NUCLEAR ACCIDENT DOSIMETRY FACILITIES AND RESEARCH & DEVELOPMENT TO IMPROVE MEASUREMENTS AND INTERPRETATION

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INTRODUCTION

Nuclear accidents involving an uncontrolled criticality excursion have been very rare in the nuclear industry but even so it is necessary to provide alarms for warning of such events and personal dosemeters for measuring doses to those in the vicinity of such an event. A reappraisal of past criticality accidents and more recent experimental studies of slow, delayed critical, excursions in liquid systems have focussed attention on the need to detect this type of excursion as well as fast transient ones[(1)]. This need is reflected in the new ISO[(2)] and IEC[(3)] recommendations for alarm systems. Personal dosimetry for nuclear accidents was the subject of intense activity by the IAEA in the 1970s which culminated in the publication of a comprehensive manual[(4)] (with an appendix summarising the 4 intercomparisons). The IAEA also provided a compendium[(5)] of neutron leakage spectra from critical assemblies for evaluating the doses for such accidents. The UK Ionising Radiation Regulations 1985[(6)] and the associated Code of Practice[(7)] require approval for an accident dosimetry service. In order to obtain approval and to minimise the administrative costs, we have set up a users group to: provide traceability of dosimetry techniques to national standards; provide irradiated dosemeters for exercises; conduct any necessary R&D; and provide liaison with international organisations.

This paper will include a discussion of the requirements for alarm systems and new developments in nuclear accident dosimetry. Also indications will be given as to future developments in computer control of counting systems and the provision of an expert system to interpret the measurements.

CRITICALITY DETECTION AND ALARM SYSTEMS

The design criteria and principles were produced by Delafield and Clifton[(1)] as a major development of earlier work by Aspinall and Daniels[(8)] incorporating the latest methods of detection (rate-of-change of dose-rate and neutron detectors) and knowledge of a wider range of criticality excursions (slow delayed to fast transient). The criteria have now been incorporated into an Atomic Energy Code of Practice[(9)], which is at the moment provisional to allow experience on its implementation to be included.

The characteristics of a criticality incident are described in terms of the minimum incident of concern and the radiation field. Consideration is given to: criteria for the threshold for detection; methods of detection; selection and siting of detectors; design principles for the alarm systems; testing and post-alarm procedures. For integrating detectors, it is recommended that the threshold of detection for solution systems of plutonium and uranium should be equivalent to a yield of 10^{15} fissions occurring over any duration between 1 ms and 1 minute. For metal or other systems for which it can confidently be judged that the probability is acceptably low that there are any mechanisms which could lead to a slow delayed criticality excursion, the upper limit of duration may be relaxed down to 5 s. In adopting a threshold yield for detection, the corresponding maximum $(n+\gamma)$ dose to personnel should be considered. In particular, where personnel are working close to an assembly, eg at a glove box, then a tighter threshold of detection of 10^{14} fissions within 1 ms to 1 min (solutions) or 1 to 500 ms (metal) should be used. The time to alarm from passing the detector threshold to the alarm system reading full sound should be not more than 200 ms. For more detail of the recommendations reference should be made to the full report(1).

The code of practice provides a step by step approach to the design of a complete system from the plant assessment to the provision of detectors, alarms and evacuation procedures. It includes:

(a) a review of the criteria and principles;
(b) plant assessment leading to the required characteristics for detection and warning;
(c) detection criteria including thresholds;
(d) detector siting to allow for shielding, background radiation, cabling and maintenance;
(e) types of alarm and warnings, viz audible and visible, and their positioning;
(f) characteristics including radiation response, time to alarm, reliability & spurious, alarms, maintainability, fault diagnosis and power supplies;
(g) installation and testing;
(h) management procedures in providing warning notices, evacuation procedures (eg routes), post-incident control and practical exercises.

The code is produced to aid designers, operators, plant managers and health physicists to ensure that proper design principles are implemented and maintained to adequate standards.

PERSONNEL NUCLEAR ACCIDENT DOSIMETRY

In response to the regulatory requirements in the UK(6), Harwell set up a Nuclear Accident Dosimetry Users Group (NADUG) in 1986 to:

(i) provide assistance to member establishments with the maintenance of their approvals for nuclear accident dosimetry services with the HSE;
(ii) maintain UK expertise in nuclear accident dosimetry in order to provide consultancy and immediate assistance to a member establishment in the event of a criticality accident;
(iii) undertake a modest programme of research & development to be steered by the Group members.

Harwell has more than 20 years experience in the field including taking part in the first three IAEA intercomparisons and organising the fourth. In addition to regular steering committee meetings, two successful training courses have been organised to give members experience of evaluating doses to personnel from theoretical criticality accidents.

The general principles, methods of dose assessment and interpretation employed in nuclear accident dosimetry are set out in a three part manual prepared in 1973(10). Neutron dose is determined by simple measuring techniques which involve the counting of the activation in: gold (thermal and intermediate-energy neutrons); sulphur (fast neutrons); indium (fast neutrons); body sodium (total neutron fluence). A thermoluminscent dosemeter is used to measure gamma-ray dose. Indium ($^{116}In^{m}$) activation in the criticality dosemeter, or film dosemeter or the site pass is used as an exposure indicator to identify those who have received the highest dose for immediate dose assessment. Following counting of the gold, sulphur, indium

($^{115}In^{m}$) and body sodium, an evaluation procedure is followed to give successively improved estimates of the neutron dose received. The total (n+γ) dose is then used to advise the doctors treating the patient as to who may require special hospitalisation. A full description of the system is given in the manuals(10) and an up-to-date summary by Delafield(11).

R&D in nuclear accident dosimetry for NADUG has concentrated on 3 main areas:

(i) development of a Mark IV Criticality Dosemeter containing a silicon diode(12) to provide an immediate measure of neutron dose above 200 keV (this project is well advanced to the final design stage before production);
(ii) reassessment of the interpretation of body sodium measurements (this project is complete);
(iii) revision of the assessment procedures for AERE/NRPB film dosemeter (this project is complete).

In the service area, NADUG has provided a revision of the assessment procedures in SI units which incorporates the latest information from the R&D; sets of traceable standard sources for calibrating counters for gold, sulphur, indium and sodium; a review of sites' instructions for use in an emergency. Future work will be discussed below but in the 18 months of operation, NADUG has demonstrated that for a small annual outlay (£5k) by up to 10 organisations it is possible to provide a service and maintain a reasonable level of R&D in order to improve and simplify its operation.

FUTURE DEVELOPMENTS

New systems for criticality incident detection are being developed to meet the new code of practice(9). These include the use of neutron detectors for operation in areas containing high transient gamma-ray dose rates.

Silicon diodes could make a considerable contribution to simplifying the immediate determination of the neutron dose after a criticality accident and in improving the accuracy of dose assessment especially for well-moderated leakage spectra. Gold, sulphur, indium and sodium measurements will still be required to provide neutron spectral information for estimating organ doses and dose equivalent information for record purposes. The biggest impact will come from the use of computers. Computerisation of the system is being introduced gradually. Firstly, interactive programs have been written to facilitate the routine testing of the system and undertake a first stage evaluation of the counts from the activation detectors. Secondly, interactive programs will be provided to directly control the counters. Finally the aim is to move towards an expert system which will compare the evaluation with data from the compendium of spectra(5) and prompt for gamma-ray doses, orientation of the man, type of event, shielding, distance, etc. This third step is important in order to retain the expertise built up over the years and to reduce training costs.

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