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ABSTRACT

The Joint European Torus (JET) Personnel Dosimetry Service (PDS) provides dosemeters for approximately 250 radiation workers. This is a relatively small number of people, but the unique nature of JET and its low radiation working limits have made the provision of an autonomous service necessary. The efficiency of such a small service is greatly enhanced by computerisation of the dose measurement and record keeping.

The Service uses thermoluminescent dosemeters (TLDs) for routine dose measurement and, in addition, small Geiger–Müller based dosemeters in the higher radiation environments. The computer used is a NORD–100 which is part of the JET computer network. The software is written in FORTRAN and uses a hashed database. An important feature of the software is that it presents a consistent interface between the user and the program and database interactions.

The system has worked quite effectively for three years with only two problems arising during its use:

Recently introduced legislation has resulted in changes having to be made to the software and database. The modular structure of the software has enabled changes to be incorporated, but the database has proved to be rather inflexible.

A conflict between computer availability and the demands on the PDS has arisen during maintenance periods. While this can be overcome by close co-operation with the computer operators, the situation is not ideal.

A solution to these problems would be to move the PDS to a stand-alone computer supporting an Indexed Sequential Access Method (ISAM) database.

1. INTRODUCTION

The Joint European Torus (JET) at Abingdon in the UK is one of the world's. foremost ventures in fusion technology. The programme aims to prove the feasability of nuclear fusion as a major energy source [1].

JET became operational in June 1983 and has successfully met or surpassed its planned objectives to date. Further development and experimentation is hoped to lead to the use of tritium in the plasma in the early 1990s.

2. DOSE MEASUREMENT PHILOSOPHY

In a fusion environment radiation exposure can arise either directly or indirectly from neutrons, from tritium, or from routine maintenance operations such as radiography.

The environment of the JET experiment has been designed to minimise the exposure of personnel to radiation and the potential for such radiation exposure is low. Never the less, a dosimetry service has been introduced to monitor and record the low levels of exposure which are incurred.

The number of workers involved is relatively small (≈250) and it would have been cost effective to have used an outside dosimetry service. However, our experience has shown that such services are geared to dosimetry measurements in higher radiation environments than were expected at JET and could not guarantee the precision in measuring such low doses. It was therefore decided that JET should have its own dosimetry service and that, to make it as efficient as possible, it would rely heavily on computerisation for its day to day operation and record keeping.

It was felt that the Personnel Dosimetry Service (PDS) had to fulfill two requirements; the monitoring of an individual's routine exposure to radiation in his normal work environment, and the monitoring of his exposure when visiting access controlled areas where radiation sources might exist, for example in the Torus Hall.

Thermoluminescent dosemeters (TLDs) are used to monitor a person's normal work environment. These are generally issued on a four-weekly basis.

A person's visits to controlled areas are in addition monitored using small. integrating dosemeters incorporating a Geiger–Müller tube. These are issued as a person enters the area and read out on exit. A typical issue period is of the order of tens of minutes.

A visit dosemeter is worn in conjunction with a TLD in the controlled areas. The TLD is used to give a person's accumulated dose over an issue period as required by safety legislation. The visit dosemeter is used to provide an immediate reassurance that a person has not received an abnormal radiation dose during his visit to the controlled area.

3. EQUIPMENT

3.1. Thermoluminescent Dosemeters

The TLDs are National Panasonic type UD–814–AS6. These have four individual elements, three of which are used to measure surface and body gamma-ray dose. Each badge is uniquely identified.

The badges are read out on a Natonal Panasonic reader (type UD–710A). This can accept cassettes which hold up to 50 TLDs at a time. The reader is connected to the General Services (GS) computer of the JET computer network via a serial interface and a line multiplexor (GANDALF).

3.2. Visit Dosemeters

The visit dosemeters are ALNOR type RAD–80S. This Geiger–Müller tube radiation detector is a pocket sized instrument which gives an audible and visible indication of dose. Each dosemeter has a unique identification code which is used by the entrance and exit dosemeter readers. These readers are connected to the GS computer via a serial interface. The dosemeters and readers are described more fully in another paper [2].

3.3. Computer System

The JET computer system is a network of over 20 NORD–100 and NORD–500 computers. These are interconnected by a message handling facility which allows for the transfer of information and files between them. Each computer can directly access terminals, floppy disk drives and a slow printer. Facilities such as fast printers and tape drives are available on particular computers and can be accessed from other computers over the communications network.

Access to computers from terminals is via a GANDALF (terminal multiplexor system). This allows any terminal in the JET buildings to be connected to any computer requested by the user.

The TLD reader and software and the visit dosemeter reader and software are installed on the GS (General Services) NORD–100 computer. This computer also controls the radiological protection instrumentation around the JET complex [2].

The computer operating system is SINTRAN III [3], a Norsk Data product which has similarities with other widely used operating systems.

3.4. Computer Software

The issue, return and read out of the dosemeters is overseen by a suite of computer programs which also handles all dose calculations, record keeping and printing.

The programs are written in ND-FORTRAN which closely resembles the FORTRAN–77 standard [4]. There are seven programs in all, each invoked by a single three-letter command. These broadly undertake the following tasks:

- DOA – TLD data accumulation;
- DOB – database management of TLD associated records and other records not directly concerned with the visit dosemeters;
- DOS – TLD dose calculations and relevant database manipulations;
- DOV – visit dosemeter dose record database manipulations;
- DOW – database management of visit dosemeter associated records;
- DOP – printing of monthly and annual dose assessments for individuals as required by legislation, and casual access to these and other records in the database via the program users terminal;
- DOH – archiving of database records no longer required.

Each program is a well-structured collection of subroutines which separate the different processes and actions. This introduces a degree of modularity and hence eases maintenance and enhancement.

3.5. Database

A database system was installed on the computer system for the use of the many different experiments associated with JET. It was decided to use this database for the PDS.

This database system uses a hashing algorithm to store and retrieve records. Hashing is a direct addressing method in which a key field in the record is converted to a pseudo-random number from which the required address in the database is obtained [5]. The algorithm used by the PDS has been optimised for their own particular use [6]. For each different type of record in the database, there exists a template which specifies how the bytes within the record are to be grouped and interpreted. Records of the same type can be grouped into areas of the database called files. Files are accessed independently of each other. For each file there exists a file definition which specifies among other things, how many records can be contained in the file, the record length, the hashing algorithm used etc.

The PDS database is divided into eight files, with the records in each placed according to the hashing algorithm acting on the key field. The eight files are;

- Personal details of dosemeter users, e.g. date of birth, keyed by a unique person number;
- Information about dosemeter users, e.g. total dose received, also keyed by person number;
- Information about individual TLDs, e.g. calibration factors, keyed by TLD number;
- Information about individual visit dosemeters, keyed by visit dosemeter number;
- Individual TLD dose readings keyed by dosemeter number and date;
- Individual visit dosemeter dose readings also keyed by dosemeter number and date;
- Dosemeter users' monthly dose records keyed by issue period and person number;
- General purpose information such as issue period start dates and lengths, keyed in relevant ways.

The database files vary in length from one containing forty 48–byte records to one having fifteen thousand 64–byte records. The total database size is over 3 Mbytes and is able to cope with up to one thousand dosemeter users, one thousand five hundred TLDs and four hundred visit dosemeters. To maintain the integrity of the information, program users can only access the database via the programs with their in-built error checking.

4. THE PROGRAMS IN USE

4.1. The TLD Programs

A TLD badge is first allocated to an individual using DOB, which checks and updates the TLD's and individual's records in the database. Before the TLD is issued it is read out to provide a zero baseline for the forthcoming exposure and the data accumulated in a file on the computer by DOA. After exposure, the TLD is again read out and the data accumulated by DOA. Program DOS is run on both sets of data. This reads a dosemeter number and its TL output from the file and, with reference to the appropriate calibration factors in the database, calculates the dose equivalent. The first set of data is used merely to keep an accurate record of the dose a TLD receives, whereas the second set of data also supplies the dose received during the issue period. The dosemeter is associated with a dosemeter user via the database and his dose record updated. Finally DOP can be used to access the dose measurement records and either display them on the terminal screen or print them.

4.2. The Visit Dosemeter Programs

Persons who are required to enter higher dose-rate areas are issued with a computer readable identity card. This is presented to an access control reader at the entrance, which is under the control of software running on the GS computer [2]. A dosemeter can only be issued, and access to the area gained, if authorisation is received via the controlling software.

On exit, the dosemeters are read and dosimetry information sent to a sequential file containing details of the day's entrance/exit operations.

At regular intervals program DOV is initiated. This program takes the visit dosimetry information file and, by referencing the database, associates the doses with dosemeter users and updates their dose records. Again DOP can be used to access this information.

4.3. General Purpose Programs

The database management program (DOB) is comprehensive in the access it gives to the database. This is necessary since information on TLDs and users can change and dose records may have to be amended in exceptional circustances. Such access is protected by a password. Program DOW performs a similar function for the visit dosemeter information in the database.

The database, although large, has a limit to the number of records it can hold and so the data archiving program, DOH, is run at intervals to delete unwanted records. Again access to this facility is protected.

5. THE USER-PROGRAM-DATABASE INTERACTION

Even in such a small dosimetry service, the user can be faced with several possible courses of action in dealing with the dosemeters. It is important that some actions are performed in a correct order at the appropriate time if the system is to work effectively.

The programs are written to detect gross errors in logic, e.g. the allocation of the same badge to different people, but it is not possible to automate the system to the extent where no user decisions are required. However, the operator can be greatly assisted to take the correct action if information is available to him in an easily understood and consistent way.

All the programs present themselves in a consistent manner. When invoked, the user is shown a display divided into three parts. There is a four line header which gives the program name and version number, the time and date and a screen heading. Below this, the major portion of the screen (18 lines) is available for information display. The bottom two lines are reserved for user interactions; it is here that the user is prompted for information and error messages are displayed. This three part division of the screen is applied for every display of all the programs.

The information area initially contains a list of actions (unless only one is possible) from which the user makes a choice. His choice generally results in the program prompting for relevant information, the user's responses being displayed in labeled fields in the information area. Depending on context, the given information is used to initiate program actions or display more information. If the latter then, again depending on context, the user can add, delete, amend or simply browse the information.

It is important that a user is able to choose a course of action confident that he can revoke that action if he discovers that he has made a wrong decision. Failure to ensure this can engender dissatisfaction and unease with the programs. To this end, a null response from the user leaves information unchanged or returns the user to the previous display. Therefore the user may return to the first display or even exit the program by repeated null responses, leaving data unaffected.

It is important that user supplied information is checked to ensure that it is of the required format; in the simplest case, that a valid number is given when requested. If it is incorrect the user is prompted to re-enter the information. The user is always given the chance to confirm his choices or data before the program invokes further action. This gives the user confidence and helps to guarantee the integrity of the information in the database.

Each time a program accesses the database to add, delete or alter the information it contains, appropriate details are written by the program into a log. This is printed and kept so that any errors which become apparent in the database can be traced and corrective action taken.

The database is further protected by copying, along with datafiles, to a back-up tape at regular intervals. Printed copies of all dosemeter data are also kept. In the unlikely event of a catastrophic loss of the on-line database, it could be recreated from the most recent back-up tape and a minimum of manual data entry at a terminal.

A facility does exist whereby the database can be accessed directly for diagnostic purposes and the correction of gross database errors. However this facility is not available to the general user and each part of the database can be password protected to prevent unauthorised access.

6. LEGISLATION AND DATA SECURITY

Two separate areas of UK legislation affect the PDS; the Data Protection Act [7] and the Ionising Radiation Regulations 1985 (IRR) [8].

The Data Protection Act is concerned with the correctness and security of data which is identifiable with individuals. To comply with this act, the PDS has to register the type and use of its data and satisfy certain criteria concerning the right of access to that data.

Access to data is restricted to authorised users by means of a password system. An outer level password allows a user to perform most actions, but for more powerful actions such as deletion of data, a second level password is required. Individuals have a right to access information relevant to themselves and this is complied with by sending summaries of this data to each dosemeter user at intervals.

The IRR are enforced by the Health and Safety Executive (HSE). To obtain HSE approval to run a dosimetry service and a dosimetry record keeping service, exacting requirements for both the dosimetry and the computerised record keeping must be satisfied. The requirements exactly specify the type of information to be kept, its accuracy and format.

The majority of the software had to be written before the final form of either sets of legislation were known and it is only now that the requirements are becoming firmly established.

7. OPERATIONAL EXPERIENCE

The dosimetry system has been operational for three years and its design and operation have proved largely successful.

Several changes have had to be made to the original specification of the system and more need to be implemented.

7.1. Hardware

The JET computer network is primarily concerned with the running of the Torus experiments. Its reliability and availability are high during these experiments. However the periodic shutdowns of the Torus for maintenance and development provide an ideal opportunity for the computer network to undergo maintenance and enhancement. This obviously has an effect on computer availability.

A fundamental conflict has emerged: just when the PDS is most needed i.e. during access to the torus itself, the computer system is most likely to be unavailable. Unavailability of the GS computer is not critical in the short term; the TLD system does not require real-time response and dosemeter processing and data management can usually be postponed for short periods; the visit dosemeter system is able to continue to function in a reduced mode, by storing data in a local buffer.

Close co-operation between the Computer Operations and Data Acquisition Service (CODAS) at JET and the PDS is able to reduce availability problems significantly, but experience has shown that this is not completely satisfactory.

A solution would be to move the PDS system to a stand-alone computer with its own power supplies and back-up arrangements in the near future. The computer would have communication facilities with the main JET computer network but be independent of it.

7.2. Software

The modularity of the programs have enabled required changes to the software to be implemented in a straightforward way, but the restrictions of the database are becoming more apparent.

Many of the database/program interactions are sequential in nature, for example, the listing of dosemeter information by number. A hashed database is less efficient for this type of access; an indexed sequential access method (ISAM) database would seem more appropriate.

Access to hashed records can become slow if contention for the same storage location occurs between records. Such 'collisions' can result in chains of records with the consequent increase in access time. To avoid this the database size needs to be significantly larger than would be required merely to store the data.

The current database does not allow records to be stored or accessed on more than one key field. This is a particularly useful feature in the management of personnel records. Multi-key access is not simple to implement efficiently for a hashed database, but can be readily done in an ISAM environment.

There is no facility for 'ad hoc' enquiry of the database. Routines have been written to allow access to the data in the most obvious ways but it is not possible to foresee all types of enquiry. The need for some form of query language is becoming apparent.

Although the legal requirements for the PDS and its data have now been formalised, the exact implications on the management of the system and data are still being worked out. This means that the data records' structures need to be changed as the specifications evolve. The current database is not ideal in this respect.

The hashed database was all that was available on the JET computer system at the time the software was originally written. Time restrictions made the writing of a database specifically for the dosimetry system impractical. Developments in database applications have been rapid over the last few years and there are now several flexible and powerful database managment systems available. The relatively small size of the database makes it feasible to transfer the data to a DBMS and this course of action is considered desirable.

8. CONCLUSION

The JET PDS has worked effectively during its three years of operation despite several changes made to it to satisfy new legislation.

Only two problems have come to light; a conflict between computer availability and PDS demand, and the requirement for a more sophisticated database and database query facility. Both of these problems could be solved if the PDS was transfered to a stand-alone computer supporting an ISAM database. The structure of the programs and the success of the user interface mean that these will be retained in any eventuality.

ACKNOWLEDGEMENT

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