it should reach within 15 - 20 seconds of the start of heater cycle in case of manual reader. This can be confirmed by taking readout of dummy cards or by plotting the temperature profile. For semiautomatic reader, the clamping temperature as per the display should be around 300°C ± 2°C and should reach within 10-12 s from the start of heating cycle. This can be confirmed by plotting the temperature/heater profile (temperature vs time) as well as from the glow curve. The flow rate of N_2 gas should be strictly controlled as small change in the flow rate can cause significant variation in the readout.

6.8. Glow Curve & Uniformity in Readout: For this purpose, 10 TLD cards (preferably selected cards) sandwiched between perspex build-up plates (thickness 4-5 mm) should be taken and exposed to about 4-5 mSv of Cs-137 gamma rays. TL readouts of all the cards should be taken and uniformity of heater contact with the TLD disc (manual reader) or uniform gas heating (semiautomatic reader) should be checked by recording the glow curves and comparing their structures. A sharp glow curve will ensure the good contact & proper heating of the TLD disc with the heater.

6.9. Stability of Recorded Counts: In case of manual TLD reader, the stability of the registered TL readout (counts displayed on the reader panel) should be checked for about 5 minutes after the readout is over. TL reading should not change by more than 1 count per minute..

6.10. Residual TL Check: Second readout of the above cards should be taken to check the residual TL. The second readout should not be more than 10-12% of the first readout. If it is more, heater contact with disc (in case of manual reader) and actual temperature at the nozzle position or flow rate (in case of semiautomatic reader) should be verified and necessary adjustments has to be made

6.11. Reproducibility of the TL Readout: For this test, at least 10 TLD cards should be used. The cards are to be annealed, exposed in build-up plates and read after one day after the exposure. Cycle to cycle variation of average TL readout should be within ± 5% and in case of any significant change, the response should have an established trend. Minimum three cycles of annealing, exposure and readout has to be carried out.

6.12. Minimum Measurable Dose: Minimum measurable dose for the TLD card and TLD reader system (for manual as well as semiautomatic TLD readers) should be verified by each processing laboratory. For this purpose, readout of some freshly annealed TLD cards (at least 10 cards) should be taken and from the value of 3σ, minimum measurable dose should be obtained.

6.13. Linearity Test: Linearity of the reader should be checked prior to its introduction in the routine use and at least once in six months thereafter. Also, after every major repair or in case of suspicion about the TLD reader's performance, this test should be conducted. For this purpose, freshly annealed cards should be exposed to various doses (a minimum of 5 doses, 5 cards for each dose) in the dose range from 0.3 mSv to 1 Sv of ^{137}Cs gamma rays and readout of all cards should be taken under similar conditions. The TL response (average TL/mSv) should be within ± 10% in the entire dose range covered.

6.14. PC Interface: Performance of PC interface unit should be checked in case of manual reader, wherever applicable.

7. CALIBRATION OF TLD BADGE READER

7.1. Exposure of TLD Cards for Reader Calibration: During every monitoring period, about 100 annealed TLD cards from freshly annealed batches (minimum of 20 cards from each batch, depending upon batch size) planned for use in the cycle, should be taken and kept for calibration purpose. These calibration cards, wrapped in paper wrapper (with identification of batch number) and sandwiched between perspex build up plates of thickness 4 -5 mm should be exposed to known dose (about 5 mSv) of ^{137}Cs gamma rays at a minimum distance of 50 cm. The source should be kept at the centre and the TLD badges should be placed on the circumference of the circle on a perspex ring / wooden table (Appendix-J). The height of the perspex ring / wooden table should be more than 1 meter from the floor. Exposure time for the geometry to be used, should be calculated from the measured air-kerma rate of the source in order to deliver dose in the range of 3-5 mSv. Exposure of calibration cards should be carried out at least 15 days in advance for monthly service and 30 days in advance for quarterly service before their actual use for calibration of the TLD readers.

7.2. Setting of TLD Reader : The TLD readers should be kept 'ON' for at least half an hour for warm-up before starting the actual measurements on it. The EHT, count suppression (only in case of manual TLD reader) and initial temperature should be noted.

In case of manual TLD reader, dark current of the reader should be noted by taking the readout in the 'EXP' mode with heater in 'OFF' position and without inserting any TLD card. Then light source reading should be taken to check the performance of the PMT of the reader. For this, minimum three readings of in-built LED in 'CAL'/'LS' mode as well as that of an external ^{63}Ni light source in 'EXP'/ 'TEST' mode should be noted for manual reader (TLD BR-3A/BR-3B). In case of semiautomatic reader, at least three reading of in-built ^{63}Ni light source should be taken in the 'Reader Test' mode. All the data should be recorded in the log book with date, model, serial number of TLD reader etc.

After LS measurements, readout of 2-3 dummy TLD cards should be taken to check the temperature and heating profile. Then minimum three exposed calibration cards should be read to confirm the calibration of the reader and if required either Reader Calibration Factor (RCF) should be changed or EHT to the PM tube should be adjusted to indicate counts in desired proportion to dose (10 μSv - 1 count). If EHT is adjusted, calibration should be verified from

readout of more number of exposed calibration cards. The relative ratio of readings from three discs of each exposed card should also be recorded and maintained in the logbook.

7.3. Intermittent Check of TLD Reader Sensitivity: The reading of ^{63}Ni light source and exposed calibration card should be taken intermittently in a day (at least once in the after-noon), in between the readout of routine service cards to confirm the stability of PM tube and calibration of the reader. In case of semiautomatic TLD reader, exposed calibration cards (at least two) are kept at fixed positions in the magazine to verify the sequence of cards. This will ensure the calibration of reader also.

8. ACCEPTANCE AND TESTING OF NEW TLD CARDS & CASSETTES

New TLD cards normally have quality control check at production level which includes testing of $CaSO_4$:Dy TL phosphor, $CaSO_4$:Dy embedded Teflon disc etc. Test reports should be confirmed from the manufacturer and the necessary certificate indicating the batch number of the phosphor used for the production of supplied discs/cards should be obtained. Date of receipt, number of TLD cards/cassettes and other purchase details should be entered in a log book entitled "STOCK".

Following steps are to be taken on receipt of TLD cards from the suppliers.

8.1. Testing of Sample TLD Cards Supplied by Manufacturer: Before receiving the ordered cards, a sample of about 50 cards should be obtained and checked for thickness and diameter of few TLD discs and dimensions of Aluminium card as per the specifications mentioned in Appendix-B. Cards should also be checked for any discoloration of TLD discs, presence of foreign particles, voids & spots on the disc, dislocation of TLD discs around the clips, proper clipping of the discs and centring of disc position on the respective holes in the TLD cards. An electrical gadget can be used to check the physical dimension of the card and the appropriateness of clipping and centring of discs in the card. All the cards should be cleaned and annealed as per the procedure described in section 9. Appropriateness of annealing should be verified following each annealing by taking readout of a few (at least 5) annealed cards in a calibrated reader, which should be close to the acceptable background reading. Normally for freshly annealed cards, background reading will be of the order of 50 ± 10 μSv for semiautomatic gas reader and 200 ± 40μSv for manual reader. If repeated background is more than 100 μSv for gas reader and 300 μSv for manual reader, manufacturer should be asked to review the process. If background is within the prescribed limits, the sensitivity check of cards should be undertaken. For sensitivity check, freshly annealed cards, sandwiched in perspex build up sheets of size 5.5 cm x 3.5 cm and thickness 4 -5 cm, should be exposed to a known dose of about 5 mSv of Cs-137 gamma rays. The minimum distance between the TLD cards and the radiation source should not be less than 50 cm. The TLD cards should be read after 24 h of exposure in a well calibrated TLD reader. A complete cycle of annealing, exposure and readout should be carried out for each of the three discs of the TLD cards. If the response (TL readouts) of TLD cards is found within ± 10%, the ordered lot should be procured.

8.2. Physical Inspection of All TLD Cards: On receipt of the whole ordered lot, all the TLD cards should be physically verified for all the points mentioned in section 8.1. The cards should be maintained in batches or lots (mixture of bathes) in same way as supplied by the manufacturer. If any defect is observed, the card should be rejected.

8.3. Batch Testing for TL Sensitivity: The cards are usually received in the batches. At least ten percent of each lot or 25 cards (whichever is more) from each batch should be checked for all the points as described in section 8.1. If the sensitivity of the TLD cards are within ± 12%, the batch should be accepted. If the total number of rejected cards during physical inspection and batch testing is significant then replacement of rejected cards may be obtained from the manufacturer.

8.4. Mixing of Different Batches of TLD Cards: The above procedure mentioned in section 8.1, 8.2 and 8.3 is to be repeated for all the batches received from manufacturer. If the average readout of different batches are within ± 5%, the batches can be mixed to form a single batch for use. If the variation is more than ±5%, those batches are to be identified separately and accordingly calibration factor should be maintained. However, any such batch should not be of size of less than 500 TLD cards.

8.5. Individual Testing of TLD Cards: All the cards of the accepted batches should be tested for their TL sensitivity as per the procedure described in 8.1 to avoid possibility of any fake/contaminated card. Only those cards exhibiting TL sensitivity within ±15% of the average sensitivity should be selected for introduction into the service. With this selection criterion it was noted that about 95% of the cards from a production lot from the present suppliers fall in the range of –15% to + 15% and the selected lot exhibits sensitivity within ± 5% (1σ). This criterion is also likely to meet the IEC recommendation that the response of any dosimeter in a batch shall not differ from response of another dosimeter by more than 30% at a dose 10 times the recording value. For special requirements, higher precision (e. g. from – 10% to + 10% or better if practically achievable) could be used, but both plus and minus values should be kept the same. A record of all the above details of individual testing and calibration of each TLD card should be maintained in the proper order in a separate logbook.

8.6. Reference / Calibration Cards: About 100 TLD cards from each lot / batch (depending upon the lot / batch size) should be removed from each accepted lot / batch and kept separately with identification of the batch for future use as calibration cards reference cards. Out of these, some 25 cards should be kept as reference cards to be used for sensitivity check of the batch after few cycles (5,10,15,20) of reuse (section 14.1.1). Sufficient number of calibration cards should be kept for calibration of TLD readers during processing of field cards in every monitoring period.

8.7. Numbering of TLD Cards: Prior to the introduction of fresh cards into the service each accepted card should be numbered specifying the batch number and serial number or the personal number of radiation worker to whom card is to be issued. For example, if the new batch is the fifth batch and card is to be issued to Mr. XYZ having personal number 0116, the card could be numbered as E-0116, and so on. All the blank cards that are not in use should have batch identification number.

8.8. Storage of TLD Cards: All the TLD card should always be stored in covered trays and boxes in an area/place with lower radiation background and should be away from radiation sources. Special care should be taken for protecting the TLD discs from dust and organic contamination.

8.9. Testing of TLD cassettes: A sample of 50 TLD cassettes (chest/wrist) should be procured from the supplier and should be checked for (i) Dimension of Cu, Al & Perspex filters as per the specification given in Appendix-C. (ii) Proper fixing and effectiveness of filters at their respective positions, (iii) Air gap between filter and TLD discs (should be less than 0.5 mm), (iv) Proper loading of the TLD card in the cassette and proper finish and smooth working of the sliding cover. It should be ensured that reverse loading of the card is not possible in the cassette. If the sample

cassettes are found to be satisfactory on the above points, the bulk supply should be procured otherwise supplier should be asked to carry out necessary changes.

9. ANNEALING OF TLD CARDS

9.1. Oven Calibration and Restriction on Use: The calibration (accuracy of temperature) of oven should be checked every month by using additional reference thermocouple system or thermometer. Oven temperature should not vary by more than ± 2 °C after attaining the set temperature. This should be recorded with date in a separate log book. The ovens used for annealing of TLD cards, must not be used for any other purpose (no warming of lunch boxes or any organic matters). Each time, not more than 500 TLD cards should be annealed in an oven.

9.2. Preparation of Cards for Annealing: TLD cards should be cleaned with acetone after the receipt from the supplier. The cards should be checked for cleanliness before each annealing during the field use also and should be cleaned appropriately as and when necessary. The trays should also be cleaned with acetone prior to their use for annealing and stored properly in clean and dust free condition. After the acetone cleaning, the cards should be dried at room temperature for 12 –16 hrs.

9.3. Temperature and Duration of Annealing: Annealing trays containing TLD cards should be put into the oven and the temperature should be raised from ambient to 230°C. This temperature of 230°C should be maintained for 4 hours. The oven temperature should be allowed to come down and trays with TLD cards should be removed only when the temperature is below 80°C.

9.4. Verification of Proper Annealing: A minimum of 5 TLD cards from each tray should be taken and read on a calibrated reader. The TL readout of these cards should be within the limits as given in section 8.1. The record of these readouts should be maintained in a separate logbook.

10. DISPATCH OF TLD CARDS / BADGES TO THE USER INSTITUTIONS

10.1. List of Radiation Workers: List of institutions and all the radiation workers (Master List) in each institutions provided by the Concerned Authority should be updated before the dispatch of TLD cards in each monitoring cycle. A register/log book entitled "ISSUE and DISPATCH" should be prepared for each institution having columns to indicate details like date of despatch and receipt, number of the cards issued for each service period.

10.2. Personnel History Form: In the case of new radiation workers duly filled in personnel data/ history form (Appendix-L), of each worker should be obtained. It should be ensured that personnel data/history form (TLD-4) of each radiation worker is available and a personnel number is allotted to each radiation worker by the concerned authority, before issuing any TLD badge to a radiation worker.

10.3. Master List and TLD-5 Form: The names of radiation workers with personnel numbers should be entered into the computer in the appropriate format which can be used for dose data

entry as well as for the preparation of the dose report. A hard copy of names and personnel numbers should also be made available for ready reference and for further addition or deletion of names of radiation workers. TLD-5 form should be prepared as per the updated 'Master List' for use in the subsequent monitoring period through the computer programme developed for this purpose.

10.4. Wrappers for TLD Cards: The name and personnel number of each radiation worker should be printed on the paper wrapper as per the master list. Type of radiation and service period should also be printed on the wrapper for each radiation worker. Two or three set of paper wrappers (depending upon in-house monitoring or postal services, respectively) may be made with different colour codes to be used in different service periods for ease of identification of TLD cards of different service periods.

10.5. Recording of TLD Card Numbers: The TLD card number could be noted against the personal number and name as per the master list. Legibility of the number on the cards should be checked before and after annealing. The cards should be physically verified for any damage like discoloration of the disc, dislocation of disc from clips etc. and if necessary, should be replaced. Paper wrapper should also be checked for any damage and should be replaced if required.

10.6. Dispatch of TLD Cards/Badges: TLD card identified with a number should be put in a paper wrapper and sealed in polythene pouch of matching size. For the new institutions and new radiation workers, the cards should be loaded in TLD cassettes/holders before despatch. In the subsequent service period, only TLD cards wrapped in paper wrapper and sealed in polythene pouch should be sent to the institution. The cards/badges should be dispatched to the respective institution by registered post/courier in case of postal service or by hand delivery if arranged by the user institution. Additional TLD cassettes are provided as per the requirement. All the instructions and user's manual should be sent for the new institutions.

10.7. Addition and Deletion of Names: The changes should be made in the master list for any addition or deletion of name of radiation workers after each service period. The number of the TLD cards and/or cassettes should be sent as per the changed requirement.

11.RECEIPT OF TLD CARDS FROM THE USER INSTITUTION

11.1. Tally of Dispatch and Receipt: The number of TLD cards/badges received from the user institutions should be tallied and compared with the number of badges / cards dispatched as per the entry in the log book entitled as "ISSUE and RECEIPT". Discrepancy if any should be noted.

11.2. Contamination Check of TLD Cards on Receipt: The TLD cards received from institution after the use should be first checked for contamination and if a card is found to be contaminated, procedure described in section15 should be followed.

11.3. Arranging Cards for Readout: The number of cards received should be checked and if any card is found missing or spoiled, it should be noted on the TLD-5 form. Polythene pouches should be cut and kept open so that the cards can be easily removed at the time of readout. TLD cards along with paper wrapper & polythene pouch may be kept in trays in sequence.

11.4. Intimation of Missing/Spoiled/Contaminated Cards: Report about the missing / spoiled / contaminated cards should be sent to the concerned person (health physicist/radiation safety officer/head of the institution) as soon as it is noticed. A record of missing TLD card number /

badge and the corresponding personnel number should be maintained in the log book and should be communicated to concerned parties and for the purpose of calculating the charges.

12. PROCESSING OF TLD CARDS AND DOSE EVALUATION

12.1. Recording of Reader Details and Personnel Number: The TLD badge reader should be calibrated as described in Section 7. Before taking actual readout of the cards, all the details like Reader no., reader calibration factor (RCF), EHT value, date of measurement etc. should be noted on each TLD-5 form and it should be signed by operator (person taking measurement). TLD card number and personal number of the worker should be checked on the TLD-5 form before heating the cards in the reader. In case of semiautomatic gas TLD reader, exposed calibration cards (at least two) should be kept at fixed positions in the magazine to the verify sequence of cards which will, in turn ensure the calibration of TLD reader also.

12.2. Recording of Readout of TLD Cards: Irrespective of availability of computer interface facilities or TLD readers having readout recording facility, the TL readings should be recorded on the TLD-5 form (Appendix-K) in the respective columns against their personnel number by the operator.

12.3. Dose Evaluation: After completion of the readouts of TLD cards, the doses should be evaluated and entered in the respective column on TLD-5 forms by using appropriate algorithm (Appendix-O). In case of computerised dose evaluation, it should be verified manually for the proper entry of data and functioning of the algorithm.

12.4. High Reading: In case of the manual TLD reader, if the reading of Disc 1(D1) in any of the TLD card is recorded abnormally high (more than 10 mSv), before taking further readings, the performance of the TLD reader should be checked by taking calibration card reading. In such cases, procedure given in Section 16 has to be followed.

12.5. Anomalous Reading: If any abnormal pattern of readings is observed, the same should be investigated as described in Section 18.3.

12.6. Dose Reports: In case of manual reader the dose report could be obtained through computer by feeding the required dose data in the required format, in case of semiautomatic reader, dose report could be prepared using the software provided by the supplier or developed by the processing laboratory/unit. The specimen format for dose report is given in Appendix-N.

13. RECORD KEEPING

Dose records as well as other records pertaining to number of cards dispatched, received, processed, missing etc., should be maintained in proper Log Books. These records should be checked by the scientific officer / in-charge of the processing laboratory/unit after each cycle and should be signed by him.

13.1. Dispatch and Receipt of TLD Cards: Account of TLD cards should be maintained in the proper log books.

Example :

Dispatch

Date of Issue	Number of TLD Cards Issued	Issued By	Issued To	Remarks

Receipt

Date of Receipt	Number of TLD Cards Received	Received By	Received From	Remarks

13.2. Accounting of Cards: Record of changes in the TLD-5 form, i.e. addition or deletion of any personnel number, any non-returned/missing TLD card or receipt of any old card should be kept separately in the logbook entitled `ACCOUNTING'.

Sr. No.	Inst. No.	Changes in each Service Month		Total No. of TLD cards		Remark
		Addition	Deletion	Issued	Not returned	

13.3. Master File: 'Master list' containing personnel number and names of workers should be maintained for future reference.

13.4. Dose Records: All the dose data should be kept in the appropriate format in the computer by each processing laboratory/unit in addition to the data maintained by the Central Dose Records at BARC.

13.5. Status of TLD Cards, TLD Readers and Other Equipment: Record of stock and performance of readers, cards & other equipments and also the details regarding repair if any, should be maintained in the respective log books.

13.6. Record of QA performance: Records of internal and external QA checks should be maintained properly and separately.

13.7. Status of TLD Cards: Each laboratory/unit should maintain a record of data on selection of TLD cards, sensitivity check and quality assurance programme, experimental card reading, blind test readings, annealed card reading etc. in the separate log book meant for each purpose.

13.8. Other records: Records of overexposure cases, TLD-DRD discrepancy cases (in case of units at power stations) and abnormal pattern of TL readings should be maintained in proper logbooks.

14. QUALITY ASSURANCE (QA) PROGRAMME

14.1. Internal QA: Each TLD Unit/laboratory should have its own internal quality assurance program in addition to the participation in the periodic external quality assurance check conducted by the concerned authority at BARC. The internal quality assurance programme should comprise the following tests/checks.

14.1.1. Periodic Sensitivity check: The individual sensitivity test of all new cards should be carried out prior to their introduction into service as per the procedure described in Section 8. The routine TLD cards in the field use should be checked for their sensitivity after every 5 cycle to avoid any significant reduction in TL sensitivity of the cards and to check average sensitivity variation among the different batches. For this purpose, minimum 25 cards from each batch should be exposed to known dose (as per the procedure given in section 8.1) along with the 5 reference TLD cards (section 8.6) of that batch and read on a calibrated reader. If the average sensitivity of any batch is reduced by more than 15% as compared to the reference cards, the particular batch should be withdrawn from the service. Also, if the sensitivity variation in a batch is more than 20% then either the whole batch should be taken out from the service or all the cards should be individually tested by exposing them to known dose and only those cards exhibiting sensitivity variation within ±15% should be selected for further use (with its proper calibration factor). Record of all the above data should be maintained in a separate log book.

14.1.2. Physical Verification: After every cycle, all the cards should be physically verified for any defect such as discoloration, deformation, dislocation of TLD disc around the clips, oxidization of aluminium card or any other visible defect. Defective cards should be removed and replaced by another card from the same batch. The personnel number on the card should be verified after each cycle and if any number is fainted, the same should be rewritten / engraved.

14.1.3. Oven & Annealing: The temperature of the oven should be verified independently with help of an external temperature meter and thermocouple at least once in month or in case of suspicion. Appropriateness of annealing should be also verified after each annealing by taking readout of 5% of the cards randomly picked from the annealing tray. The record should be maintained in the respective log books. All the cards of the batch whether used or unused should be annealed, almost within the same duration after each cycle.

14.1.4. Linearity Test of TLD Readers: Linearity test of all the TLD readers (manual as well as Automatic readers) should be conducted prior to their introduction into routine use and at least once in six months thereafter, after every major repair or any time in case of suspicion about the performance of the reader. Detail procedure is given in section 6.11.

14.2. External QA: External quality assurance test is required to check the dose evaluation procedure and overall performance of the processing laboratory. Calibration and Dose Records Section, RPAD, BARC, Mumbai, conducts this test on half yearly basis. Each processing laboratory (viz. all TLD units and accredited laboratories) have to participate in external QA programme. The detailed procedure of this test is given in Appendix-R.

The results of the test is analysed at BARC as per the ANSI Criteria (Appendix-P) and by trumpet curve criterion (Appendix-Q). This is communicated to the respective TLD units/laboratories. The laboratories are to follow the given instructions/ suggestions. The records of all results should be maintained.

14.3. Blind Test: Blind test is the performance check of the processor without his knowledge during routine processing of the service cards. At present, it is being conducted regularly (monthly/quarterly) at all TLD Units at Nuclear Power Stations in collaboration with Health Physics Unit (HPU). The detailed procedure of blind testing is given in Appendix- S.

14.4. Performance Test of Accredited Laboratory: The overall performance of the accredited laboratory and status of the infrastructure facilities available are thoroughly reviewed at regular intervals (half yearly). In addition to the external QA checks, performance testing is conducted for all the radiation categories for which the laboratory is providing the service. Performance tests is

carried out following the latest ANSI criteria (Appendix-P) and Trumpet Curve criteria (Appendix-Q).

14.5. Spot Test of Accredited Laboratory: Spot testing is specially conducted for the accredited laboratories. As a part of periodic review of the overall performance, a surprise visit is conducted and infrastructure facilities of the accredited laboratory are ensured. The detailed procedure is given in the Appendix-T.

15. HANDLING OF CONTAMINATED TLD CARDS

In certain situations, TLD badges of radiation workers while handling open sources or working in environment of radioactive materials, may get contaminated. For handling such cases, the following procedures are to be followed before processing of the contaminated TLD badges by the laboratory/unit.

15.1. Checking for Contamination : The TLD cards received after use should be checked for contamination. For this purpose, the whole lot of cards is to be checked first and in case of any doubt, each card from the lot should be checked. If required polythene pouch, paper wrapper and card should also be checked individually. If the card, paper wrapper or polythene pouch is found contaminated, it should be removed and stored separately. The problem may be indicated on the TLD-5 form against the particular number. The same should also be reported to the concerned agencies. **Contaminated TLD cards should not be read in the TLD reader.** In case, the contaminated card has been read in the TLD reader, a thorough check of the reader magazine/card holder should be carried out and if necessary decontamination may be done before taking any further readout or introducing next magazine in this TLD reader. Readout of contaminated card should not be considered for reporting the dose.

15.2. Contamination Check of Cards with Very High TL Reading: Apart from recording the glow curve, the cards which gives abnormally high TL reading should also be checked for contamination of the cassette / storage place etc. to rule out the possibility of contribution to the reading due to radioactive contamination. In case of detection of any contamination, suitable action should be initiated.

15.3. Decontamination: If the card is found to have radioactive contamination or higher reading is confirmed due to contamination, the card must be removed from the lot of field cards and discarded. TLD badge reader and work place should be decontaminated if necessary. Further readout on this TLD reader should be carried out only after ensuring that there is no contamination and re-confirming the calibration of the reader. Contaminated cards / wrappers should be disposed off as per the procedure of disposal of radioactive waste which depends on the level of contamination. Investigation should be initiated to know the cause of contamination.

15.4. Reconciliation of Dose: In case of contaminated card, personal doses are usually not estimated from the readout of the card. However, for radiation protection requirements, the doses could be estimated from the work details, doses received by co-workers and / or dose measured by other dosimeters such as use of DRD (pocket dosimeter) etc. if any. If the source of contamination is confirmed, the dose can also be reconciled by taking into account the exposure to the disc due to contamination. This can be achieved by collecting the work details of the worker and also by calculation and/ or experimental verification.

16. HANDLING OF OVER EXPOSURE CASES

During routine processing of the TLD cards, if dose of any radiation worker found to be more than 10 mSv in a monitoring period (monthly / quarterly), this should be considered as a case for overexposure (OE). Special procedure should be followed for the overexposed (OE) cards as given below:-

1. After recording a high reading of disc D1 in the manual reader, TLD card, wrapper, polythene pouch & if available, cassette should be checked for any contamination and senior person should be informed about OE case. The remaining readings in the manual reader should be taken in the presence of another concerned expert / senior person. In case of semiautomatic gas reader, after the readout of the OE TLD cards in the magazine the reading of the other cards should be terminated if the readout of the OE cards approaches counts equivalent to 1Sv of ^{137}Cs gamma rays. For lower readouts, all the remaining cards in the magazine could be read before starting the special procedure of the OE card.
2. Three annealed TLD cards (as test cards) should be taken from the same lot of field card and exposed to a known dose of ^{137}Cs gamma ray source.
3. In case of semiautomatic reader, readout of freshly exposed test cards should be taken on the same reader on which over exposed card was read. Second readout of the OE card and freshly exposed test cards should also be taken on the same reader and reading of second readout should be compared. In case of manual reader, readout of disc D2 of OE card, 2nd readout of OE card and freshly exposed test cards should be taken in presence of Senior Scientific Staff (for accredited laboratory) or Health Physicist (for TLD units at power station). All the glow curves of the OE card and test card of first and second readout should be recorded.
4. In case of very high exposure (≥500 mSv), special precaution should be taken to avoid PMT fatigue while taking the readout and the TLD reader should be checked by using calibration card for any change / fatigue in the PMT tube response before taking further readouts of the TLD card.
5. All the OE and test TLD cards should be annealed and should be exposed to about 5 mSv of ^{137}Cs gamma rays after taking the background reading.
6. Readout of all TLD cards should be taken on same TLD reader on which OE card was read.
7. If all steps go in convincing direction, report the over exposure. In case of any doubts, final discussion could be arrived by the mutual consent of the concerned persons.
9. Once a TLD card records an over exposure, it has to be removed from the service.

17. ADDITIONAL SPECIAL PROCEDURES/GUIDELINES FOR TLD UNITS AT NUCLEAR POWER PLANTS

17.1. <u>TLD - DRD Dose Discrepancy Cases:</u> Once the TLD dose report is submitted to Health Physics Unit (HPU), the TLD doses are compared with the DRD doses. The list of TLD-DRD dose discrepancy should be obtained from HP Unit. TLD-DRD dose discrepancy cases are to be identified as per the criterion laid down by TLD-DRD Discrepancy Task Group Report (1991). Once the TLD-DRD discrepancy is identified, special procedure should be followed as given below:-

1. In case of manual TLD reader, if readout of Disc 2 is not taken earlier during the regular readout, it should be read to confirm the TLD reading. In case of auto TLD reader the glow curves of the first readout should be recalled to verify its normal pattern and TLD readings. Second readout of the cards should also be taken to confirm the residual TL.
2. All TLD Cards of TLD-DRD discrepancy cases as well as cards where significant difference from the expected dose has been observed, should be annealed and re-tested for their sensitivity by exposing them to known dose of ^{137}Cs. All the records of TLD-DRD Discrepancy should be maintained in a separate logbook.
3. Information on the sensitivity and leakage of all DRD's used by the worker should be obtained from Health Physics Unit. In addition, information on number of occasions the worker had used DRD during the particular month and the dose received each time should also be obtained.
4. Doses received by the co-workers should be noted.
5. Job details of the worker should be collected and if necessary the worker may also be interrogated.
6. On the basis of the above data, the dose to the worker will be reconciled by the TLD-DRD Discrepancy committee constituted by the Station Director of each Nuclear Power Plant and OIC, TLD unit is supposed to be a member of this committee.

17.2. Urgent Processing of TLD Cards: There are some situations of suspected acute exposure and the TLD card may be required for urgent processing immediately after exposure. Once the TLD card is received for urgent processing, following steps should be followed:-

TLD cards should be checked for contamination and card should be read after confirming the dark current and calibration of the reader. The readings with name and number should be noted on a separate TLD-5 form. If the card is received immediately within few hours after the actual exposure, a factor of 0.9 should be applied to the readouts of the TLD card. Alternatively such urgent cards should be read after a heat treatment of 120°C for 20 min. The evaluated dose from the urgently processed card should be entered into the computer and on the TLD-5 form against the respective radiation worker.

18. MISCELLANEOUS

18.1. Calibration of Radioactive Source: The Radioactive source used for exposure of TLD cards should be calibrated by the Radiation Standards Section (RSS) of Radiation Safety System Division, BARC. The air-kerma rate should be measured by RSS at the processing laboratory/unit in the actual geometry to be used for the exposure of calibration/experimental cards and the source calibration should be re-confirmed after every 5 years.

18.2. Swipe Test of Radioactive Source: Swipe sample of radioactive source should be collected occasionally (once in a years) and sample should be checked using contamination monitor for any radioactive contamination or damage to the source. If significant counts (> equivalent of activity 185 Bq) are observed, the source should be sealed in the polythene bag and kept in container. Matter should be reported to Head of the institution; Head, RP&AD, BARC & AERB and source should be disposed off as per the procedure approved by regulatory body AERB. Arrangements should be made to procure a new source.

18.3. <u>Investigation of Abnormal Pattern of TL Readings:</u> During the routine readout of cards, if the TL readout pattern of the discs in any card is noticed to be abnormal then special measures should be taken. The card, paper wrapper and polythene pouch should be first checked for any contamination (radioactive/chemical). If necessary, the history of that TLD card should be traced out to check the initial performance of that card before introduction into service. The matter should be immediately reported to the Health Physicist/Concerned Authority or Agency, who would in turn inform the concerned institution to check the physical integrity/ contamination of the particular cassette and obtain the details regarding the contamination/ radiation level in the area where the individual has worked and where cards were stored while not in use for that service period. Area monitoring should be advised in such cases and nature of radiation should be traced out to ensure remedial steps. If the nature of radiation is not confirmed and no reason is assigned for abnormal pattern, dose should be reconciled either by calculation method or from dose/s received by co-worker/s . In case of Nuclear Power Stations, the dose can be assigned on the basis of the readings recorded by alternate dosimeter for the said period such as DRD (pocket dosimeter) reading.

If the TLD card is found to be contaminated then the procedure as described in section 15 should be followed and dose should be assigned accordingly. In case, there is no radioactive contamination, the card should be checked for contamination of luminescent material by taking the readout of cards without heating. If the readout without heating is high, the card should be discarded and dose should be reconciled as above. If the readout without heating is close to the expected value, the second readout of each of the discs should be taken and compared. The second readout should be about 10% of the first readout. The card should then be cleaned in the acetone, annealed and read in the TLD reader to confirm the TL readout to be close to the background signal. This card should then be exposed to a known dose of ^{137}Cs gamma rays and readout to confirm the behaviour of the card by recording the glow curve. If found to follow the normal pattern, investigation for conditions of exposure may be carried out subject to the discretion of scientific officer /in-charge of the laboratory/unit.

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APPENDIX - A

Characteristics of $CaSO_4$:Dy Teflon TLD disc

Ratio of $CaSO_4$: Dy and Teflon	: 1: 3
Effective Atomic Number (Z)	: 15.1
Density of the TLD Disc	: 2.52 g/cm^3
Softening Point of Teflon	: 330°C
Main Glow Peak Temperature	: 230°C (as shown in following figure)
Sensitivity of TLD Disc	: About 30-40 times more than LiF TLD-100
Fading	: 2 -3% in six months.
Climactic Effect (Environmental)	: Negligible
Effect of Sunlight	: Negligible when covered by paper wrapper & polythene pouch and loaded in the badge

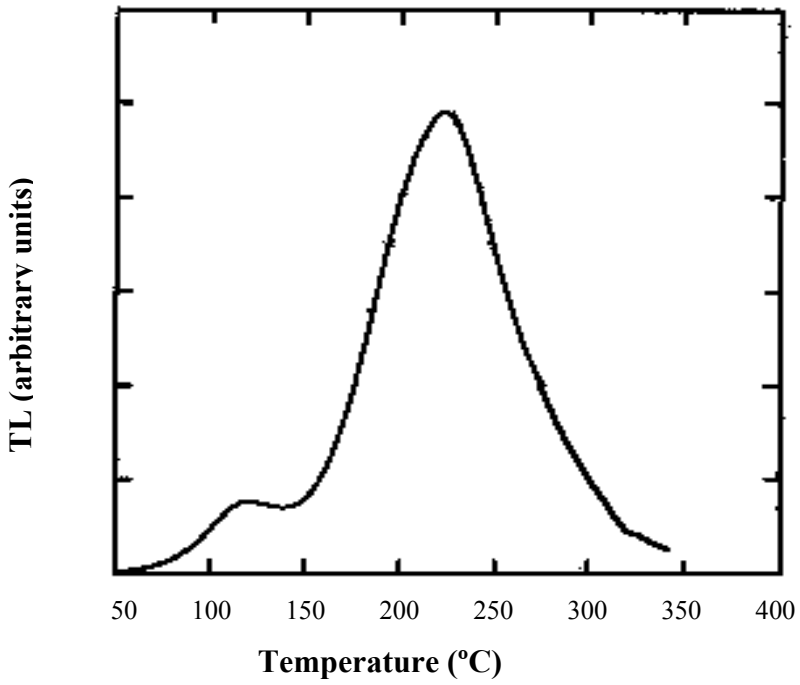


Fig.1 Glow Curve of $CaSO_4$: Dy Teflon TLD Disc after irradiation to 1 mGy of Cs-137 (Heating rate 1 °C/s)

APPENDIX – A (contd.)

Useful Linear Dose Range : 0.10 mSv to 20 Sv (linearity within ± 10%)

Reusability : 20 cycles

Beta Response : 60% of ^{60}Co gammas for Nat.U (effective energy 0.8 MeV)

Thermal Neutron Response: ^{60} Co gamma ray equivalent to 2.4 mGy per 10^{10} n/cm^2

Fast Neutron Response : Negligible

Energy Response: Following figure shows the photon energy dependence of $CaSO_4$: Dy Teflon TLD disc from 30 keV to 1.25 MeV. The TLD disc under the metal filter shows a modified response, with a 65 % over response at 80 keV and 25% under response at 30 keV.

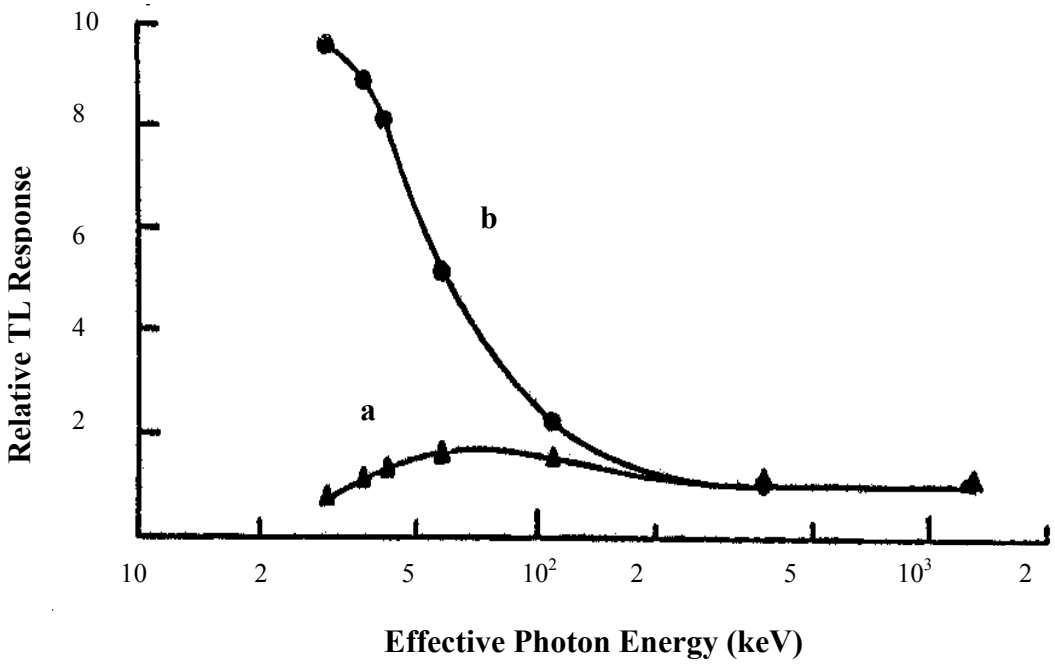


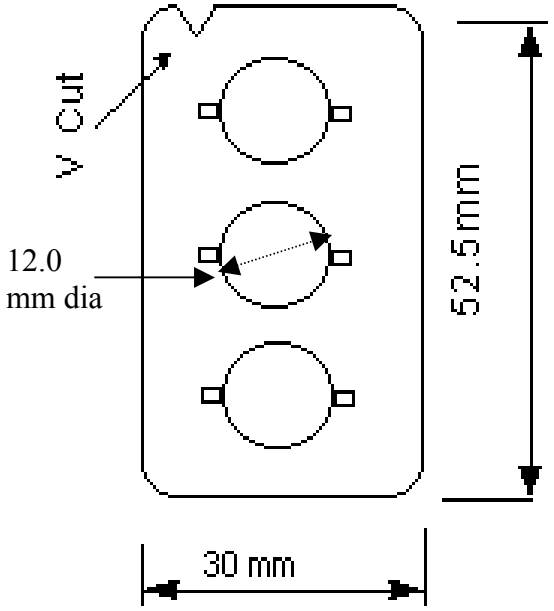
Fig.2 Photon Energy dependence of TLD Badge (a) Response under metal filter, 1mm Cu+1mm Al (b) Response of bare disc

APPENDIX - B
Specifications of TLD Card

Three $CaSO_4$:Dy Teflon TLD discs are mechanically clipped on an Aluminium plate. An asymmetric "V" cut is provided in the card to ensure its loading in the plastic cassette as well in heater drawer/ magazine of TLD reader in only one orientation. Aluminium material is of "2s" grade of Indal or equivalent. Aluminium card should be uniformly Nikel plated or buffed, having plating thickness of about 10 micron.

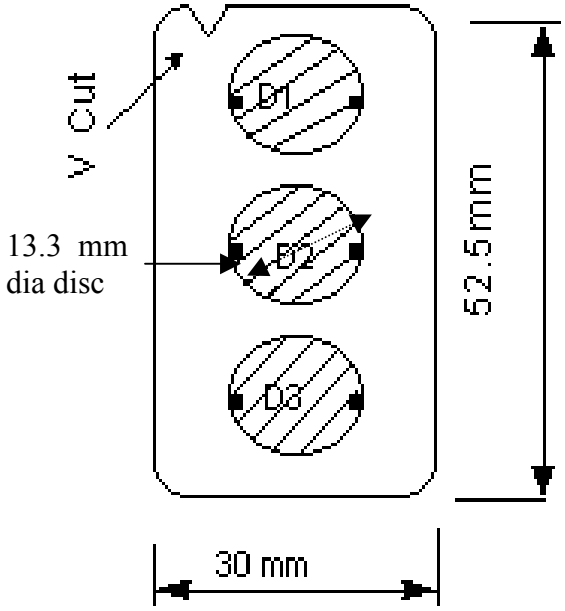
Dimensions of TLD Card

Dimensions of Al Card : 52.5 mm x 30.0 mm x 1.0 mm
Dimension of hole on Al plate : 12.0 mm dia
Dimension of TLD Disc : 13.3 mm dia



Clips for fixing the TLD Discs

Fig. 3a TLD Card Without Disc



Clips in which TLD Discs are fixed

Fig. 3b TLD Card With Discs

APPENDIX- C

Specifications of TLD Cassette

TLD chest badge cassette consists of three regions corresponding to three TLD discs of the card. Rectangular copper filter is fixed with adhesive or embedded by molding in main body and circular copper filter is embedded by molding in slider. Aluminium emblem is fixed by adhesive (Araldite) in the main body and on the slider. Transparent windows is embedded by double moulding within main body and slider. TLD cassette has a S.S Crocodile clip fixed with silver plated eyelets to the slider part for affixing to the user's clothing. Quality of filter and plastic material of the cassette should be as per the specifications given below.

Dimensions

(a) Main body:

Cu filter : 30 mm x 16 mm x 1 mm
Al filter : Dia- 15.6 mm, thickness- 1.0 mm
Plastic filter : 30.5 mm x 21 x 1.6 mm
Open window : Dia - 14.5 mm

(b) Slider part:

Cu filter : Dia – 16 mm, thickness- 1 mm
Al filter : Dia –15.6 mm, thickness-1 mm
Plastic filter : Dia –25 mm, thickness-1.6 mm
Open window: Dia – 13.5 mm

Material

Eyelet	: Silver eyelet 2030
Transparent window	: General purpose polystyrene 666 clear
Copper Filter	: Copper 99.9 % purity
Alluminium Filter	: Aluminium (Emblem)
Slider	: High impact polystyrene -975 (Ultra white)
Main Body	: High impact Polystyrene -975 (Ultra white)

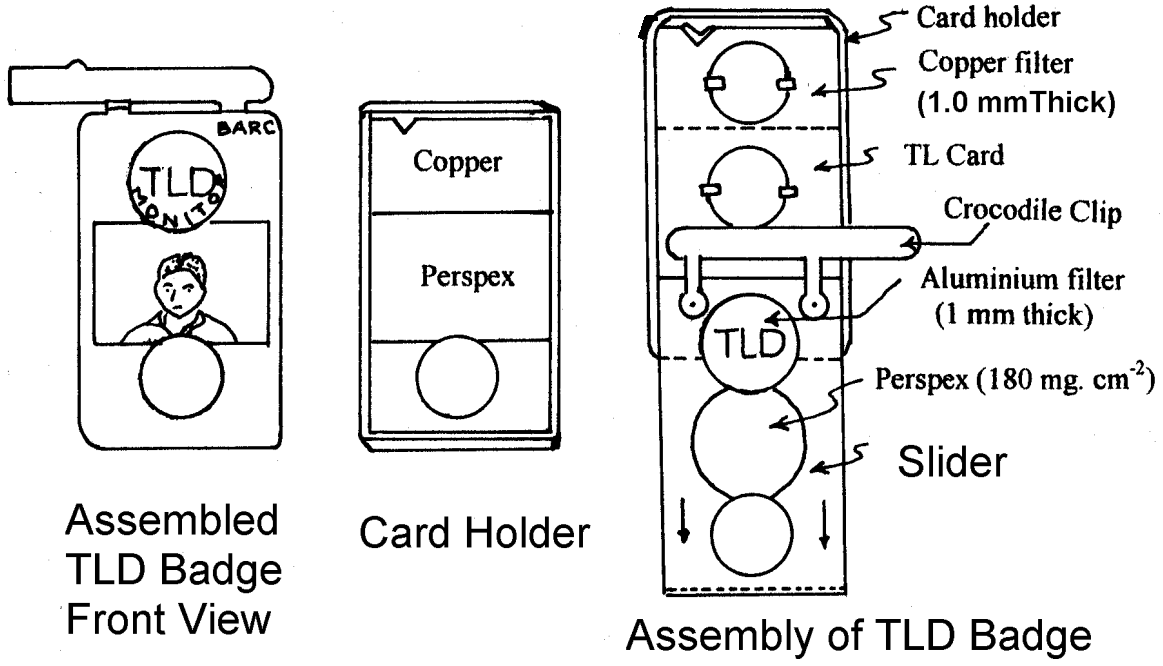


Fig. 4

APPENDIX- C (contd.)

Specifications of TLD Cassette of Altered Filter Dimension

In this design of the TLD cassette, dimension of some of the filters was altered and crocodile clip was replaced by a smaller size clip. The cassette was made of ABS plastic (white) and filters were embedded into the plastic body. Dimensions of the filters are as given below.

Dimensions:

Main body:

Cu filter (rectangular)	: 32 mm x 16 mm x 1 mm
Al filter (circular)	: 13.6 mm & thickness- 0.6 mm
Plastic filter (rectangular)	: 30.5 mm x 21 mm x 1.6 mm
Open window	: Dia- 14.5 mm

Slider part:

Cu filter (circular)	: Dia - 15.6 mm, thickness- 1 mm
Al filter (circular)	: Dia -12.6 mm, thickness – 0.6 mm
Plastic filter (circular)	: Dia - 25 mm, thickness- 1.5 mm
Open window	: Dia - 13.5 mm

APPENDIX - D

Specifications of Manual TLD Reader (Model BR-3A)

Heating method	: Electrical
Heater element	: Kanthal
Temperature profile	: Non-linear and reproducible
Clamping temperature	: 280 °C± 2 °C
Light detector	: Photo multiplier tube (PMT) selected for dark current < 1 nA at 1000V
PMT supply (EHT)	: 500 V to 900 V (adjustable)
Reading cycle time	: 60 seconds or manual
Exposure range	: 0.15 mSv – 10 Sv (auto-range from 1 Sv to 10 Sv)
Readout accuracy	: ± 30% at 1 mSv ± 10% above 10 mSv
Display	: 3½ - digits 7-segment LED to indicate exposure (in R), temperature in (°C) and EHT to PMT (in volts).
Routine check	: With built-in light-source and ^{63}Ni light source
Recorder output	: TLD glow-curve and temperature profile.
Radiation detector	: TLD card based on $CaSO_4$:Dy Teflon TLD discs
Power supply	: 230 V (AC), 50 Hz
Over all dimensions	: 46 cm (L) x 39 cm (H) x 25 cm (W)
Weight	: 14 Kg (approx.)

APPENDIX-E

Specifications of Semiautomatic TLD Reader (Model BR-7B)

Dosimeter :Three-element BARC $CaSO_4$:Dy Teflon disc dosimeter

Light measurement system : Photomultiplier tube (EMI 9125B-bialkali)

Dark current : Dark current is 1μSv (TL output from $CaSO_4$:Dy) equivalent with software based sampling & subtraction

Heating method : Hot gas (N_2) heating

Heating cycle : The temperature is raised to 300 °C in 8 –10 sec and clamped at 300 °C

Dose range : 50 μSv - 2 Sv

Readout time : 100 second per badge

Facilities available
*Entry of badge ID numbers, calibration factor, etc.
*Storage of dose and glow curve data of badges in floppy/hard disk,
* Motorized driver assembly for automatic feeding of 50 dosimeter cards loaded in a magazine.

Software
IBM PC compatible menu driven software for transfer of data to a user defined file, storage and display of glow curves, computation of dose and generation of dose reports.

Temperature monitoring
Chromel - Alumel thermocouple in hot gas stream. External temperature monitoring facility is provided at the back panel

Calibration
Coarse adjustment by varying the EHT through a potentiometer in the EHT circuit; Fine through software.

Power
Power supply: 230V, 50 Hz: Power requirements: 500 VA (including PC)

PC requirement
IBM PC 486 or upward compatible with FDD & HDD, SVGA monitor, Serial & Parallel ports, Dos 6.20 and MS Windows 95/98/NT.

APPENDIX-E (contd.)

Safeguards: A constant vigil should be kept during the entire readout procedure to avoid loss of any TL reading due to reader malfunction/failure. Special attention should be given to the following.

(1) Heater/Gas flow Failure: The heater and gas flow should be checked for failure in every dosimeter readout cycle. In the event of failure of heater or gas flow, the readout should be terminated and a message indicating heater/gas flow failure is flashed on the PC monitor.

(2) Mechanical failure: Any mechanical failure during readout cycle is sensed using a time-out watch dog programme and the cycle is terminated with an option for the user to restart the cycle.

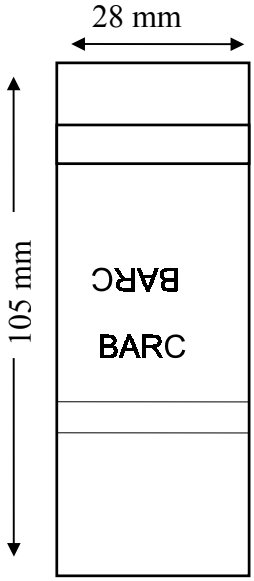
(3) EHT/Input circuit failure: Failure of EHT or the input circuit (I-F converter) is sensed and reading cycle is terminated in case of failure.

APPENDIX-F

Specification for Paper Wrapper and Polythene Pouch

1) Paper wrapper

Paper thickness : 10 mg / cm^2
Size : 28 mm width x 105 mm length



Paper Wrapper

Wrapper should be in 3-4 different dark colours like orange, blue, green, pink, yellow etc. for ease of identification of TLD cards of different service periods.

2) Polythene pouch

Thickness : 3 - 4 mg /cm^2
Size : 32 mm width x 60 mm length

APPENDIX-G

Specification of Air Circulating Oven

A) Material and Dimension of Oven Body :

1) Internal dimension - 30 cm x 30 cm x 20 cm.
2) Inside Material - Stainless steel, Painted with heat resistant paint.
3) Outside Material - Mild steel, powder coated
4) Insulation - Glass wool (or better)
5) Selves - SS net type, 2/3 nos.
6) Door - Insulated handle, locking arrangement, insulated door.

B) Heater:

1) Material - Nichrome
2) Type - Tubular
3) Rating - 3.0 kW.
4) Heating Rate - Three different heating rates.

C) Temperature:

1) Range - Room temp. to 450 °C
2) Controller - Digital
3) Accuracy - ± 2 °C (upto 400 °C)
4) Sensor - Chromel Alumel Thermocouple
5) Display - Digital
6) Outer surface temperature at operating temp of 400 °C should be less than 50 °C

D) Air Circulation:

Vacuum leakage - Nil
Circulation - Forced (By fan)
Rating of fan motor - ¼ HP
Blower size - 5" x 2"

E) Electrical Supply:

Voltage - 230 V ± 10 V, 50 Hz single phase
Power - 4.5 kW

APPENDIX-H

Specifications of Contamination Monitor

Radiation detected : Beta and Gamma Radiation

Detector : Halogen quenched End Window G.M tube
Window thickness - 1.5 - 2.0 mg / cm^2
Effective diameter - 29 mm
Dead time - 200 μ sec

Aluminium shutter : This is located on the rear side of instrument. If this shutter is open the counter detects both beta and gamma radiation. If it is closed only gamma radiation is detected.

Ranges : 1.0 -1000 cps
2.0-20 mR/hr

Indication : **Visual** - Four and half digit seven segment LCD display to indicate contamination levels in counts per second or mR/h

Aural – Audio with a fixed volume, can be made 'ON' or 'OFF' by a front panel switch

Battery low - Indicated on the LCD panel meter with a "BAT LOW " caption. When this appears the batteries are to be replaced by fresh ones.

Accuracy : ± 20 % of the reading

Operating Voltage : 500 volts

Power Requirement : 4 x 1.5 Volt batteries

Controls : Power ON /OFF
Audio ON /OFF
CPS or mR/hr

APPENDIX-I

Specifications of Gamma Zone Monitor

Radiation detected : Gamma Radiation

Detector : Halogen quenched End Window G M tube

Dose rate ranges : 0.1 – 100 mR/h (Auto ranging)

Accuracy : Within ± 20 % of the reading

Climatic conditions

Temperature range : 10 °C to 50 °C

Relative Humidity : 0 to 99%

Operating Voltage : 500 volts

Display : Large Size DPM for Dose rate display

Alarms : Loud, continuous pulsed tone, large area red alarm light with remote indication on a I/O connector (optional)

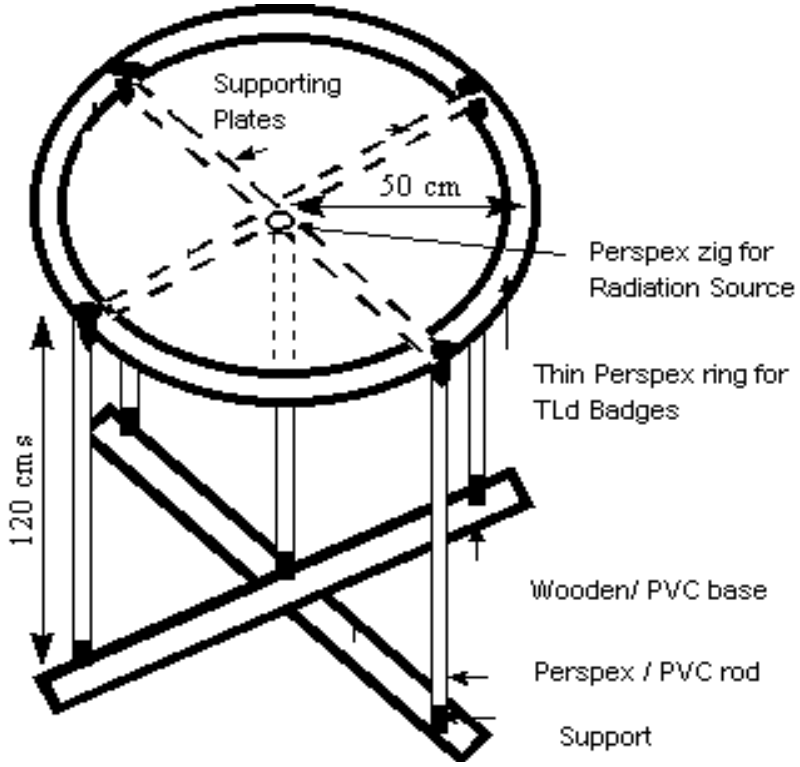
Controls : External manual reset pushbutton, internal alarm point set potentiometer

Additional options : Remote meter/ recorder output

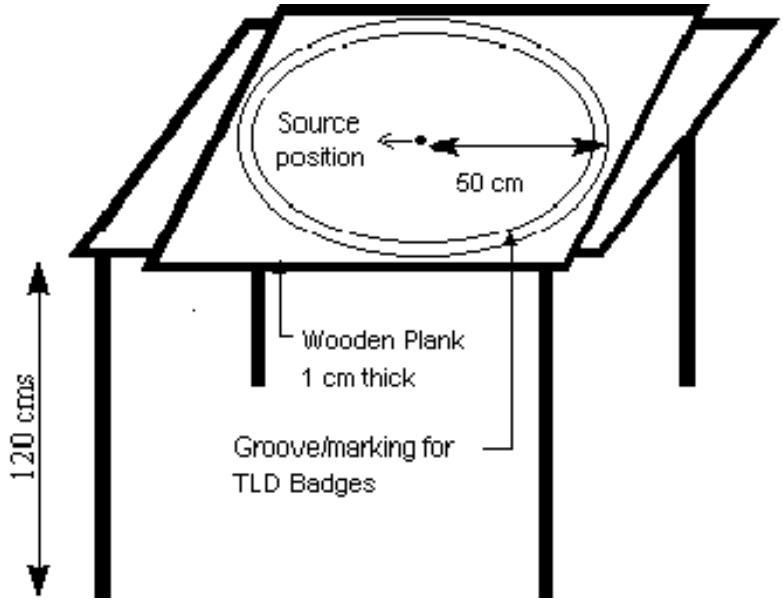
Power requirement : 4 x 1.5 Volt batteries

APPENDIX-J

Calibration Ring / Table



Perspex Calibration Ring



Wooden Table

APPENDIX-K

Specimen Format* of TLD-5 Form – Recording of TL Readout

Name & Address of the Laboratory / Unit

INSTITUTION NUMBER:
No. of cards sent: Reader No. :
No. of cards received: EHT:
TLD cards read on: RCF:

NAME OF THE USER	PER. No.	WORN AT	DOSE (mSv)		TLD READING			REMARKS
			X or GAMMA	BETA	Cu+Al	PLASTIC	OPEN	

**Format / specification may vary depending upon the requirements of the TLD unit*

APPENDIX-L

Specimen Format* of TLD-4 Form - Personal Data of Radiation Worker

Name & Address of the Laboratory / Unit

(I*nstruction: Use block letters, leave one blank square between each word)*

1. Institution Number:

2. Personal No.:

3. Name and Address of Present Institution:

4. Name in Full of the Radiation Worker: Shri / Smt. / Kum. / Dr.

5. Name with initials:

6. Name of father/ : Husband

7. Date of Birth : (Christian era)

D M Year

8. Sex : M F

9 Place of Birth: (Village/Town)

State

10. Qualification (Mark X in applicable box)

☐ Graduate ☐ Post Graduate ☐ Doctor ☐ Engineer

☐ Med. Doctor ☐ SSC/H ☐ Engg Dip ☐ Others

11. Designation (Mark X in applicable box)

☐ RSO ☐ Site –in-Charge ☐ Radiographer ☐ Med. Physicist

☐ Radiologist ☐ Radio Therapist ☐ Technician ☐ Nurse

☐ Wardboy/Ayah ☐ Scientist ☐ Trainee ☐ Others

12. Nature of Work (Mark X in applicable box)

☐ Ind. Radiography Painting	☐ Nucl. Guage	☐ Ind. X-Ray	☐ Luminous
☐ Diag. X-ray Radiography	☐ Radio therapy	☐ Nucl. Med	☐ Dental
☐ Reactor Operation	☐ Civil Maint.	☐ Mech. Maint.	☐ Elec. Maint.
☐ Control Maint.	☐ Health Phys.	☐ Fuel Fabrication	☐ Mining & Milling
☐ Research	☐ Well Logging	☐ Others	

13. a) Have you worked with radiation prior to joining the present institution Yes ☐ No ☐

b) If the answer is "Yes" Duration of work from (Yr) ☐ To (Yr) ☐

14. a) Have you availed the personnel monitoring service in the previous institution Yes ☐ No ☐

b) If the answer is "Yes" , please give the following details:
(In case of more than one institution, please furnish the information on a separate sheet)

15. Institution Number ☐☐☐☐ 16. Personal Number ☐☐☐☐

17. Duration of work from (Year) ☐☐☐☐ To (Year) ☐☐☐☐

18. Name & Address of Previous Institution:

19.TLD badge required for CHEST only/ both CHEST & WRIST

20. Details of radiation sources to be handled:

☐ Signature of Head/RSO of present Institution

Date

☐ Signature of Radiation Worker

Date

**Format / specification may vary depending upon the requirements of the TLD unit*

APPENDIX-M

Specimen Format[#] of TLD-2 Form - Application for Personnel Monitoring Services

Name & Address of the Laboratory / Unit

Note: (i) Please read TLD Personnel Monitoring Service Manual before filling the form.
(ii) Separate sheet may be attached if space is not sufficient.

1. Name of the Institute: _____
2. Postal Address for Correspondence: _____
   (with phone no, fax and email address): _____
   _____

3. Details of persons who will be using the TLD badges:

Sr. No.	Name in Full	Sex	Date of Birth	C/W*	Remarks**

* In case of TLD badge to be worn on chest only, please write C
** In case of TLD badge to be worn on both chest & wrist, write C+W

4. Number of cassettes/Holders required: Chest _____ Wrist _____Control _____
5. Number of TLD cards required per month including control ; _____
   (a) Duly filled in Personal Data Form (TLD-4 form) for each radiation worker should be sent along with this form .
6. Details of Radiation Sources (Please fill in whatever applicable in your case)
   (a) Industrial / Research X-ray units

Sr.No.	Make, Model and Type of Unit	Operating Range		Fixed or Mobile	Date of Installation	Remarks
		Voltage (kV)	Current (mA)			

(b) Industrial Radiography Camera / Unit

Sr.No.	Make and Model	Radioisotope	Activity		Date of Installation	Remarks
			Curie or GBq	On Date		

(c) Medical X-ray units (viz. Radiography, Fluoroscopy, Dental, Therapeautic, CT Scan, Cardiac Catheterisation, Angiography, etc.)

Sr. No.	Make, Model and Type of unit	Operating Voltage (kVp)	Current (mA)	Fixed or Mobile	Year of Installation	Remarks

(d) Telegamma Units

Sr. No.	Details of Make and Type of unit	Name of the Isotope	Activity		Date of Installation	Remarks
			Curie or GBq	On Date		

(e) Sealed Sources such as Ra-226, Co-60, Ta-182, Sr-90 Au-198 Cs-137, Ir-192 etc.

Sr. No.	Source & its Physical form	Activity		Type of Use	Remarks
		Curie or GBq	On Date		

(f) Unsealed Sources such as Tc-99m, Na-24, P-32, K-42, Cr-51, Fe-59, Y-90, I-131, Au-198 etc. in liquid and powder form

Sr. No.	Source	Activity in Stock		Quantity handled at a time (mCi/ MBq)	Physical form	Chemical form	Activity to be procured		Remarks
		mCi (MBq)	On date				Month	Year	

***Note**: Please give similar details on a separate sheet if any other radiation generating machine or sources which have not been mentioned above are available with you*

DECLARATION

I HAVE READ THE TLD BADGE USER'S INSTRUCTION MANUAL AND THE ATTACHED TERMS AND CONDITIONS AND I UNDERTAKE TO

1. Comply with all instructions stated in the manual and any other instruction to be given time to time by the competent authority.
2. Comply, agree and follow all terms & conditions
3. Investigate the cases of over exposures or contamination of TLD cards and send the reports promptly whenever called for

Date — Signature of the Head of the Institution with Stamp and Seal
Place — Name of the Signatory
Designation

 # Format / specification may vary depending upon the requirements of the TLD unit

APPENDIX-N

Specimen Format[#] of Dose Report

Name & Address of the Laboratory / Unit

Institution Number:
Address:

Service Frequency: **Quarterly**
Service Period:
Report Date:

Per No.	Name	Worn at	Whole Body Dose (mSv)					Beta Dose (mSv)	Current Year Beta Total (mSv)	Wrist Dose (mSv)	Current Year Wrist Total (mSv)
			Jan-Mar	Apr-Jun	Jul - Sept	Oct-Dec	Current Year Total				

 # Format / specification may vary depending upon the requirements of the TLD unit

Notes:

1. All doses are reported in millisievert (1mSv=100 mrem)
2. No Dose Reported unless PDF (TLD-4) form received.
3. When more than one cards are used, dose is added.
4. Dose below measurable dose is shown zero.(low energy X= 0.05 mSv, β= 0.5 mSv or γ= 0.2 mSv).
5. Annual effective dose in any calendar year shall not exceed 30 mSv,
6. Cumulative effective dose constraint for the 5 year block from 1.1.1999 to 31.12. 2003 is 100 mSv.
7. '_' means in any service period dosemeter not used.
8. '* ' means Total dose> 20 mSv. Inform details of the radiation work/ practice to BARC/AERB
9. '* * ' means letter sent to the institution.
10. '* * * ' means under any service period dose >100 mSv.

APPENDIX-N (Contd.)
Specimen Format[#] of Dose Report

Name & Address of the Laboratory / Unit

Institution Number:
Address:

Service Frequency: **Monthly**
Service Period:
Report Date:

Per No.	Name	Worn at	Whole Body Dose (mSv) Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec Total	Beta Dose (mSv)	Current Year Beta Total (mSv)	Wrist Dose (mSv)	Current Year Wrist Total (mSv)

 # Format / specification may vary depending upon the requirements of the TLD unit

Notes:

1. All doses are reported in millisievert (1mSv=100 mrem)
2. No Dose Reported unless PDF (TLD-4) form received.
3. When more than one cards are used dose is added.
4. Dose below measurable dose is shown zero (low energy X= 0.05 mSv, β= 0.5 mSv or γ= 0.2 mSv).
5. Annual effective dose in any calendar year shall not exceed 30 mSv.
6. Cumulative effective dose constraint for the 5 year block from 1.1.1999 to 31.12.2003 is 100 mSv.
7. '_' means in any service period dosemeter not used.
8. '* ' means Total dose> 20 mSv. Inform details of the radiation work/ practice to BARC/AERB
9. '* * ' means letter sent to the institution.
10. '* * * ' means under any service period dose >100 mSv.

APPENDIX -O

Algorithm for Dose Evaluation

Key to abbreviations:

D1 : reading of dosimeter under Cu-Al filter

D2 : reading of dosimeter under plastic window

D3 : reading of dosimeter under open window

RV : reporting value.

D1', D2', D3' are D1, D2, D3 minus the control card reading.

D1', D2', D3' are equated to zero if less than RV.

RV = 0.2 mSv for gamma
= 0.5 mSv for beta
= 0.05 mSv for Low energy X-ray

Depending on the nature of the radiation, the following algorithm is used.

1. Gamma Ray Dose: If the ratio of D3' to D1' is less than 1.3, only gamma ray dose should be evaluated using the value of D1' i.e.

Gamma Dose = D1' (equated to zero if less than RV)

2. Beta Dose: If the ratio of D3' to D1' is more than 1.3, also the ratio of D3' to D2' is more than 1.3 and D1' is very close to background reading, then beta dose should be evaluated as follows.

Beta Dose = BMF x (D3' - 1.3 x D1')
= Zero if less than RV.

Where BMF is the Beta Modification Factor and is dependent on the energy of beta radiation (e.g. BMF =1.6 for Natural Uranium).

3. Beta and Gamma Ray Doses: If the ratio of D3' to D1' and D2 to D1 are more than 1.3 also ratio of D3' to D2' is more than 1.2 and D1 is significantly higher than background, both beta and gamma doses should be evaluated.

Gamma Dose = D1' (equated to zero if less than RV)

Beta dose should be calculated as per the calculation shown above taking appropriate value of BMF from the ratio of D2 & D3

APPENDIX –O (contd.)

4. X and Gamma Ray Doses:

Case –I

If the ratio of D2' to D1' is less than 1.3, gamma ray/ X-ray (>200 keV) dose should be evaluated using the value of D1' i.e.

Dose = D1' (equated to zero if less than RV)

Case –II

If the ratio of D2' to D1' is more than "1.3" but less than or equal to "5" (i.e. 1.3<D2'/ D1'≤ 5) which indicates that the TLD badge is exposed to X rays of energy between 40 keV to 200 keV or TLD badge is worn under lead apron and exposed to diagnostic X-rays. In this case X-ray dose should be evaluated as follows

$$\text{Dose} = D1' \times (A_0 + A_1 R_{12} + A_2 R^2_{12} + A_3 R^3_{12} + A_4 R^4_{12}),$$

Where $R_{12} = D1'/D2'$ and $A_0 = 2.6017$, $A_1 = -15.8861$, $A_2 = 45.5412$, $A_3 = -53.2834$ and $A_4 = 22.5612$

Case -III

If the ratio of D2' to D1' and D3' to D1' are more than "5" and D2~D3 (within 20%), which means the TLD badge is exposed to X rays of energy less than 40 keV or the badge is worn over the lead apron. Dose should be evaluated as follows:

Dose = (D2' + D3') / 20

Note:

1. In case there is any ambiguity in the ratio of D2'/D1', D3'/D1' etc., information on the type of radiation source handled by the worker should be obtained and accordingly the dose should be evaluated.
2. Beta & Gamma doses are evaluated when it is ensured that photons of effective energy less than 60 keV are not encountered significantly.
3. X ray doses are evaluated when it is ensured that beta radiation is not encountered.
4. For the algorithm example of Case-II, other tested methods developed by individual TLD units could also be used. It may be noted that Dose = D1 (Case-I) remains valid even for this category (Case-II) if over estimation up to 50 % could be tolerated.
5. Evaluated doses in all the above cases should be rounded off to the nearest multiple of 0.05 in the dose report.

APPENDIX – P

ANSI Criteria for Testing the Performance of Personnel Dosemeters

American National Standard Institute (ANSI), provides a procedure for testing the performance of dosimetry system. These procedures are periodically reviewed[1,2] by ANSI and the latest revision has been carried out in 2001[3]. According to ANSI performance criteria, the definition of some parameters which need to be evaluated are given below

Performance quotient is the relative difference of the personal dose equivalent reported by the TLD unit from the delivered personal dose equivalent which for the i^{th} dosimeter is

$$Pi = \frac{H_i^{'} - Hi}{Hi} \qquad : \text{i =1 to n (number of dosimeters i. e. 15)}$$

where, Hi is the personal dose equivalent assigned by the testing / irradiating laboratory to irradiated dosimeter and H_i' is the corresponding personal dose equivalent reported by the test participant / TLD unit.

The mean value of performance quotient Pi, of a set of dosimeters ($\bar{P}$) or Bias (B) is

$$B \equiv \bar{P} = 1/n \sum_{i=1}^{n} Pi$$

Where sum is extended over all n values of Pi. The large magnitude of B indicates the bias in the data. A positive value of B means the reported dose is higher than the delivered dose, and a negative means that the reported values are less. If $\bar{B}$ is systematically too high or too low for all the test categories, it may indicate calibration or algorithm error.

The standard deviation S (σ_p) of the values of performance quotient *Pi,* is

$$S \equiv \sigma_p = \left\{ \left[\sum_{i=1}^{n} \left(Pi - \bar{P} \right)^2 \right] / (n-1) \right\}^{1/2}$$

Where the sum is extended over all n values of *Pi* for a particular test in a given radiation category or test category. If the values of S (σ_p) are large, it indicates a lack of precision or large random scatter.

Performance in a given radiation categoy is considered to be acceptable if the specified Tolerance Level (L) is not exceeded by the sum of the absolute value bias B and the standard deviation S i. e.

$$| B| + S \leq L$$

Tolerence level L, is a quantity which collectively reflects the overall uncertainty in the calibration, measurement and dose evaluation procedure as well as it takes into account the recommendations of Competent Authorities in the field of Radiation Protection.

According to the latest criteria, the tolerance level (L) value has been brought down from 0.5 to 0.4. Also, no separate limit has been kept for the bias B or standard deviation S. A performance quotient limit PQL (commonly called 10% rule) which is consistent with the current practices of International Organization for Standardization (ISO) has been adopted by ANSI. This means that regardless the value of the tolerance level L, not more than 10% of the tested dosimeters for any test category should have absolute value of performance quotient |Pi| greater than the value of permitted tolerance level (0.4). With fifteen dosimeters tested in any category, if two or more have $|Pi|$ greater than 0.4, the results of the test should be considered as fail i.e. unacceptable and unsatisfactory.

The revision by ANSI became inevitable because it was noted that as per the previous test criteria, any test category could be passed even if 25% of the test dosimeters (3 or 4 of 15) exhibited $|Pi|$ values more than the permitted value. The adoption of trumpet curve criteria by us in addition to the ANSI criteria was however prevented such situation in our QA programme.

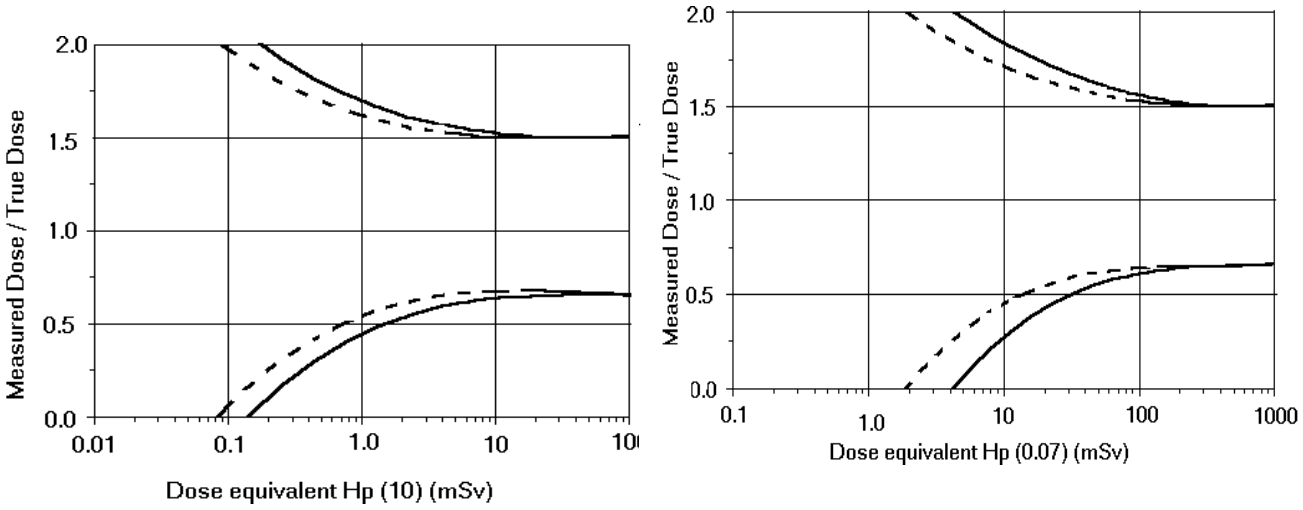
Procedure for Performance Testing:

To determine the performance of dosimeters in a particular radiation category, required number (minimum 15) of freshly annealed dosimeters / TLD cards randomly selected from the lot under routine use will be submitted by the participating laboratory / TLD laboratory to the testing / irradiating laboratory (BARC) for irradiation to different values of doses. The exact values of doses will not be disclosed to the laboratory. A few dosimeters / TLD cards will not be subjected to any irradiation and used as control cards for evaluation of transit doses, which could also be used for verification of the adequacy of annealing procedure. All the dosimeters / TLD cards will be returned to the laboratory for readout and dose evaluation along with the control cards (duly marked). The dose report received from the TLD laboratory will be evaluated as per the ANSI HPS N13:11-2001 Criteria and Trumpet Curve Criteria and the result of analysis will be sent to the laboratory and all concerned.

APPENDIX-Q

Trumpet Curve

The trumpet curve is the graphical representation of the permissible accuracy interval around the conventional true dose as a function of personal dose equivalent as shown in the figure (J. Bohm, 1994). The performance of the dosimetry system is considered to be satisfactory if ratio of measured dose to conventional true dose lies in the trumpet curve for 95% of the dosimeters.(IAEA-TECDOC-1126**)**



(a) **(b)**

Fig. 5 Acceptable upper and lower limits for the ratio of measured dose / conventional true dose as a function of dose: (a) for Hp (10); and (b) for Hp (0.07). (Broken lines: monthly monitoring periods; solid lines bi-monthly monitoring periods.)

The upper limit of the permissible accuracy limit (i.e. upper part of the trumpet curve) is given by

$H_{ul} = 1.5\ [1+ H_0 /(2H_0+H_1)]$

and the lower limit is given by

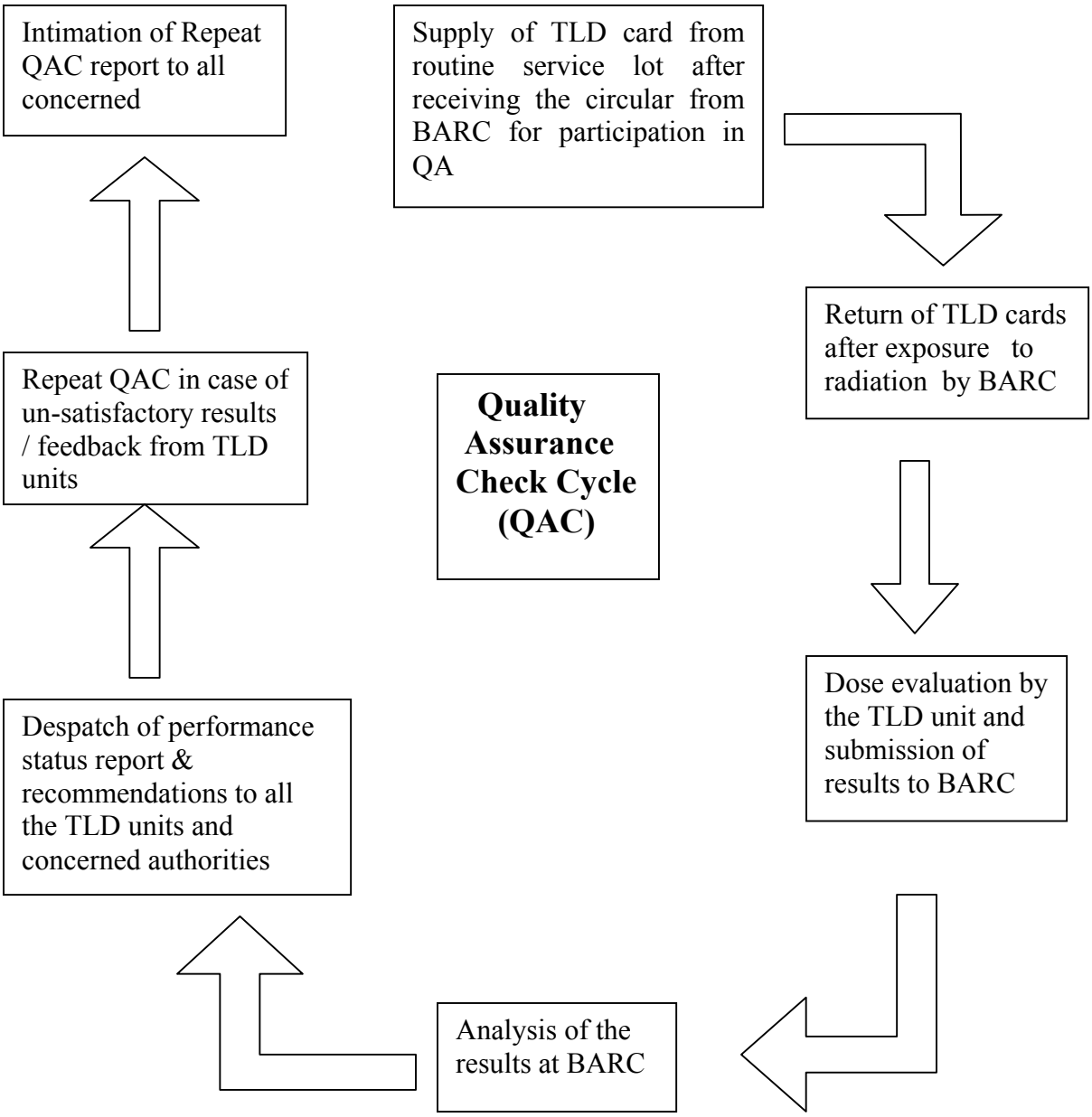
$H_{ll} = (1/1.5)\ [1 - 2H_0 /(H_0 +H_1)]$ for $H_1 \geq H_0$

$H_{ll} = 0$ for $H_1 < H_0$

Where H_1 is conventional true dose (delivered dose) and H_0 is the lowest measurable dose (i.e. recording level). Recording level H_0 can be calculated from the formula 1 mSv x Frequency of service/ 12. For monitoring period of one month the recording level H_0 is not lower than 1 mSv/12 = 0.085 mSv according to ICRP 60/75

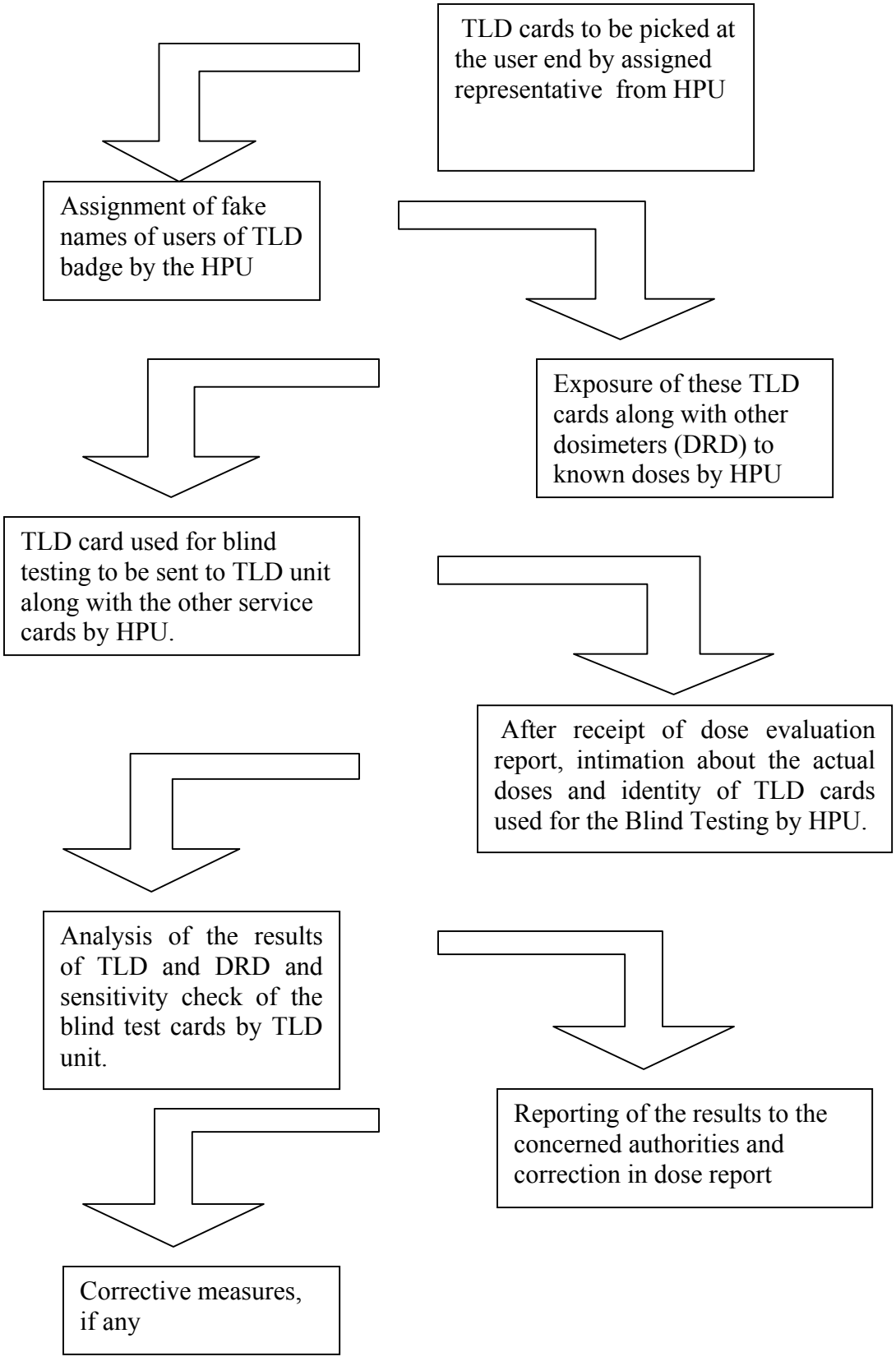
APPENDIX - R

Procedure for External Quality Assurance Check



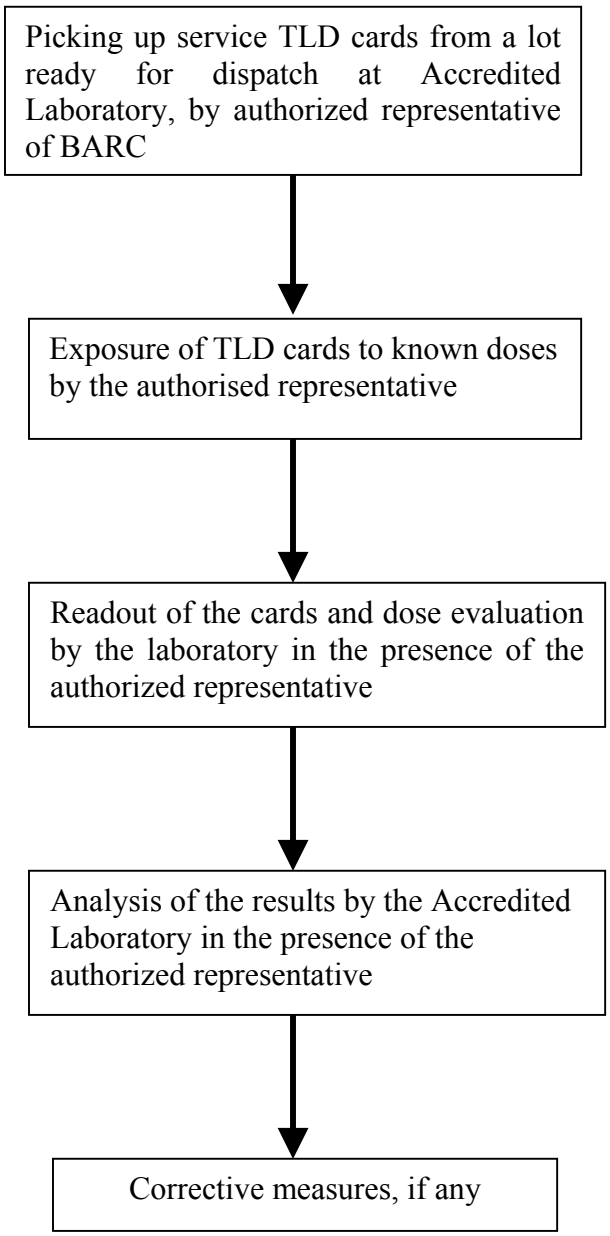
APPENDIX – S

Procedure for Blind Testing



APPENDIX - T

Procedure for Spot Testing of Accredited Laboratory



APPENDIX-U

List of the Suppliers

$CaSO_4$:Dy TLD PHOSPHOR/TLD DISCS:

1. **Renentech Laboratories Pvt.Ltd**
   C-106, Synthofine Industrial Estate
   Off Aarey Road, Goregaon (East)
   Mumbai-400 063
   Telefax: 022-8759451
   Email: rentech@vsnl.com

TLD CARDS:

1. **Renentech Laboratories Pvt. Ltd**
   C-106, Synthofine Industrial Estate
   Off Aarey Road, Goregaon (East)
   Mumbai-400 063
   Telefax: 022-8759451
   Email: rentech@vsnl.com

2. **Mediflow Pharmaceuticals Pvt. Ltd**
   3/120, Nahar & Seth Industrial Estate
   L.B.S.Marg, Bhandup (west)
   Mumbai-400078
   Ph: 022-5607853

3. **ANI Associates**
   302, Daffodil, Tata Colony
   Sainath Gardens, Mulund (East)
   Mumbai- 400 081
   Phone: 022-25607484

TLD CASSETTE:

1. **Kiran Electromech Systems**
   36, Virwani Industrial Estate
   Western Express Highway
   Goregaon (East)
   Mumbai- 400063
   Ph: 022-8751365

2. **Shartronics India**
   115, M. Krishnappa Layout
   Lalbaug Main Road
   Bangalore- 560 027
   Ph: 080-2240 613
   Fax: 080-2279 783

APPENDIX-U (Contd.)

MANUAL TLD READER:

1. Kiran Electromech Systems
36, Virwani Industrial Estate
Western Express Highway
Goregaon (East)
Mumbai- 400063
Ph: 022-8751365

2. Kaustabh Industrial Engineers
148, Madhani Estate
Senapati Bapat Marg
Dadar, Mumbai- 400028
Ph: 022-4361954

AUTO TLD READER:

1. Radiation Safety System Division
Bhabha Atomic Research Centre
Mod Labs, Mumbai-400 085
Fax: 022-550 5151

2. Nucleonix Systems Pvt. Ltd
Plot No. 162/A & B, Phase-II,
IDA, Cherlapally
Hyderabad- 500 051
Ph: 040-7123701
Fax- 040-7122146

CONTAMINATION MONITOR & AREA MONITOR:

1. **Nucleonix Systems Pvt. Ltd**
Plot No. 162/A & B, Phase-II,
IDA, Cherlapally
Hyderabad- 500 051
Ph: 040-7123701
Fax- 040-7122146

2. **Electronics Corporation of India Ltd**
Instruments & Systems Division
(Marketing)
ECIL Post office, Hyderabad – 500 062
Ph: 040-7120131/7125588

3. **Electronic Enterprises (India) Ltd.**
306, Nimesh Industrial Estate,
90 feet Cross Road, Mulund (East)
Mumbai – 400 081
Ph: 91-22-5909904
Fax: 91-22-5693960

4. **Pla Electro Appliances Pvt. Ltd.**
Thakore Estate, Kurla Kirof Road,
Vidya Vihar (West)
Mumbai – 400 086
Ph: 5116864/5116865
Fax: 91-22-5168948

ANNEALING OVEN:

1. Thermex Industrial & Laboratory Instruments Co.
113, Satyam Induatrial Estate, Govandi Station Road
Deonar, Mumbai- 400 088
Ph: 551 2070/ 3071, Fax: 558 4519