AN APPROVED PERSONAL DOSIMETRY SERVICE BASED ON AN ELECTRONIC DOSEMETER

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ABSTRACT

At the Second Conference on Radiation Protection and Dosimetry a paper was presented which, in part, announced the development of an electronic dosemeter to be undertaken in the U.K. by the National Radiological Protection Board (NRPB) and Siemens Plessey Controls Ltd. This dosemeter was to be of a standard suitable for use as the basis of an approved personal dosimetry service for photon and beta radiations. The project has progressed extremely well and dosemeters and readers are about to become commercially available. The system and the specification of the dosemeter are presented.

The NRPB is in the process of applying for approval by the Health & Safety Executive (HSE) to operate as personal monitoring service based on this dosemeter. As part of the approval procedure the dosemeter is being type tested and is also undergoing an HSE performance test and wearer trials. The tests and the wearer trials are described and a summary of the results to date presented.

The way in which the service will be organised and operated is described and a comparison is made between the running of the service and others based on passive dosemeters at NRPB.

INTRODUCTION

Personal dosimetry services, approved by their national authorities for category A workers, invariability use passive dosemeters incorporating photographic film or thermoluminescent detectors. However, for several years the NRPB has felt that the next major development in personal dosimetry should be an electronic dosemeter mainly because the instantaneous indication of radiation levels to the wearer should lead to improved control of exposures and a reduction in individual doses. This became a possibility when an arrangement of solid state detectors and filters was developed at NRPB[1] which was suitable for the measurement of individual dose equivalent penetrating, $H_p(10)$ for photons.

Since then further development has taken place at NRPB[1] for the measurement of individual dose equivalent superficial, $H_s(0.07)$ for beta-radiation. The quantities $H_p(10)$ and $H_s(0.07)$ have been recommended by ICRU[2] for individual monitoring.

Thus, the basic detector system for the development of an electronic dosemeter had been established. However, the successful development and production of an electronic dosemeter requires expertise in the design, manufacture and marketing of electronic devices. To this end NRPB and Siemens Plessey Controls agreed to develop jointly the device which will, in due course, be manufactured and distributed by Siemens Plessey.

THE DOSEMETER SPECIFICATION

It is the intention that the device is suitable for use as a legal dosemeter, i.e., one which in the U.K., for example, could be the basis of a dosimetry service, approved by the Health & Safety Executive (HSE) for "Classified" workers. In order to achieve this the HSE were closely consulted during the development. Information was also obtained on the necessary requirements in other countries, in particular on any performance tests the dosemeter would need to pass for it to obtain official acceptance.

The dosemeter will measure $H_p(10)$ and $H_s(0.07)$ for photons and beta-rays both as the accumulated dose or instantaneous dose rate and the wearer is free to choose at any time which of these is displayed. The dose range which can be displayed for $H_p(10)$ and $H_s(0.07)$ is 1 μSv to 999.9 mSv. On its own this range is insufficient but the dosemeter will store up to 10 times this value, which will be accessible with an external reading unit. The dose rate ranges which can be displayed for $H_p(10)$ and $H_s(0.07)$ are 1 to 9999 μSv h^{-1} and 0.01 to 99.9 mSv h^{-1} respectively.

For photons and beta-rays the dosemeter can cover the energy ranges 20 keV to 7 MeV and 250 keV to 1.5 MeV (mean energies) respectively. Over the more important regions of these ranges the response is constant to within about 30% and the variation of response with angle of incidence will be contained within these limits.

Audible and visual alarms are provided, the setting up of which is restricted to authorised persons. The wearer, using keypads provided on the unit, can cause dose rate, or accumulated dose, or the alarm settings or his personal unique identifier to be displayed. This facility may, however, be inhibited by the local health physicist or the approved dosimetry service if required. Warning signals such as battery low or calibration required are automatically displayed. Another important feature is that if for some reason the wearer is doubtful of the operation of the unit (if it has been dropped for example), the keypad can be used to carry out a comprehensive test routine. An essential feature for a legal dosemeter is that the accumulated values of $H_p(10)$ and $H_s(0.07)$ are stored securely. This security will be maintained even if the battery is discharged or the unit is damaged providing the storage chip is intact.

Important internal features are the use of semi-conductor detectors together with state of the art electronics. A single customised chip (to maintain stability) contains the input amplifiers and a customised battery will have a life of at least 1 year under normal conditions. Each dosemeter has a unique

identifier and authorised stations (i.e., approved dosimetry services in U.K.) will be able to read and reset the stores for $H_p(10)$ and $H_s(0.07)$ prior to re-issue to a different person.

CURRENT STATE OF THE DEVELOPMENT

Fully developed pre-production models of the dosemeter and reader are now available. Figure 1 shows the dosemeter with the display indicating an accumulated dose of 38 μSv for the quantity $H_p(10)$. Figure 2 shows all the elements of the display together with an indication of which of these would become visible under various conditions. It should be noted because of the available space in the display $H_p(10)$ is displayed as HP and $H_s(0.07)$ as HS.

THE ELECTRONIC PERSONAL DOSIMETRY SYSTEM (EPDS)

The Electronic Personal Dosemeter based System is much less complicated than those based on passive dosemeters. Other than the dosemeters themselves, a reader is required which is an interface unit enabling information to pass to and from the dosemeters by optical means. The reader is linked to a personal computer to form the issue and receipt station. This can be linked to a further computer in which the dose records are stored. The system is shown diagrammatically in Figure 3.

An important feature is that data are stored in the dosemeter at two levels. Access is permitted, via the reader, to the operational or shallow level dose record store to allow approved persons such as local health physicists to exercise day to day control within their area. These persons are able to clear and reset the operational dose store but only read the information in the legal store. On the other hand, free access to the legal or deep store is available to the Approved Dosimetry Service (ADS). The ADS is able to read information in the legal store, commit it to the individual's legal dose record and clear and reset the store prior to re-issuing the dosemeter either to the same or a different worker.

The operational concept is that the dosemeter will be issued to a given worker for a period of one year:- a custom built, high capacity battery with a life in excess of one year under normal working conditions, allows this. During the year the dosemeter is read at appropriate intervals (monthly in the majority of cases) and the dose registered in the worker's legal dose record.

At the end of the year the dosemeter is returned to the ADS who will read the total dose for the year and check that this agrees with the sum of the individual doses read throughout the year. If they agree the legal store in the dosemeter is cleared prior to re-issue, if not the matter is investigated. The ADS will also fit a new battery and check that the dosemeter and, in particular, each individual detector is functioning correctly and that the calibration still applies. The design of the dosemeter is such that practically all units will pass these tests. In the rare case of a failed dosemeter the dosemeter will probably be discarded after the reason for its failure has been established.

In some cases the ADS will serve only staff within its own establishment so that workers have ready access to the ADS read station. However, some services such as that to be operated by the National Radiological Protection Board (NRPB) will serve external customers. In these cases remote stations are envisaged with readers, of the ADS type, operating by a direct interactive link with the ADS. Alternatively this could be achieved by down loading the dose information via the reader on to some computer compatible medium which could be used to forward the dose information to the ADS for entry into the dose record keeping system. Of course in all cases adequate back-up facilities would be necessary to ensure no loss of dose information.

APPROVAL OF THE ELECTRONIC PERSONAL DOSIMETRY SERVICE IN THE UK

The NRPB will establish an electronic personal dosimetry service, initially for its own staff and subsequently on general offer within the U.K. To do this the service must be approved by the Health & Safety Executive. This approval involves the consideration and inspection of the whole service including

the qualifications and experience of staff and the overall facilities. Detailed information on the performance of the dosemeter must be available and the dosemeter must have passed the appropriate HSE performance test. In addition a laboratory statement must be provided giving details of the uses for which the dosemeter is intended and on the way the service will be operated. Since this is the first time an electronic device has been used as a legal dosemeter a six month trial of which four months will be wearer trials will also be undertaken to support the application for approval.

Type Testing the Dosemeter

The dosemeter is being type tested in order to demonstrate its overall performance characteristics. Central to these tests is an investigation into the way its response varies with radiation type and energy and with the angle of incidence of the radiation. The dosemeter is intended for the measurement of $H_p(10)$ and $H_s(0.07)$ for photons and beta-rays. The above tests are being carried out with ISO reference radiations with energies between 17.4 keV and 7 MeV for photons and with beta particle spectra from ^{204}Tl, $^{90}Y/^{90}Y$ and ^{106}Rh. In all cases the dosemeters will be exposed at angles of incidence 0°, 20°, 40° and 60°. The dosemeters are being exposed on the phantom recommended by the ICRU for this type of test namely a slab of dimensions 30 x 30 x 15 cm. Appropriate conversion coefficients, recommended by ICRU, are used to convert the air kerma intensity in the radiation beam to $H_p(10)$ and $H_s(0.07)$ in the phantom, i.e., the quantities against which the reading of the dosemeter is compared. The results will be presented in the form of a family of 4 curves being the energy response for each of the angles of incidence. To gain acceptance the mean of these curves at each energy should be within $\pm$30% of that at the calibration energy over the whole energy range. So far this work has been completed for photon radiations. Figure 4 shows the photon energy response for the dosemeter at angles of 0°, 20°, 40° and 60°. It can be seen that all values of the combined energy and angular response are within the range 1.0 ± 30%. Figure 5 shows the linearity of response with dose rate. It can be seen that the dose rate is linear to within 20% for dose rates up to 2 Sv h^{-1}.

In addition the type test will include an investigation of the following:-

i) effects of temperature and humidity
ii) effects of interfering radiations, i.e., neutrons and radon
iii) effects of electromagnetic and electrostatic fields
iv) effects of shock, vibration and immersion in water
v) the ease of radioactive decontamination
vi) the stability of the dosemeter with time.

HSE Performance Test

The HSE performance test is carried out at the calibration energy. Twenty-five dosemeters are exposed to doses in the range 0.5 mSv to 1 Sv and the readings compared with the conventional true value of $H_p(10)$. The ratio of the reading to the conventional true dose is calculated for each dose and the deviation of the mean value of this ratio from the conventional true dose must not exceed 25% and the standard deviation on the distribution of these ratios must not exceed 15% for the dosemeters to pass the test unconditionally.

The Wearer Trials

The wearer trials are being largely limited to NRPB staff at its centres in Chilton, Leeds and Glasgow using the system described above. The service will be operated from Chilton and the trials at Chilton are being used to simulate an ADS serving its own on-site staff. The staff at Leeds are being used to simulate a remote customer linked to the dose record keeping system by an interactive computerised system and those at Glasgow to simulate a remote customer transferring data by means of some computer compatible medium. During the trials staff are, of course, continuing to wear their current passive dosemeters.

THE EPDS IN OPERATION

Although the electronic personal dosimetry service is not yet in operation a number of substantial differences between its operation and that of a typical passive dosemeter service can be anticipated. From a radiological protection point of view the instant read facility will allow the wearer and his supervisors to control his exposure to radiation more efficiently and hence keep it to a minimum. The increased sensitivity will also allow low doses to be measured more accurately with the EPDS. This feature will have increased importance when lower dose limits are introduced.

From an organisational point of view a number of important advantages will accrue. The dosemeters will be issued for a whole year which will substantially reduce the effort and/or the investment in expensive issue stations which are necessary with passive dosemeters. Probably the most important factor is that no processing equipment is necessary since the dosimetric information, in its final form, exists within the dosemeter and all that is necessary is for the reader to extract this information. This will substantially improve the reliability and accuracy of the service since a great deal of care and attention to detail is required in the processing of passive dosemeters to maintain good dosimetric standards. The processing equipment used with passive dosemeters also requires a considerable amount of maintenance so that the use of a simple reader as in the EPDS will lead to a further reduction of effort to run the service. These factors could be of over-riding importance for developing countries.

The electronic dosemeter will be more expensive than a typical passive dosemeter. The dosemeter is also larger and heavier than the passive types but it can nevertheless be worn conveniently. These factors are not prohibitive, however, in view of the advantages in protection. Moreover they are not relevant for those who currently wear an electronic dosemeter as well as the legal passive type. In such cases the wearer is no longer obliged to wear two dosemeters and the local health physicist does not need to operate a separate database for day to day control. In addition the dosemeter together with the dose record keeping system may be used as a means of controlling entry into radiation controlled areas.

SUMMARY

An electronic personal dosimetry service has been described together with the procedure which is being adopted to gain approval in the U.K. for monitoring the exposure of classified workers. The NRPB considers this to be the next logical development in personal dosimetry and it has been shown that the device offers a number of advantages for this purpose.

REFERENCES

1. Burgess P.H. Private communication.

2. International Commission on Radiation Units and Measurements. Determination of Dose Equivalents Resulting from External Radiation Sources. ICRU Report 39, Bethesda, MD, 1985.

Figure 1 The Electronic Personal Dosemeter

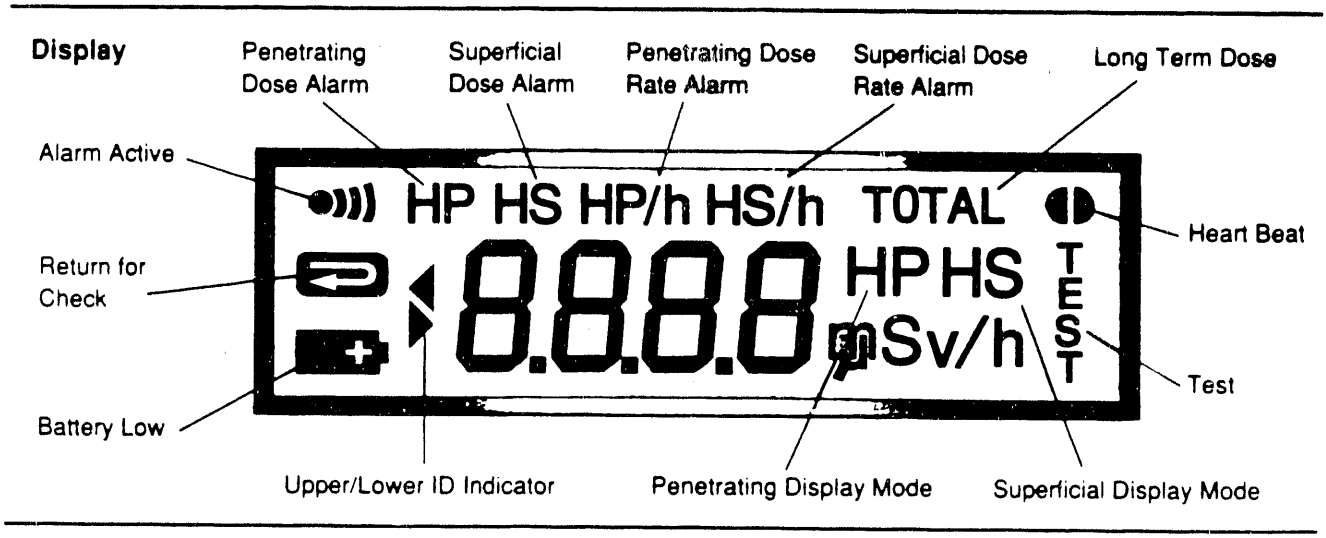

Figure 2 The Dosemeter Display

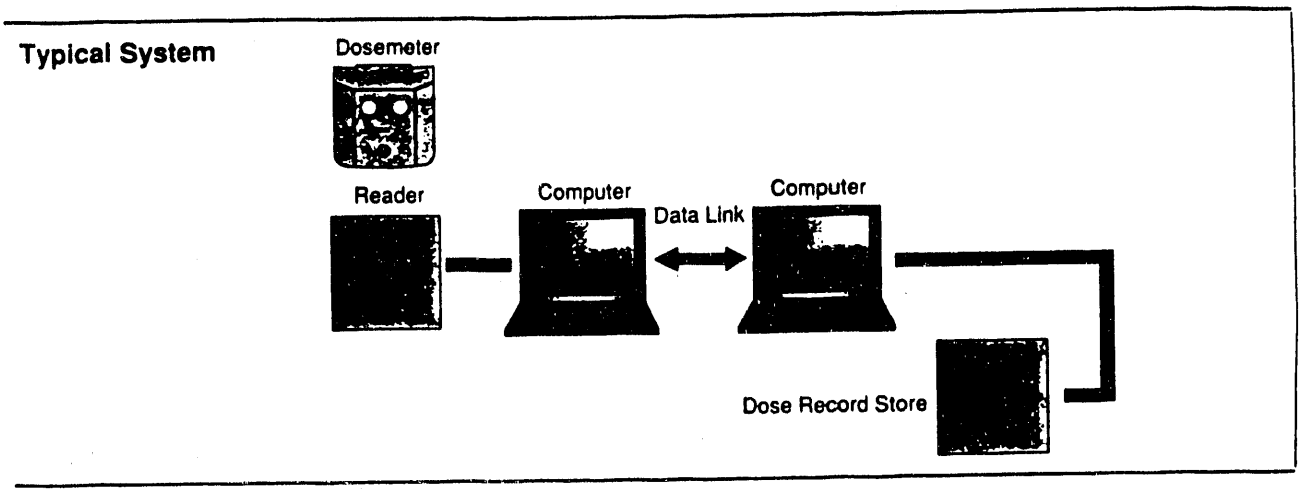

Figure 3 The Electronic Personal Dosimetry System

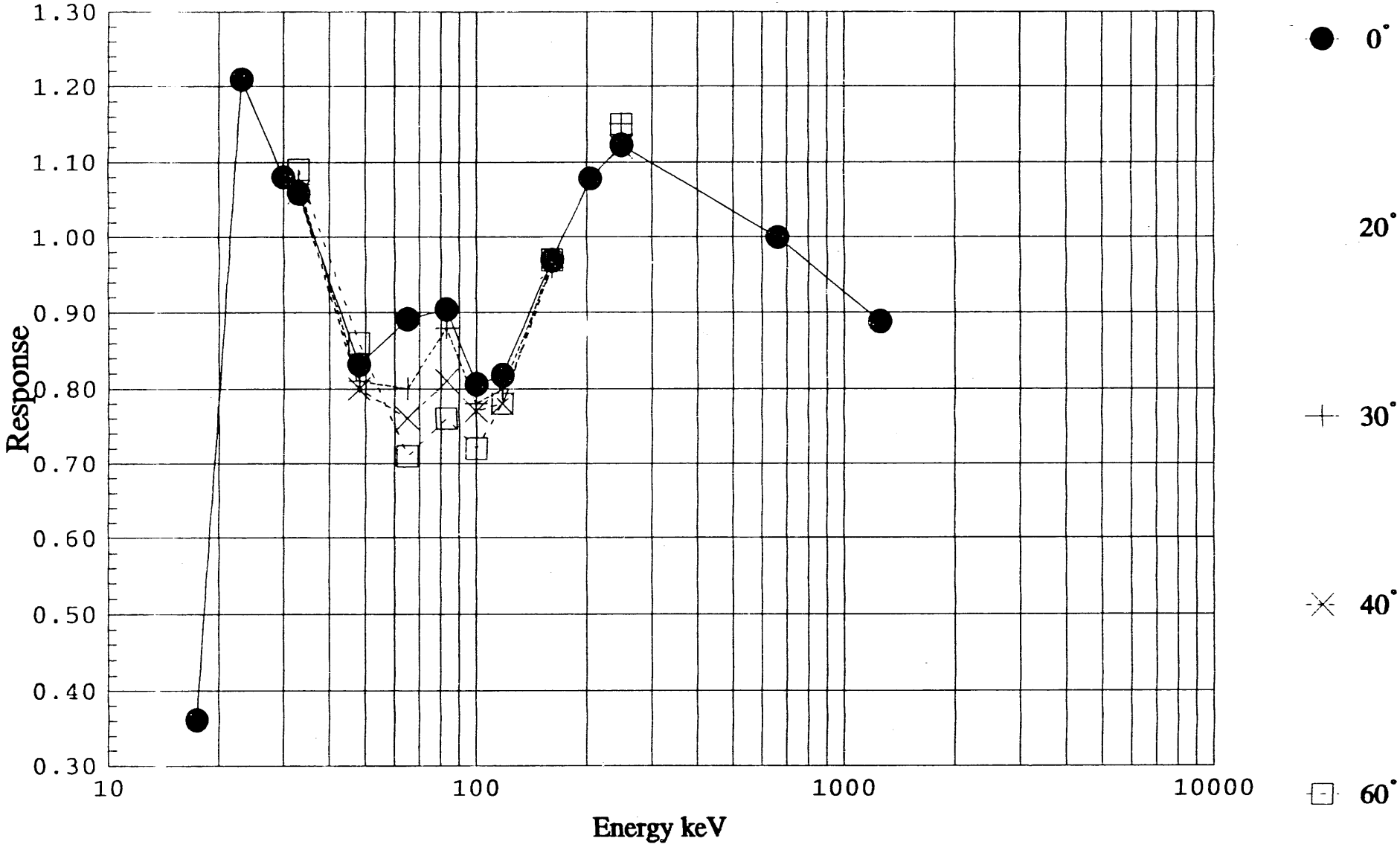

Figure 4 Variation of Response with Radiation Energy and Angle of Incidence

Figure 5 Dose Rate Dependence of Dosemeter Response