HIGH-LEVEL EXPOSURE: PROGRESS IN DOSIMETRY

In the event of people being accidentally exposed to unusually high levels of radiation, it becomes important to obtain as quickly as possible a reasonably accurate indication of the dose which each individual may have received. This serves in the first place to show which, if any, of the persons who may have been involved should receive medical treatment or be kept under observation. In the second place the information supplements clinical observation as a guide to treatment.

A symposium in Vienna, held from 8 to 12 March 1965, discussed the assessment of doses received by persons who have been accidentally irradiated, by exposure to external radiation fields, by the intake of radioactive materials, or by radioactive contamination being deposited on the surface of the body. The symposium, organised jointly by IAEA and the World Health Organisation, was entitled "Personnel Dosimetry for Accidental High-Level Exposure to External and Internal Radiation." There were 179 participants from 34 countries and five international organisations. This was a specialized conference, fairly narrow in scope, since it formed one in a succession of meetings on kindred subjects. For example, a symposium held in May 1964 dealt with general methods of assessing radioactive body burdens in man; a joint IAEA/WHO meeting in October 1960, and another in October 1962, dealt with medical aspects of radiation injury and of radioactive poisoning.

"It is very gratifying that so few accidents involving the exposure of persons to excessive amounts of radiation have so far marred the development of the uses of atomic energy and ionizing radiation for the benefit of man", said Mr. Gennady A. Yagodin, IAEA Deputy Director General, Technical Operations, who opened the meeting. "It is nevertheless of the utmost importance that methods of personnel dosimetry should be available which would give information of the type required and at the time required, that would enable the physician to provide the best medical care for persons who may, as the result of an accident, receive excessive radiation doses either by exposure to external radiation, by the intake of radioactive materials or by the deposition of radioactive contamination on the body surface."

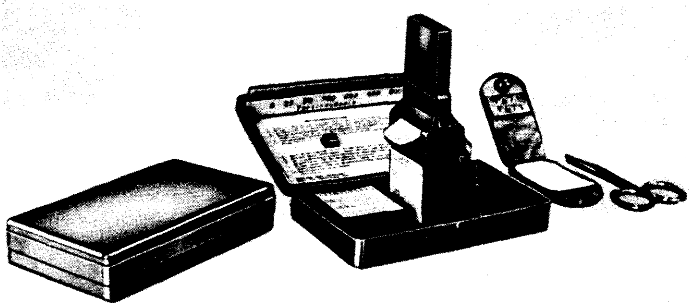
About half the proceedings were devoted to discussion of measurement techniques for external radiation, with detailed discussion of various kinds of warning and recording devices, monitors and personal dosimeters. From these the meeting passed on to consider supplementary methods such as estimation of neutron dosage by analysis of blood or hair, and experiments conducted by means of polyethylene "phantoms" to establish the dose likely to be received under particular circumstances. Other sessions dealt with the determination of internal contamination, and with the assessment of dose under a variety of conditions. The last day was spent on "experience and practice in various centres". A major interest of the symposium lay in criticality accidents and resulting neutron exposure, since such accidents are very likely to lead to high-level exposure.

PURPOSES OF DOSIMETRY

In view of the many persons who have worked among the potential hazards of the atomic energy industry since 1940, there have been a surprisingly small number of serious or fatal radiation accidents, G.A. Andrews, J.A. Auxier and C.C. Lushbaugh (USA) pointed out in an introductory survey. They took as the prototype for most types of acute radiation effect, acute total-body irradiation received from an external source. There are special problems when the external radiation is of very low penetrating ability, because skin effects are produced out of proportion to the effects on the blood or internal organs. Similarly, uneven exposures of various parts of the body to penetrating radiation may alter the response and make dosage determination difficult if not impossible. A certain amount of non-uniformity is the rule, and it is a matter of judgment to determine the point at which it is no longer possible to rely implicitly on the dosimetry, or specific biological response. Some person should be responsible for keeping a very careful record of all pertinent events and the exact time at which they occurred. It would be reasonable to assume that at large nuclear installations at which both individual and other monitoring systems are used, estimates of dose could de made with a precision of ± 25 per cent within one to three hours of exposure, unless the exposure is grossly non-uniform.

Dosimetric studies have a variety of objects – medical, legal, administrative and scientific – and though these are not necessarily in conflict, the purpose must be borne clearly in mind. K.P. Duncan and H.J. Dunster (UK) distinguished three distinct phases in the main objective, which is individual patient care. The first phase is to decide whether further treatment or observation is needed; speed in dosimetry is required here, but not great accuracy. The second is to decide whether the individual should be transferred to some special centre or hospital, or not; the third phase –

Pocket processing apparatus for monobath film. (Photo: F. Wachsmann)

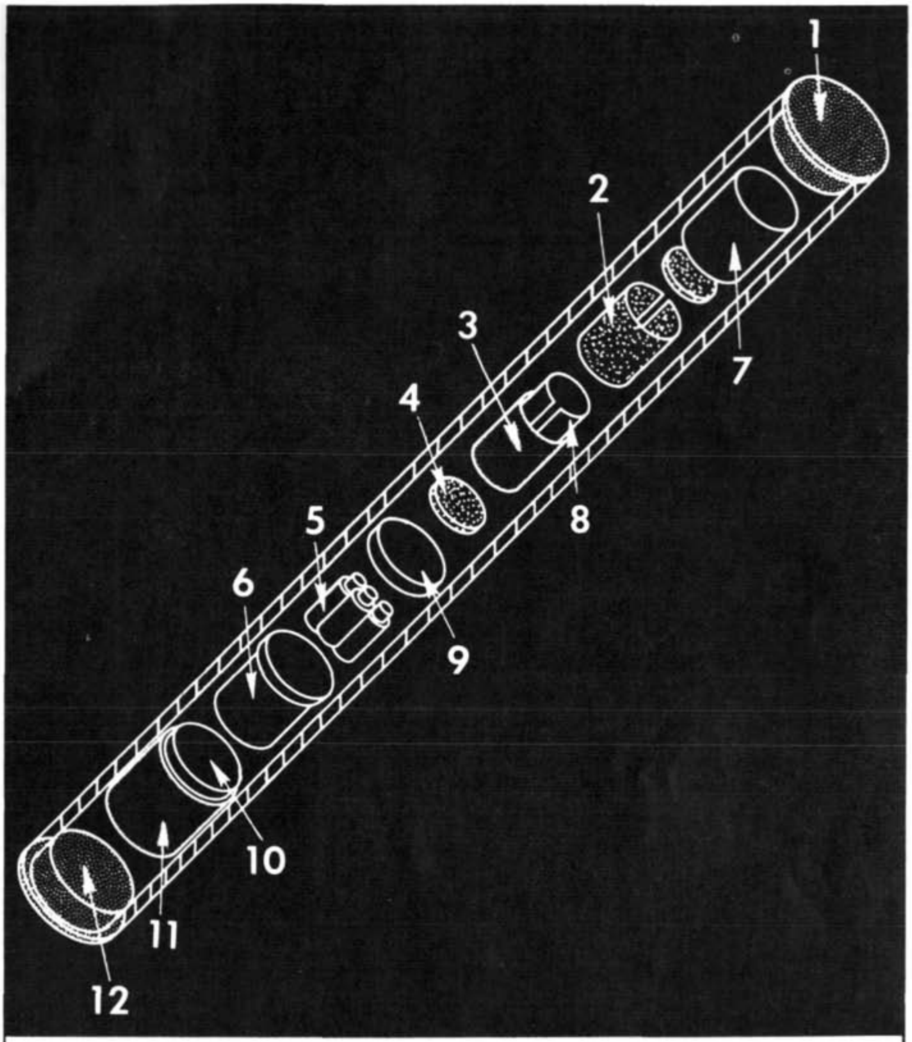


treatment — calls for decisions which will be based more on observation of the patient than on dosimetry. After this, other considerations may arise when decisions have to be taken about appropriate future employment for the individual ; these decisions are likely to be influenced by legal or administrative considerations, and it is of critical importance to separate the biological implications of a dose of radiation from other factors. Because national codes and regulations must be based on clear definitions, such as provisions enunciated by the International Commission on Radiological Protection, these tend to be converted into rigid rules. Therefore, while a degree of error in the dosimetry might be totally acceptable in assessing biological effects, it might not be acceptable from the legal standpoint. The numerical precision appropriate for administrative, medico-legal or scientific reasons should not be allowed to govern fundamentally human decisions.

Since the establishment of nuclear technology in the United States, there have been 25 nuclear criticality accidents, 12 of which resulted in significant personal radiation exposures. E.J. Vallario (USA) described the system planned to provide a direct and rapid assessment of absorbed dose in such cases. He also recognized that the reasons for needing the estimates are varied, and may not all require information in the same form nor with the same accuracy. It is necessary to use both fixed and individual dosimeters in a combination system. Dosimeters at fixed points in the working area can in principle provide a map of the dose field, but to rely on this exclusively would make it necessary to know the exact position of the persons involved at the time of exposure. The response of small individual dosimeters depends markedly on the direction from which the radiation has come, unless corrections have been applied for the shielding effect of the wearer's body. This correction can be made for gamma radiation, but not as yet for neutron exposure. G. Ganouna-Cohen, Fitoussie et al. (France) described a pocket dosimeter designed to give audible warning when the exposure reaches a certain level. In places where the radiation level is high, or threatens to become high, it is not always possible to maintain a close check on the dose received by personnel. Direct-reading personal dosimeters can be carried, but it is not easy to consult these when protective clothing is being worn, or under serious conditions of emergency where the radiation level cannot be foreseen. Pocket alarm dosimeters to meet this need should be light and self-contained ; they should be capable of being pre-set over a very wide range of absorbed dose ; they must be simple to operate and certain in use. The authors of the paper described possible designs for such dosimeters, which are intended as alarm devices rather than measuring apparatus.

ACTIVATION OF HAIR AND METALS

There was considerable discussion of the uses and limitations of film badges. J. Trousil and I. Bučina (Czechoslovakia) pointed out that several methods have been developed for measuring a wide range of exposures and for reading doses rapidly and precisely. Although these methods are cheap and can be used in series, they are not attractive for laboratories measuring the individual exposures of many thousands of persons. The authors have therefore endeavoured to extend the range of photographic dosimetry towards



1. End Cap
2. Cadium Shield
3. Indium Foil
4. Cadmium Shield
5. Thermoluminescent Gamma Dosimeters
6. Vial No. 2 Sodium Fluoride
7. Vial No. 1
8. Copper Foil
9. Vial Cap
10. Vial No. 3 Sulfur
11. Unshielded Indium Foil
12. End Cap

The Savannah River Plant criticality dosimeter. (W.C. Reinig)

high levels without decreasing its sensitivity to small exposures, and to cover the entire range with only two films. This means that for measurement of accidental high-level exposure, the same film badges and all other equipment are used, and the same staff can handle them. F. Wachsmann (Federal Republic of Germany) described film which could be quickly and simply processed by a pocket processing device which is always ready for use. Film dosimetry is the most widespread method of personnel monitoring, but high-level exposure films cannot be sent to central institutes for evaluation, as are normal film badges – on the contrary, they must be evaluated on the spot, perhaps by untrained persons. A suitable film can be processed in only one bath, and the darkening is independent of the developing time within the limits of two to 20 minutes. By this method, one person can process and evaluate about 40 films in an hour without a darkroom.

In spite of recent improvements in photographic dosimetry, K. Becker (Federal Republic of Germany) considered phosphate glass to be superior to film as a cheap, compact integrating dosimeter in many respects. It has special advantages in cases of accidental exposure, since evaluation is made by a simple fluometric reading, and this can be done within a few seconds by an untrained person using a portable reading instrument. The dosimeter can be used again immediately after evaluation and the choice made between storing earlier exposures, or extinguishing the dose effect by heat treatment.

Techniques for measuring the neutron dose received, independently of physical dosimeters, were described in several papers. D.F. Petersen (USA) described methods based on the effect of neutrons in activating certain chemical elements – such as sulphur and sodium – so that small quantities of radioactive substances are produced. Although these are minute, they can be detected and measured with sufficient accurary to provide an estimate of the neutron dose. The sulphur content of human hair is remarkably constant, regardless of colour or anatomical distribution, and hair is readily available in sufficient quantities to permit prompt analysis after an exposure. In order to carry out controlled experiments, hair samples were placed in polyethylene envelopes, and appropriately positioned on a plastic mannequin filled with a tissue-equivalent solution, and these were then exposed to strong radiations. It was found possible, by subsequent analysis of the samples, not only to estimate total dose, but also the distribution of the radiation dose to different parts of the body. Similar methods were described by R.L. Lehman and O.M. Fekula (USA), who used human "phantoms" to test the behaviour of fast neutron radiation as it penetrated the human body; this knowledge is important in evaluating the internal radiation doses received by persons exposed to neutrons emitted from nuclear fission. Pieces of nuclear emulsion films were placed in various positions inside and around the phantoms, which were arranged 10 to 200 metres from an unshielded pulsed reactor. In the discussion, R. Cowper (Canada) remarked that speakers had commented on the difficulties of obtaining hair samples in order to find the distribution of neutron intensities over the body. It should be a simple matter, he said, to arrange for the incorporation of suitable elements in laboratory clothing to provide a more precise way of obtaining essential data.

The shielding effect produced by the body of the wearer coming between his individual dosimeter and the source of radiation is corrected by a computer calculation, in a system described by C.N. Wright, J.E. Hoy and W.C. Reinig (USA). A small lightweight dosimeter to measure neutron and gamma exposures has been designed, with a unit cost of about $15; low cost was an objective because several hundred units were needed. It contains indium, copper, sodium, sulphur, and other substances which become radioactive after exposure to neutron radiation of varying degrees of intensity. Immediately after a nuclear accident dosimeters and film badges are collected from workers in the vicinity, the activities of the materials within the dosimeter are measured, and the results are calculated by means of the computer. This system can evaluate doses received by up to 20 workers within six hours of exposure, and can provide a preliminary estimate within one hour. The same principle of neutron activation of metal foils or discs is used in a dosimeter described by M. Bricka and J. Geroy (France). The advantages of such detectors for neutron flux measurement are that they do not react to other forms of radiation such as gamma rays, need no connections or maintenance, and provide correct integration of the dose.

DOSIMETRY IN PRACTICE

Hitherto unreported events, and the lessons derived from a criticality accident involving 22 employees, were described by H.M. Parker and C.E. Newton (USA). The accident occurred at Hanford, USA, in 1962, in a plutonium waste recovery plant. The alarms sounded and the building was promptly evacuated, and the employees concerned were "quick-sorted" and contamination surveys made and dosimeters collected. At the time, the radiation protection personnel had limited confidence in the estimates of dose derived from the "quick-sort" measurements, because the procedure had never before been tested in practice, the estimated doses were much lower than one would have expected, based on the reported distances from the source of radiation, and an error of unknown magnitude might have been introduced by the difference between the radiation intensity used for calibrating dosimeters, and that to which the employees were actually exposed. However, in retrospect, it was found that the procedure gave what proved to be rapid and sufficiently valid estimates of the neutron radiation dose. The preliminary measurements were followed by other and more refined measurements – analysis of blood samples and of hair, whole-body counting, etc. Neutron activation analysis was carried out on materials from personal effects carried by the people exposed such as aluminium, copper and gold from coins, jewellery, belt buckles, pens and wrist watches; this, however, was merely supplementary action, main reliance being placed on the dosimeters.

The emergency dosimetry system at Hanford, designed to cope with any serious radiation accident, was described in detail by H.W. Larson and A.R. Keene (USA). Production and test reactors, fuel fabrication and chemical separation plants, and research laboratories, all contain many and varied sources of radiation. Persons working at the plant are trained to respond to alarms and to follow correct evacuation routes. They must report to prearranged staging areas where all must be accounted for, and they are quickly checked to identify any who may have received excessive radiation doses.

In the case of a serious accident, a radiological emergency staff is summoned at an emergency control centre. Primary reliance for dose evaluations is placed on the Hanford personal dosimeter and analysis of blood, etc. The Hanford dosimeter contains film and glass to measure beta, gamma and X-ray exposure, metal foils which react to neutron radiation, and a photograph of the wearer to ensure that he is wearing the correct dosimeter. Thus, the dosimeter which is worn as a matter of daily routine is also capable of registering an accidental high-level exposure. To identify a film positively with the wearer when it is being processed, the film is perforated with the wearer's identification number. A set of calibration films which have been exposed to various gamma ray levels is continuously maintained, and these are processed with the dosimeter film. These calibration films eliminate variables in film processing such as developing time and solution strength, and save time by allowing the film to be read while it is still wet.

Although the symposium brought to light many differences of detail in the procedure and equipment used in different centres, there was complete agreement on the main lines of approach. A number of speakers considered, however, that further investigation and research was desirable in order to arrive at the best possible system.

THE IAEA AS A PUBLISHER

One of the largest publishing enterprises in Vienna has developed in the Agency, incidental to its function of disseminating scientific information. The Agency recently completed its sixth year of scientific publication of literature dealing with the peaceful uses of atomic energy.

Quite early in the history of IAEA, this work grew to considerable dimensions. In 1959 the programme consisted of two volumes in the Proceedings series, one in the Safety series, and four Technical Directories, making a total in that year of 18 000 books, in addition to those prepared for free distribution. In the following year, as Agency meetings and other activities developed, the list was much longer consisting of six volumes in the Proceedings series, two in the Safety series, two in the Technical Directory series, eight in the Review series, two in the Bibliographical series, three panel reports, one volume in the legal series and the first issue of "Nuclear Fusion". The total number of volumes sold was 24 000, in addition to the large number for free distribution. Thereafter, there was some difficulty in keeping up with the expanding demands, and some arrears of contract printing began to accumulate. It was therefore decided to introduce internal printing