Code of practice for the protection of persons against ionizing radiations arising from medical and dental use.

Department of Education and Science
Ministry of Health
Scottish Home and Health Department
Ministry of Health and Local Government for Northern Ireland

Code of Practice for the Protection of Persons against Ionising Radiations arising from Medical and Dental Use

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1964

Preface

This Code is a revision of the previous Code prepared by the Standing Advisory Committee set up to advise Ministers under the Radioactive Substances Act, 1948. The previous Code, which was published in 1957, was intended primarily for the protection of staff exposed to ionising radiations in National Health Service Hospitals.

This revised Code applies to the use of ionising radiations arising from all forms of medical and dental practice and from allied research in hospitals. Where research procedures in hospitals are not covered by the present Code reference should be made to the Code of Practice for the Protection of Persons exposed to Ionising Radiations in Research and Teaching, which has been designed to harmonise with it. The present Code includes aspects not previously dealt with, such as radiation hazards to patients and disposal of radioactive waste.

Although the arrangements recommended relate primarily to institutions they should be applied, as far as practicable, by all medical and dental practitioners.

As before, the policy pursued by the Committee has been to set out the basic principles of radiation control and to give general guidance on good practice.

The Code has been drawn up in the light of the recommendations of the International Commission on Radiological Protection and of the views of the Medical Research Council's Committee on Protection against Ionising Radiations.

Technical information which will assist in the implementation of this Code is being prepared for a separate Handbook of Radiological Data.

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APPENDICES

NOTE

In this Code the word " must " indicates an essential requirement, the word " should " a desirable requirement. Specialised terms are defined in Appendix M.

1. Scope of the Code

1.1. *Establishments*

1.1.1. This Code applies to the use of ionising radiations arising from medical and dental practice. It does not deal with the use of ionising radiations in Medical Schools and Colleges or in Medical Research Council Units, since these are covered by the Code of Practice for the Protection of Persons exposed to Ionising Radiations in Research and Teaching.

1.2. *Persons*

1.2.1. The Code applies to all persons who are exposed to ionising radiations arising from medical and dental practice. For the purposes of the Code they are divided into the following categories.

(i) Designated persons*. These are members of the staff, including temporary or visiting staff, whose work involves exposure to ionising radiations to such an extent that the maximum permissible doses recommended for occupational exposure apply. There are two classes of designated persons, namely, those who are between the ages of 16 and 18 years and those who are 18 years of age or more. While each class will be subjected to medical examinations and personnel monitoring tests (see Sections 2.2 and 2.3), the distinction is that different levels of maximum permissible doses will apply (Appendix B).

(ii) Other staff. Students not on the staff but who may be working in the hospital are included in this category.

*Certain other codes use the terms " occupationally exposed persons ", " classified workers " or " radiation workers " for similar classes of persons.

(iii) Patients. These include both those undergoing examination or treatment by ionising radiations and those who, by their proximity to such patients, are indirectly subjected to radiation.

(iv) Persons not included in (i), (ii) or (iii) above.

(For maximum permissible doses see Appendix B.)

1.3. *Hazards*

1.3.1. The provisions of this Code relate to hazards arising from

(i) any radioactive substances, whether sealed or unsealed and

(ii) any machines or apparatus which emit ionising radiations, including such apparatus in which charged particles are accelerated by a voltage of not less than five kilovolts.

2. General Measures for Radiological Protection

2.1. *Responsibility for radiological safety arrangements*

Allocation of responsibility

2.1.1. The ultimate responsibility for protection measures in hospitals lies with the Controlling Authority*. To assist in the discharge of this duty the Controlling Authority must set up a Radiological Safety Committee; one Radiological Safety Committee may be nominated for several hospitals. The Committee must consider the reports of the Radiological Protection Advisers, must inform controlling authorities of the state of protection arrangements and, where any specific problems arise, must advise the controlling authorities on any further measures which may appear necessary to protect patients, staff and the general public.

2.1.2. In every department where there is radiological equipment, the responsibility for ensuring that the Code of Practice is observed must lie with the head of the

* See Appendix M

radiological services, in collaboration with the radiological safety organisation of the institution. This responsibility extends to the use of X-ray equipment in his charge outside the radiological department. Where radioactive substances are applied to patients, e.g. in wards and operating theatres, radiological safety measures are the responsibility of the clinician in charge of the patient, in collaboration with the radiological safety organisation of the institution.

Radiological Protection Adviser

2.1.3. Each Controlling Authority must appoint an appropriately qualified and experienced physicist to act as Radiological Protection Adviser. He should regularly visit the hospitals and departments to which he has been nominated, to review, in consultation with the heads of departments, the protection measures laid down.

Radiological Safety Officer

2.1.4. In every department in which radiological equipment is used, a competent person, who must be selected from among the full-time employees of the institution concerned, must be appointed as Radiological Safety Officer to ensure that the protection measures laid down for each department are carried out.

Supervisory Medical Officer

2.1.5. Each Controlling Authority must appoint a Supervisory Medical Officer who will be responsible for the medical supervision of the staff concerned in the hospitals under its administrative control. Such staff will include

(i) all persons who are designated persons or potential designated persons and

(ii) other staff who may have been significantly irradiated as a result of accidental exposure to ionising radiations.

Type of administrative organisation

2.1.6. An example of the administrative organisation suitable in National Health Service Hospitals is shown in Appendix A.

2.1.7. Each Radiological Safety Officer must make regular reports to the Radiological Protection Adviser giving details of the doses received by the designated

persons. Additionally he must make special reports when circumstances warrant this course. The Adviser must inform the Controlling Authority, the Radiological Safety Committee, and the Head of Department or clinician concerned, of any report which indicates unsatisfactory conditions and must set out the measures to be adopted to remedy them. The Controlling Authority, in consultation with the Radiological Safety Committee, the Head of the Department or the clinician concerned, must decide whether any action, including the suspension of operations, shall be taken.

Designation of staff

2.1.8. The Controlling Authority must determine, in respect of all persons coming within the scope of the Code (See Section 1.2.1.), whether or not they shall be identified as "designated persons" as specified in Section 2.1.9. Persons other than those covered by Section 2.1.9. may be designated in exceptional circumstances, but the number of designated persons should be kept to the minimum. The Controlling Authority should ensure that the designation of a person is kept under review.

2.1.9. All persons employed in

(i) work associated with sealed or unsealed radioactive substances or machines or apparatus emitting ionising radiations or immediately ancillary work or

(ii) the cleaning of active areas or the cleaning of plant, apparatus, equipment, materials or articles which are contaminated or are liable to have been contaminated

must be identified as "designated persons" unless the Controlling Authority is satisfied, on the advice of the Radiological Safety Committee, that the operating and working conditions and the system of control and instruction are such that the radiation doses received will not exceed those set out for "other staff" (see

Section 1.2 and Appendix B) and that there is adequate protection against contamination from any unsealed radioactive substances.

Instruction

2.1.10. Each Controlling Authority must ensure that all members of the staff liable to be exposed to ionising radiations during the course of their occupation are adequately instructed about the hazards they may meet and about the precautions to be observed. In hospitals, controlling authorities should be advised in this respect by the Radiological Safety Committee. All authorised visitors to areas in which ionising radiations are present should be informed, as necessary, of the precautions to be observed.

Local rules

2.1.11. Each Controlling Authority must arrange for local rules, consistent with the principles of this Code, to be drawn up in consultation with the Radiological Safety Committee. The rules must set out clearly and precisely the procedure in force in each establishment and the names and duties of the persons such as the Supervisory Medical Officer and the Radiological Safety Officer who are allocated responsibilities for health and safety. Any such person must be given a clear written statement of his duties.

Responsibility of individuals

2.1.12. It must be impressed on every individual designated person that he has a duty to protect himself and others from any hazard arising from his work.

2.1.13. Every member of the staff to whom this Code applies should be required to read the sections which affect his work and well-being and the local rules. He must sign a statement that he has understood the sections and rules.

2.2. *Medical examinations*

Purposes

2.2.1. The main purposes of medical examinations are

(i) to assess the fitness on medical grounds of a person to perform his duties without danger to himself or to others;

(ii) to establish a record of the condition of the individual to serve as a base-line against which any subsequent change can be evaluated; and

(iii) to assess continuing fitness and to detect any deterioration in health.

2.2.2. As respects any medical examination, the Supervisory Medical Officer may at his discretion require a " full blood examination " or any other special examination (including X-ray examination, ophthalmological examination and examinations of the skin and nails).

2.2.3. A " full blood examination " should either consist of or include

(i) in the case of red blood cells, a measurement of the packed cell volume;

(ii) in the case of white blood cells an estimate of the number present per cubic millimetre of whole blood;

(iii) a differential white cell count;

(iv) a search for abnormal cells and a description of any seen; and

(v) an estimation of the haemoglobin in grammes per one hundred millilitres of whole blood.

Preliminary examinations

2.2.4. A person must not be employed as a designated person unless within the period of four months immediately preceding first employment as a designated person he has been subjected to a general medical examination including a " full blood examination ". (The expression " first employment " means first employment as a designated person, and also re-employment as such following any cessation of such employment for a period of 12 months or more).

Annual re-examination

2.2.5. Every designated person should be re-examined annually to check continued fitness for such work, unless it is clear from personnel monitoring that he is consistently receiving no more than the maximum permissible dose levels for other staff (see Section 1.2.).

Over-exposure of persons

2.2.6. Where there is reason to think that any person (whether designated or not)

(i) has received an external radiation dose in excess of the maximum levels permitted for him as in Appendix B or

(ii) has contaminated any part of his body to a level exceeding ten times the permitted level shown in Appendix D and such contamination has persisted for more than three days or

(iii) has ingested, inhaled or otherwise absorbed a significant amount of any radioactive substance,

an investigation must be made.

2.2.7. The Supervisory Medical Officer should decide whether or not

(i) to carry out a medical examination of that person, or such other investigation as may be indicated;

(ii) to arrange remedial treatment; and

(iii) to make recommendations on the amount of subsequent exposure of a person as a designated person or on suspension of a person from employment as a designated person. (If the dose received as a result of over-exposure exceeds that permitted in a calendar quarter (see Appendix B) the person must be suspended for at least the remainder of the quarter from employment as a designated worker. If the sum of the dose from over-exposure and the total occupational dose received up to the time of the accident exceeds that permitted in the light of the person's age, the excess must be redressed by lowering the subsequent exposure rate so that within a period not exceeding 5 years the accumulated dose will conform with the limit set by the person's age.)

Where necessary, a special entry approved by the Controlling Authority must be made in the radiation dose record kept in accordance with Section 2.3.6. In the case of a person who is not designated a radiation dose record must be specially created for this purpose.

Suspension from work as a designated person

2.2.8. When the Supervisory Medical Officer so recommends in writing, a person must be suspended from his work as a designated person and not allowed to resume such work until the Controlling Authority is satisfied that he may do so. He may however carry out duties incurring radiation exposure not exceeding that permitted for " other staff ".

Records of medical examinations

2.2.9. To enable the health of designated persons to be kept under progressive review, the Controlling Authority must arrange for records to be kept of all medical examinations including blood examinations and such other investigation as is necessary. These records must be retained for 30 years after the last entry.

2.3. *Personnel monitoring*

External radiations

2.3.1. The dose of ionising radiations from external sources received by a designated person must be systematically checked. Normally it is sufficient if the person wears a film badge (comprising a suitable photographic film in an appropriate holder) on an appropriate part or parts of his body, during the whole time he is liable to be exposed to ionising radiations. A single test with a film badge should not normally extend beyond four weeks. In some circumstances it may be necessary for the person to wear, in addition to a film badge, some other radiation measuring device, such as a pocket ionisation chamber, in order to obtain intermediate readings of the dose received. Radiations such as low energy beta rays which cannot easily be measured by film badges should be checked by site monitoring or other procedures.

2.3.2. The film badge, or other device if used, will normally be worn on the trunk at chest or waist level but in some circumstances it will be desirable in addition, to measure the dose to other parts of the body (e.g. to the fingers by means of ring film badges) so as to ascertain that the relevant maximum permissible doses are not exceeded.

2.3.3. In some cases it may be necessary for other staff, who in the course of their duties only occasionally enter

areas normally occupied by designated persons, to wear film badges during their occupancy of such areas so as to ascertain the doses received.

Internal radiations

2.3.4. The doses received from internal radiations arising from the intake of radioactive materials into the body, by inhalation or ingestion, by absorption through the skin or by entry through wounds, must be evaluated, where necessary, by appropriate physical or chemical methods which enable the body burden of radioactive materials to be estimated.

Contamination of the skin, hair and clothing

2.3.5. In addition to personnel monitoring of external radiation by film badges or other measuring devices, where appropriate, the levels of contamination of the skin, hair and clothing must be checked regularly to ensure that any excess contamination is detected without delay.

Records of personal radiation doses

2.3.6. A separate radiation dose record must be maintained by the Radiological Safety Officer for each designated person. It should show any dose received as a result of previous work with ionising radiations and the doses received in each calendar quarter together with the cumulative dose. When it is possible to estimate the doses received from any radioactive substances deposited within the body, these should be noted, if significant.

2.3.7. The radiation dose record provides a continuous check on the extent of the radiation doses received and acts as a useful pointer to the efficacy of the safety measures in force. It must be available for inspection by the Supervisory Medical Officer, the Radiological Protection Adviser, the Head of the Department and the individual concerned.

2.3.8. A summary of the radiation dose record (known as a " transfer record ") must be handed to each designated person when he finally leaves the establishment so that he can produce it on taking up work involving exposure to ionising radiations elsewhere. A specimen form of transfer record is shown in Appendix E.

2.3.9. When the Controlling Authority is aware that a designated person has worked elsewhere with ionising radiations it must obtain a transfer record for him.

2.3.10. The radiation dose records and the transfer records relating to previous exposure must be retained for a period of 30 years after the last entry as they may be of considerable value in considering long-term effects of radiation on the individual.

2.3.11. A separate record retained for two years should be kept of cases of contamination of skin, hair and clothing, which cannot be reduced by first-aid measures to a level below that given in Appendix D and should be attached to the medical record. The record should indicate the cause of the contamination, the action taken to deal with it and the length of time during which the excess contamination lasted.

2.4. *Environmental monitoring*

Radiation surveys

2.4.1. The working environment should be surveyed at regular intervals to determine

(i) the levels of external radiation;

(ii) the levels of radioactive contamination of the surfaces in wards, operating theatres, clinics and laboratories where unsealed sources are used and of the surfaces of personal protective equipment; and

(iii) the concentration of radioactive substances in the air of laboratories and clinics either where volatile substances are in use or in exceptional cases as advised by the Radiological Protection Adviser. (See Section 5.6.8. (iv).)

2.4.2. A radiation survey of any new or modified department must be made under the guidance of the Radiological Protection Adviser. It should be appreciated, however, that for work with unsealed radioactive materials, protection is as much a matter of procedure as of design. (A " modified department " means one in

which the radiation output of radiological equipment or of sealed sources or the amounts and/or types of unsealed radioactive materials have been so increased or the positions of the radiation sources have been so changed or the techniques so " modified ", that the original protection may no longer be adequate).

2.4.3. If a radiation survey indicates that persons may, under normal working conditions, receive doses in excess of the maximum permissible levels, the Radiological Protection Adviser should indicate the measures to be adopted to rectify the situation. The installation involved should not be used until the protection is satisfactory.

2.4.4. A radiation survey should also be carried out if personnel tests indicate that the doses received by designated persons exceed or are likely to exceed the maximum permissible levels and if enquiries have failed to reveal the cause. When the cause has been determined (e.g. defective equipment, inadequate protection afforded by screens and walls, wrong technique or insufficient staff), the Radiological Protection Adviser should indicate the measures to be adopted to rectify the situation. Appropriate action must then be taken to reduce the hazard.

Limitation of exposure

2.4.5. Every effort must be made to keep exposure to the lowest practicable level. Persons should not be exposed to ionising radiations to a greater extent than is necessary. Designated persons and other staff should not, in any case, be intentionally subjected to any radiation doses in excess of those laid down in Appendix B.

2.4.6. The Controlling Authority must supervise carefully the conditions of work of persons under the age of 18 years. Persons under 16 years must not in any circumstances be allowed to engage in work which would require them to be designated persons, and designated persons between 16 and 18 are subject to the specially restricted doses given in Appendix B.

2.5. *Planning of radiological departments*

2.5.1. During the planning of a new radiological department or modifying an existing one, authoritative advice* should be obtained about the suitability of the location, design and construction of the premises and equipment, and about the arrangements for the storage of radioactive substances and for the disposal of radioactive waste. (A " modified department " is defined in Section 2.4.2.).

2.5.2. In the planning of a new radiation installation, account should be taken of the expected work-load of any equipment, the use factors of the barriers, and the occupancy factors of the adjacent areas. Allowance should be made for possible future increases in these factors, for changes in the outputs or positions of radioactive sources, and for future modifications in technique.

3. Diagnostic Uses of X-Rays

(including Mass Miniature Radiography, Dental Radiography and the use of Mobile and Portable Apparatus)

3.1. *Principles*

3.1.1. Protection arrangements in diagnostic radiology should be based on the principles

(i) that the exposure of the patient during X-ray examination must be no greater than is absolutely necessary to produce a satisfactory result;

(ii) that all provision for absorbing primary and secondary radiation should be as close as possible to the apparatus or patient; and

(iii) that X-rays be used only when there is adequate protection of all persons in all surrounding areas.

*Advice may be obtained from the Radiological Protection Service.

3.2. *Protection of patients*

3.2.1. Attention is drawn to Section 6 of this Code and to the recommendations of the Second Report of the Committee on Radiological Hazards to Patients reproduced as Appendix H. (See also Sections 3.4.10., 3.6.1., 3.6.2., and 3.6.3.)

3.3. *Structural aspects*

3.3.1. To afford adequate protection to persons working in X-ray rooms, the following measures are required.

(i) All X-ray rooms must have adequate working space and also sufficient space to provide safe accommodation for all persons who are in the room.

(ii) Protective cubicles must be provided for personnel at all control tables. Where complete protection from secondary radiation cannot be provided by protective screens, all exposed must wear protective aprons and stand as far away as possible from the radiation source. This is important in certain elaborate investigations such as cardiological procedures where there may be a staff of ten or twelve and a number of students in the room.

(iii) An X-ray room should not be used for more than one radiological procedure at a time.

(iv) X-ray rooms must be marked with a symbol to indicate ionising radiations. (See Appendix F.)

3.3.2. Adequate protection must be provided for persons in all occupied areas adjacent to X-ray rooms. This can be done most efficiently and economically by

(i) wherever practicable, pointing the useful beam away from adjacent occupied areas;

(ii) absorbing the useful beam and scattered radiation as close as possible to the film or fluorescent screen and patient;

(iii) where necessary, applying protection to the floor, ceiling and walls, including windows and doors*; and

(iv) having no unnecessary openings from the X-ray room and limiting the size of those necessary.

3.4. *General procedures*

3.4.1. In hospitals all X-ray examinations, except mass miniature radiography and dental radiography, should preferably be carried out in the main radiological department, unless the condition of the patient makes it advisable for the examination to be carried out in a ward or in an operating theatre where proper facilities exist. Access doors to all radiological departments should be wide enough to allow beds from the wards to pass through and equipment should be so arranged that the patients are subjected to the minimum degree of disturbance.

3.4.2. Only those persons whose presence is essential should remain in an X-ray room when radiological examinations are being carried out.

3.4.3. The operator must stand as far as practicable from the useful beam and must not be exposed to it unless it is attenuated so as to reduce the radiation to within acceptable limits.

3.4.4. Whenever possible, staff should remain behind protective screens during all types of radiographic or fluoroscopic examinations. If this cannot be done, protective clothing must be worn.

3.4.5. Support for sick children or weak or anaesthetised patients is sometimes needed in wards and X-ray departments. This is a hazardous practice but cannot always be avoided. One person should not regularly perform this duty. Persons supporting a patient who is being X-rayed or holding films must wear a protective apron and gloves

*The necessary protection can be assessed from data given in the Handbook of Radiological Data.

and should be provided with a film badge or pocket dosemeter for the occasion. A record of each incident when anyone assists in this way must be sent to the Radiological Safety Officer who should keep some note of exceptional exposures of this nature.

3.4.6. The X-ray examination of young children offers exceptional difficulties and special devices exist to restrict movement and to protect the child's gonads and should always be employed. Child patients should, if possible, be held only by their parents or other accompanying adults, who must wear suitable protective clothing and (if possible) be so positioned as to avoid the useful beam.

3.4.7. Radiographers should ensure that patients, staff and escorts are properly instructed before X-ray examinations are made.

3.4.8. It is particularly important with children that the field should always be restricted to the essential area and should always be smaller than the film size.

3.4.9. Diagnostic X-ray tubes should be kept as far away from the patient as possible. Careless methods with wide open diaphragms often lead to increased and significant scattered radiation. The intelligent use of cones and collimators recommended in this Code should largely eliminate one of the major sources of increased radiation.

3.4.10. To avoid accidental over-exposure of patients, it is imperative that there should be a rigid drill in operating apparatus and that each member of the staff should be aware of the drill and of the measure of his responsibility. The drill must include the checking, by the person responsible for operating the machine, of the operating conditions on each occasion before an examination is made.

3.4.11. See also Section 6 on the " Protection of the Patient ".

3.5. *Radiographic procedures*

3.5.1. The X-ray exposure should be controllable from the control panel only, except in the case of special techniques when it is necessary to control the exposure from the couch or stand. In such special techniques it may be necessary for the staff to wear protective clothing as specified in Section 3.17.

3.5.2. The operator should always have a clear view of the patient through the window of the control cubicle.

3.6. *Fluoroscopic procedures*

3.6.1. The dose from fluoroscopic examination is relatively very high. The clinical indications for fluoroscopy are becoming less frequent and this method should only be used when they are clear and when an equivalent result cannot be obtained from radiography alone.

3.6.2. All fluoroscopic examinations should be conducted as rapidly as possible with minimum dose-rates and apertures. (See also Section 3.13.3.) Ordinarily the factors used should be of the order of 75 kV and 2 to 3 mA. There must be adequate dark adaptation so that there should be no need to exceed either 100 kV or 4 mA. Dark adaptation will take not less than 10 minutes.

3.6.3. Where possible image intensification should be used in order to reduce the dose received by the patient.

3.6.4. A radiographer who stands near the radiologist during vertical screening operations should ensure that he takes up a position in such a way that he is protected by the lead glass of the screen and by the aprons suspended from it, and is not directly exposed to scattered radiation from the patient.

3.6.5. During fluoroscopy, palpation with the hand should be reduced to a minimum.

3.7. *Mass radiographic procedures*

3.7.1. In order to minimise any radiation hazard to the general public, there must be arrangements to protect persons awaiting examinations.

3.7.2. In mobile units for mass radiography, the tube must be so positioned that the irradiation of persons in the vicinity is at the lowest practicable level.

3.8. *Dental radiographic procedures*

3.8.1. Wherever possible the dental film should be fixed in position; otherwise it should be held by the patient or, exceptionally, by a person who is not a designated person. (See Section 1.2.1.) It should never be held by the dentist or his staff.

3.8.2. The tube housing should not be held by hand during exposure.

3.9. *Dental fluoroscopic procedures*

3.9.1. The results obtained by intra-oral fluoroscopy do not justify its use.

3.10. *Procedures with mobile and portable equipment*

3.10.1 The procedures already enumerated apply equally to mobile and portable equipment.

3.10.2. When mobile or portable apparatus is used, it is especially important that the operator makes certain that no part of his body is exposed to the useful beam and that the beam does not irradiate other persons in the vicinity of the patient.

3.11. *Equipment: general requirements*

3.11.1. A diagnostic-type tube housing (see Appendix G) must be used.

3.11.2. The permanent total tube filtration, including inherent filtration, should be equivalent to 1 to 2 mm aluminium.

3.11.3. Tube apertures should be permanently limited to permit the emission of a beam of no larger cross-section than the maximum required in practice for that particular tube. Such permanent limitation should be applied close to the tube.

3.11.4. Apertures, cones or diaphragms which serve to limit the useful beam should, as far as is practicable, afford the same degree of protection as the tube housing.

3.11.5. Image intensifiers are essential in certain special procedures such as cardiac catheterisation and cine-radiography. (See Section 3.6.3.) They should afford protection equivalent to at least 2 mm lead for 100 kV. From 100 to 150 kV an additional lead equivalent of 0·01 mm per kV is required.

3.11.6. A visible signal must be provided to indicate that the tube is excited.

3.11.7. Any persons concerned must inform the radiographer in charge (in writing) on every occasion when they have carried out any modification to, or maintenance of, any apparatus which might alter the output or quality of the radiation or the protection of the tube, and they must enter the details in a Record Book kept for that purpose. An appropriate visible notification of such modification or maintenance should be attached to the apparatus.

3.12. *Radiographic equipment*

3.12.1. All X-ray apparatus must be equipped with adjustable beam-limiting devices or cones to keep the useful beam within the limits of the X-ray film selected for each examination. (See also Section 3.11.3 and 3.11.4.) The film selected should be as small as possible consistent with a good result.

3.12.2. The fastest film or film-intensifying screen combination consistent with the desired radiographic objective should be used.

3.13. *Fluoroscopic equipment*

3.13.1. All couches and stands which are used for fluoroscopy must be provided with an adequate arrangement for protecting the operator against scattered radiation from the patient. This may take the form of an " apron " which should be not less than 45 cm wide and

45 cm long and should be made of protective material, having a lead equivalent of not less than 0·5 mm. It should be attached to the lower edge of the screen holder when the latter is vertical and to the side when the screen is horizontal. In addition, separate protective aprons or fixed shields should be attached to the edges of both sides of the couch or screening stand when the screen is horizontal and, if practicable, also when it is vertical. The beam limiting device should extend as close as is possible to the back of the couch or stand.

3.13.2. Cumulative timing devices are recommended which indicate the total time of irradiation or give an audible warning when a preset value has been reached.

3.13.3. The circuit on the primary side of the equipment used for fluoroscopy should incorporate a limiting device to guard against excessive tube currents during screening examinations.

3.13.4. The protective enclosure of the X-ray tube used for fluoroscopic examinations should be provided with an adjustable diaphragm system of such a design as will permit it to be completely closed. To prevent the lateral escape of radiation, the diaphragm system should be fitted within a protective enclosure. The material of the diaphragm should, as far as practicable, afford the same protection as the tube housing. The tube diaphragm and housing must be mounted in such a way that they will always move together.

3.13.5. The tube aperture must be limited, preferably by automatic means, so that the useful beam is confined within the fluorescent area of the screen, whatever the distance of the tube from the screen.

3.13.6. The lead glass of the fluorescent screen must have a lead equivalent of

(i) 1·5 mm for apparatus capable of operating up to 75 kV;

(ii) 2·0 mm for apparatus capable of operating up to 100 kV; and

(iii) an additional 0·01 mm per kV above 100 kV.

3.13.7. Protection of 0·5 mm lead equivalent should be provided on foot switches.

3.14. *Mass radiographic equipment*

3.14.1. The useful beam should be restricted to the area of the fluorescent screen and the beam should also be limited to the minimum consistent with the clinical requirements. The use of a light-beam localiser is recommended.

3.14.2. The equipment must be so arranged and shielded that all staff associated with the procedure are adequately protected during routine use without the necessity for protective clothing.

3.14.3. The use of high-speed optical systems, which enable the dose to the patient to be reduced, is recommended.

3.15. *Dental radiographic equipment*

3.15.1. Localising cones must be employed with all dental equipment. Such cones must provide the maximum practicable focus-skin distance and the minimum practicable field size.

3.15.2. A timer must be provided to terminate the exposure after a preset time, or earlier at the discretion of the operator.

3.15.3. Installations operating up to 70 kV should be so arranged that the operator can remain at least 1 metre from the tube and patient; in the case of installations operating above 70 kV, the operator should be able to remain at least 1·5 metres away. Even under these conditions, protective screens having a lead equivalent of not less than 0·5 mm should be used for work-loads exceeding 30 mA min per week.

3.16. *Mobile and portable equipment*

3.16.1. The cable from the apparatus to the exposure switch should be at least 2 metres in length.

3.17. *Protective clothing*

3.17.1. Gloves must have a protective equivalent throughout both front and back (including fingers and wrist) of not less than 0·25 mm lead for X-rays excited at voltages up to 150 kV.

3.17.2. Body aprons must have a minimum lead equivalent of 0·25 mm for X-rays excited at voltages up to 150 kV.

3.17.3. Gloves and aprons should be examined visually at regular intervals to ensure that the protection afforded has not been impaired as a result of cracks in the material. The gloves should not be permanently covered with leather. A detachable cover of nylon or similar material is to be preferred, so that any cracks which might develop may be revealed.

3.17.4. Gloves and aprons should be examined radiographically at regular intervals in order to find out if any defects are present. (See British Standard 2606:1955.)

3.18. *Small departments without qualified radiographic staff*

3.18.1. In some hospitals, doctors or nurses who have no radiographic qualifications are obliged intermittently to make an X-ray examination. No person should be allowed to do this until he has received instruction in the precautions necessary for safe operation. Responsibility for ensuring that this instruction has been given lies with the radiologist in charge of the department.

4. Therapeutic Uses of X-Rays, Gamma Rays, Electrons, Neutrons and Small Sealed Radioactive Sources

4.1. *X-ray installations*

Equipment and housing

4.1.1. A therapeutic-type tube housing (see Appendix G) must be used.

4.1.2. Permanent diaphragms or cones used for collimating the useful beam must afford the same degree of

protection as the tube housing. Adjustable or removable beam-defining diaphragms or cones must be constructed so as to reduce the integral dose to the patient as much as practicable. They must not transmit more than 2 per cent of the useful beam.

4.1.3. Each accessible filter must be marked with its thickness and material. A filter indication system should be used which permits easy recognition, from the control panel, of the filtration.

4.1.4. Unless it is possible rapidly to bring the X-ray output to the prescribed value, the tube housing must be fitted with a shutter operated from the control panel and of lead equivalent not less than that of the tube housing. The position of the shutter must be indicated at the control panel.

4.1.5. For installations operating above 100 kV, interlocks must be provided so that when any door to the treatment room is opened the equipment will shut off automatically or the radiation level within the room will be reduced to an average of not more than 2 mr/h and a maximum of 10 mr/h at a focal distance of 1 metre and not more than 10 times these values at a distance of 5 cm from the surface of the tube housing. After such a shut-off it must be possible to restore the machine to full operation only from the control panel.

4.1.6. The equipment must be provided with an automatic timer, or integrating dosemeter, to terminate the treatment after a preset time or dose.

4.1.7. During treatment the dose-rate of the useful beam should be ascertained

(i) by means of a calibrated meter used at each treatment or

(ii) by reference to calibration charts which give the dose-rates at specified kilovoltages, tube currents, filters, sizes of applicators and focus-skin distances. (The charts should be frequently checked against a dosemeter.)

A transmission monitoring chamber in the useful beam is recommended for observing the constancy of the radiation.

4.1.8. A visible signal must be provided outside the treatment room to indicate that the tube is in operation.

4.1.9. The treatment room in which the X-ray tube is housed must be provided with adequate structural shielding. If the useful beam is directed away from areas occupied by personnel, intervening barriers may need to afford protection against leakage and scattered radiation only. Full protection must however be provided in all those directions in which the useful beam can be directed.

It is desirable that observation windows should be so located that they cannot be exposed to the useful beam. Observation windows must provide at least the same degree of protection as that required of the barriers in which they are located.

Treatment rooms must be marked with a symbol to indicate ionising radiations. (See Appendix F.)

4.1.10. Means must be provided for observing the patient and should be provided for oral communication with the patient from the control panel during treatment.

4.1.11. Installations for superficial therapy must comply with the general requirements of Section 4.1., except that interlocks may not be required at 100 kV or below. (See Section 4.1.15.)

4.1.12. To avoid accidental over-exposure of patients, it is imperative that there should be a rigid drill in operating apparatus and that each member of the staff should be aware of the drill and of the measure of his responsibility. The drill must include the checking by the person responsible for operating the machine of the operating conditions of the apparatus on each occasion before a treatment is given.

4.1.13. Any persons concerned must inform the radiographer in charge (in writing) on every occasion when

they have carried out any modification to, or maintenance of, apparatus which might alter the output or quality of the radiation or the protection of the tube, and they must enter the details in a Record Book kept for that purpose. An appropriate visible notification of such modification or maintenance should be attached to the apparatus.

Operating procedures

4.1.14. For installations operating at voltages above 100 kV the operator must always be outside the X-ray room during actual treatment.

4.1.15. For treatment at voltages below 100 kV it may be permissible for the operator and other essential persons to remain in the room, provided adequate protection is afforded by means of a screen or screens. Under these circumstances interlocks may not be required. Where short treatment distances are involved and the operating potential is 50 kV or less, the use by the operator and any other persons present of protective clothing having a lead equivalent of not less than 0.25 mm is generally adequate.

4.1.16. The operator must never stand in the useful beam. When the inherent filtration is low and the focus-window distance is short, special precautions must be taken to avoid accidental exposure to the useful beam, brief exposure to which may cause serious injury.

4.1.17. Only tubes which are intended to be used at 50 kV or less may be held by hand during treatment and this procedure must only be used when clinically necessary. Such tubes must be so protected that the maximum permissible doses to the hand and other parts of the body are not exceeded. Protective gloves and coats or aprons having a lead equivalent of not less than 0·25 mm (see Section 3.17) must be worn during this work.

Calibration

4.1.18. All X-ray generators used for therapeutic purposes should be calibrated at intervals of not more than 4 weeks by a competent physicist.

4.1.19. The measurements made at each calibration should be sufficient to ensure that the output dose-rate for all operational conditions can be estimated.

4.1.20. Where output dose-rates vary by more than 5 per cent between successive calibrations, it is recommended that the interval between calibrations be reduced to one week.

4.1.21. Near the control table of each generator a chart or charts should be provided showing dose-rates for all operational conditions, as indicated by the most recent calibration. All calibration dates should be shown on these charts and signed or initialled by the physicist or physicists responsible.

4.1.22. (i) Wherever practicable an ionisation monitor should be fitted into the tube housing to indicate the constancy of the X-ray output. If, at any time, this monitor shows an apparent variation of output of 5 per cent from normal, it should be reported immediately to the physicist responsible as it may indicate a fault in the apparatus.

(ii) Where a monitor is not fitted, the radiographer in charge should be provided with a simple dosemeter and instructed to make an output check under standard conditions. This check should be made at least once every day and any variations from normal of more than 5 per cent reported to the physicist responsible for the calibration.

(iii) Whenever adjustments have been made to the equipment, following breakdown or for any other reason, the physicist must re-calibrate the apparatus before it is used in the treatment of patients.

(iv) The use of one machine for treatments at different settings of radiation output and quality is best avoided.

4.1.23. Dosemeters used for calibrations should be checked against a recognised secondary standard meter

over the operating radiation quality range at intervals of not more than one year.

4.1.24. For details of more extensive calibration procedures, the Hospital Physicists' Association's Code of Practice for X-ray Measurements should be consulted.

4.2. *Gamma-ray beam units*

Equipment and housing

4.2.1. A teletherapy-type source housing (see Appendix G) must be used.

4.2.2. The use of standard source capsules is recommended.

4.2.3. Permanent diaphragms or cones used for collimating the useful beam must afford the same degree of protection as the source housing. Adjustable or removable beam defining diaphragms or cones shall be constructed so as to reduce the integral dose to the patient as much as practicable. They must not transmit more than 2 per cent of the useful beam.

4.2.4. A remotely operated beam control mechanism must be used which is capable of functioning in any orientation of the housing. The mechanism must be so constructed as to return the source automatically to the 'OFF' position both at the end of an exposure and in the case of any breakdown or interruption of the activating force. The source must stay in the 'OFF' position when the force is restored until the mechanism is operated from the control panel.

4.2.5. In addition to the beam control mechanism the apparatus should be so constructed that it can be turned off manually with a minimum risk of exposure.

4.2.6. Warning devices which plainly indicate whether the apparatus is 'ON' or 'OFF' must be provided at the source housing, on the control panel, and at the entrance to the treatment room.

4.2.7. Interlocks must be provided so that when any door to the treatment room is opened, the beam control

mechanism will return the source to the 'OFF' position. After such a shut-off, it must be possible to return the source to the 'ON' position only from the control panel.

4.2.8. The equipment must be provided with an automatic timer, or integrating dosemeter, to terminate the treatment after a preset time or dose.

4.2.9. The treatment room in which the source is housed must be provided with adequate structural shielding. If the useful beam is directed away from areas occupied by personnel, intervening barriers need afford protection against scattered radiation only. Full protection must, however, be provided in all those directions in which the useful beam can be directed.

It is desirable that observation windows should be so located that they cannot be exposed to the useful beam. Observation windows must provide at least the same degree of protection as that required of the barriers in which they are located.

Treatment rooms must be marked with a symbol to indicate ionising radiations. (See Appendix F.)

4.2.10. Means must be provided for observing the patient and should be provided for oral communication with the patient from the control panel during treatment.

4.2.11. The surface of the equipment housing the source capsule, particularly the beam aperture, must be tested periodically for leakage of radioactive material from the source capsule and a record kept of the result of all such tests. Should the test indicate the probable presence of free activity of more than 0·5 μc, the source capsule must be considered as leaking and arrangements must be made immediately for its repair. (See the Handbook of Radiological Data.)

Operating procedures

4.2.12. The operator must always be outside the room during treatment. At all other times the room should be occupied only for necessary purposes associated with the operation and maintenance of the installation.

4.3. *Electron beam units*

Equipment and housing

4.3.1. Normally an installation designed for the production of X-rays and satisfying the requirements of Section 4.1 will be satisfactorily protected when used for the production of an electron beam. The shielding of the treatment room in those directions in which the useful electron beam can be directed should, however, take into account the production of bremsstrahlung in the shield itself.

4.3.2. In an installation for the production of electron beams only, the tube housing should be designed to minimise the emission of bremsstrahlung. Dose-rates in the neighbourhood of the tube should conform to the requirements of a therapeutic-type tube housing. (See Appendix G.)

4.3.3. Unless it is possible rapidly to bring the electron output to the prescribed value, the tube housing must be fitted with a shutter, operated from the control panel, of lead equivalent not less than that of the tube housing. The position of the shutter must be indicated at the control panel.

4.3.4. Interlocks must be provided so that when any door to the treatment room is opened the equipment will shut off automatically or the radiation level within the room will be reduced to an average of not more than 2 mrad/h in air and a maximum of 10 mrad/h in air at a focal distance of 1 metre and not more than 10 times these values at a distance of 5 cm from the surface of the tube housing. After such a shut-off it must be possible to restore the machine to full operation only from the control panel.

4.3.5. The equipment must be provided with an automatic timer, or integrating dosemeter, to terminate the treatment after a preset time or dose.

4.3.6. During treatment the dose-rate of the useful beam should be ascertained

(i) by means of a calibrated meter used at each treatment or

(ii) by reference to calibration charts which give the dose-rates under specified operating conditions; the charts should be frequently checked against a dosemeter.

4.3.7. When the tube is operating the fact must be indicated by a visible signal.

4.3.8. The treatment and other rooms in which the electron beam unit is housed must be provided with adequate structural shielding. (See the Handbook of Radiological Data.) Full protection must be provided against scattered radiation, bremsstrahlung and neutrons if produced. Treatment rooms must be marked with a symbol to indicate ionising radiations. (See Appendix F.)

4.3.9. Neutrons may be produced by electrons of energy exceeding about 10 MeV, and consequently form a significant fraction of the stray radiation from high energy electron accelerators. The extent of this hazard should be assessed in the planning stage and appropriate safety measures incorporated in the design of the treatment room. In addition, the neutrons may induce radioactivity in surrounding materials, including air and dust, causing further hazards which should be considered in the planning stage. (See Section 4.4.8.)

4.3.10. Means must be provided for observing the patient and should be provided for oral communication with the patient from the control panel during treatment.

4.3.11. The operator must always be outside the room during treatment. **Operating procedures**

4.4. *Neutron beam units* (*excluding nuclear reactors*)

4.4.1. In an installation for the production of neutron beams, the housing of the neutron generator or source should be designed to minimise the emission of neutrons and gamma rays in directions other than that of the useful beam. **Equipment and housing**

4.4.2. Gamma-ray dose-rates in the neighbourhood of the housing should conform to the requirements of a therapeutic-type X-ray tube housing.

4.4.3. The equipment must be provided with an automatic timer, or integrating dosemeter, to terminate the treatment after a preset time or dose.

4.4.4. A visible signal must be provided outside the treatment room to indicate that the equipment is in operation.

4.4.5. The treatment room in which the neutron generator or source is housed must be provided with adequate structural shielding. (See the Handbook of Radiological Data.) Where significant amounts of gamma radiation are present, this should be allowed for in the choice of barrier thickness and material. Treatment rooms must be marked with a symbol to indicate ionising radiations. (See Appendix F.)

4.4.6. Interlocks must be provided so that when any door of the treatment room is opened, the equipment will be shut off automatically.

4.4.7. Means must be provided for observing the patient and should be provided for oral communication with the patient from the control panel during treatment.

4.4.8. As a result of neutron irradiation, materials, including air and dust surrounding the neutron source, may be activated and present a radiation hazard. The extent of this hazard should be assessed at the planning stage and any necessary safety measures, e.g. choice of appropriate wall material or forced ventilation, incorporated in the design of the treatment room. Expert advice on these problems should always be obtained at this stage.* Following installation of the neutron generator or source a detailed radiation survey should be carried out to determine activity levels, if any,

*Advice can be obtained from the Radiological Protection Service.

within the room and the appropriate safety precautions, e.g. delay in entering the room, should be specified.

4.4.9. The operator must always be outside the room during actual treatment. Operating procedures

4.5. *Protection from small sealed radioactive sources*

(This Section includes, for example, radium, radon, caesium-137 and cobalt-60 needles and tubes and strontium-90 β-ray plaques.)

4.5.1. A separate room must be provided for the 'make-up' and cleaning of sources and applicators and this room should only be occupied during such work. The room must be adequately ventilated. The placing of objects in the mouth, eating, smoking, drinking or the application of cosmetics whilst within the room must be prohibited. The use of personal handkerchiefs should be avoided. There must be an adequate supply of paper handkerchiefs. General requirements

4.5.2. A permanent record must be kept of the issue, distribution and return of all sources.

4.5.3. In order to ensure the minimum irradiation of personnel engaged in the preparation or application of sources, appropriate handling tools or implant instruments must be used at all times. These tools should be constructed so as to provide the maximum handling distance compatible with effective manipulation. All operators should have adequate training in these manipulative procedures.

Source capsules must not, under any circumstances, be picked up directly by the hands.

In order to ensure that doses in excess of the maximum permissible levels are not exceeded, a rota system of duties must, where necessary, be instituted.

4.5.4. All appliances should be carefully designed for ease of handling. For example, needle eyes should be designed for easy threading and thread ends subject to

fraying should be prepared with wax; screw threads should be of optimum size and pitch to allow fast 'jam-proof' operation.

All steps possible in the preparation and assembly of appliances must be carried out before the insertion of the source.

4.5.5. When multiple needles or capsules of the same appearance but of different strengths are used, they must be identified with different coloured threads, beads, or other means when in clinical use.

4.5.6. The number and position of removable sealed sources in or on the patient must be regularly checked. Dressings from patients receiving treatment with sealed sources of radioactive materials must not be destroyed until all the sources used have been accounted for. As an additional precaution, dirty dressings and excreta should be monitored.

Sterilisation of small sealed sources

4.5.7. For details of the sterilisation of small sealed radioactive sources, see Section 8.4.

Loss or breakage of a sealed source

4.5.8. An emergency procedure to be adopted in the case of loss or breakage of a radioactive source must be specified and notices indicating the action to be taken must be displayed in each room where such sources are handled or employed. All staff should be fully aware of their duties in such an event.

4.5.9. All source capsules must be tested for leakage or contamination (see the Handbook of Radiological Data) both initially and periodically and a permanent record must be kept of the result of such tests. Should the test show a free activity of 0·5 μc the source must be regarded as leaking and must be sealed immediately in an airtight container and arrangements made for its repair.

Beta-ray sources

4.5.10. Suitable shields or baffles must be provided, where required, to ensure adequate protection when manipulating sources. In order to prevent the head from being placed too near the source, and to protect the eyes and face from β-rays, a transparent plate of adequate

thickness should be mounted or worn between the source and the face of the operator.

4.5.11. It should be recognised that pure β-ray sources will emit bremsstrahlung and may emit characteristic X-rays and/or annihilation radiation. In the case of large sources these radiations may present a hazard which should be evaluated and the necessary precautions taken. Some β-ray sources are also γ-ray emitters and should be protected as such. (See Section 4.5.13.)

4.5.12. Sources intended for the utilisation of β-rays outside the container require a thin window. When not in use this window must be covered by a shield of sufficient thickness to stop all β-radiation and, when cleaning the window, care should be taken to prevent its being damaged and to minimise irradiation of personnel.

Gamma-ray sources

4.5.13. Benches used for the preparation, assembly and cleaning of source capsules and appliances must be provided with adequate protection for the operator and for other persons either associated with the work or in adjacent areas. (For data on protective materials see the Handbook of Radiological Data.)

4.5.14. In operating theatres and other treatment rooms where sources are applied to patients all practicable physical protection must be given. Protective barriers may be mounted on wheels and provided, where necessary, with sterile drapes. The barriers should be so designed as to give protection in all directions where persons are usually stationed during radiotherapeutic procedures.

Sources must remain behind protective barriers as long as possible and be removed individually as required for application to the patient.

In all cases expeditious handling and the use of suitable instruments (see Section 4.5.3.) will reduce the hazard.

4.6. *Protection of hospital staff, visitors and other patients in proximity to patients undergoing treatment with sealed sources.*

4.6.1. The instructions for the protection of hospital

staff, visitors and other patients in proximity to patients undergoing treatment with sealed radioactive isotopes might be based on the following rules.

(i) Beds in which there are any such patients must carry a notice indicating the fact, and giving details of the number and nature of sources, total amount of material, the time and date of application and removal and relevant nursing instructions. The standard symbol to indicate ionising radiations is shown in Appendix F.

(ii) Where possible such treatment should be carried out in one or two bed wards, care being taken to ensure that adjoining rooms are protected. Where a general ward is used, the beds of the patients under treatment must be at least 8 ft from centre to centre and must be distributed as widely as possible throughout the ward.

(iii) Sisters, nurses and other persons must not remain unnecessarily in the vicinity of patients undergoing treatment with gamma-ray sources.

(iv) Patients with sources in or upon their bodies must not be permitted to leave the ward or treatment room without the approval of the appropriate medical officer. (For rules of discharge of such patients from hospital, see Section 7.)

(v) The Radiological Safety Officer must in each case measure or estimate the maximum gamma-ray dose-rate at a distance of 2 ft from the patient. If this dose-rate is greater than 10 mr/h, a special symbol (see Appendix F) must be attached to the bed indicating that a radiation hazard exists, and the Radiological Safety Officer must give instructions regarding the daily time allowable for nursing procedures and visitors.

5. Therapeutic and Diagnostic Uses of Unsealed Radioactive Sources

5.1. *Control of hazards from unsealed sources*

General nature of hazards

5.1.1. In manipulating unsealed radioactive isotopes great care should be exercised to minimise deposition of the isotopes in the body as a result of ingestion, of inhalation or of absorption through intact or damaged surfaces of the body. The hazard will arise, in general, from small amounts of activity on contaminated hands, cigarettes, cosmetics and other items brought to the mouth, or from inhalation of radioactive dust, gas or vapour, from contaminated clothing, rooms, floors, equipment and air.

5.1.2. Particular attention is given in Section 5 to hazards arising from ingestion and inhalation, as described below. However, even when these hazards are small, there are still risks in handling isotopes which will depend essentially upon the effects of external β- and γ-radiations and the appropriate recommendations given under Section 4.5 should be applied.

Containment

5.1.3. The choice and design of all medical and experimental equipment or processes should be aimed at controlling the spread of the radioactive material into the working environment. This can be achieved by reducing to the utmost the production of dust, fumes, mist and splashes, by avoiding unnecessary transfers of radioactive material from one vessel to another, and by containing any contamination that may result from normal operations or from accidents in the immediate vicinity of the equipment. Drip trays and double containers should be used whenever practicable and much of the work should be done in fume cupboards. In the case of patients containing radioactive material, special care will be needed in controlling the contamination of the ward.

Relative harmfulness of isotopes

5.1.4. The values which are given in the Appendices for the maximum permissible body burdens and maximum permissible concentrations in air and water of the isotopes most commonly used in hospitals are a good guide to the relative harmfulness of the isotopes when deposited in the body. (See Table I.) However, in practice, the hazards associated with the manipulation of unsealed radioisotopes will also depend upon the other factors such as the skill and care of staff, the types of compounds in which the isotopes appear, the specific activity (depending on degree of dilution or, in the case of naturally occurring radioactive isotopes, on the half-life), the volatility, the radiochemical laboratory facilities provided, the complexity of the procedures involved and the relative radiation doses to critical organs and tissues (including the gastro-intestinal tract) when accidental inhalation or ingestion occurs.

5.1.5. Even in laboratories, some contamination will reach the working area and the effects of this should be minimised by the use of protective clothing and by a firm working discipline. Protective clothing has two principal functions—it prevents radioactive material from coming into contact with the worker's skin and contamination from spreading beyond the confines of the laboratory (or ward).

5.1.6. It is also important to pay attention to routine cleaning, which prevents low level contamination of surfaces from building up to serious levels.

Classification of laboratories

5.1.7. The ease with which contamination of laboratories, wards and theatres is controlled depends a great deal on the design of the rooms and on the quality of the facilities available. As far as laboratories are concerned, these have been classified into three grades (A, B and C) according to the standard of their design.

(i) *Grade C laboratory.* For the manipulation of small amounts of radioactivity (see Table II) few modifications are needed in any modern conventional chemical laboratory having floors covered with linoleum. Work-benches should be provided with

non-absorbent tops or with disposable covers. There should be at least one good fume hood with induced draught. The exhaust air should be carried outside the building but need not be filtered.

All working surfaces, including fume hoods, should be strong enough to carry any necessary shielding against γ-rays.

(ii) *Grade B laboratory*. A high-grade laboratory should be provided for work involving the use of isotopes in quantities of the order shown in column 3 of Table II below. Greater care in design is necessary to facilitate the control of contamination.

(iii) *Grade A laboratory*. For the higher levels of activity a specially designed laboratory will be required.

(iv) It is unlikely that at present there will be the need for a Grade A laboratory for clinical work in hospitals. For diagnostic or therapeutic applications of isotopes, a Grade B or Grade C laboratory will suffice, according to the types and quantities of isotopes to be used. Details of the design of laboratories are given in Section 5.2. If exceptions arise (that is, if a Grade A laboratory is proposed), reference should be made to the Radiological Protection Service.

Classification of isotopes

5.1.8. The radioisotopes at present being used in hospitals are classified in Table I according to their relative radiotoxicity per unit activity*. In each of the four classes, the isotopes are listed in order of increasing atomic number. The classification is based on the values recommended by the International Commission on Radiological Protection for the maximum permissible concentrations of the various isotopes in air. With the exception of radium, these I.C.R.P. values relate to the parent isotope and not to any daughter products which might be present.

* A complete classification of radioisotopes is given in Appendix L.

TABLE I

Classification of isotopes used in hospitals

High Toxicity (Class 1) Sr-90+, Ra-226+.

Medium Toxicity

Upper Sub-Group A (Class 2) Na-22, Cl-36, Ca-45, Co-56*, Co-60×, Ag-110m, I-124*, I-131, Cs-134+, Cs-137+, Ba-140, Ce-144+, Tm-170+, Ta-182+, Ir-192, Tl-204, Ra-224 (Th-X)

Lower Sub-Group B (Class 3) C-14, F-18, Na-24, P-32, S-35, Cl-38, K-42, K-43*, Ca-47, Cr-51, Fe-52*, Fe-55, Fe-59, Co-57, Co-58, Ni-65, Cu-64, Zn-65, As-74, As-76, Br-82, Rb-86, Sr-85, Y-90×, Nb-95, Ru-103+, Ag-111, Te-132, I-130*, I-132, La-140, Ce-141+, Pm-147, Lu-177, Au-198×, Hg-203, Rn-222+.

Low Toxicity (Class 4) H-3, O-15*, Ge-71, Kr-85, Xe-133.

× Used in both sealed and unsealed form.
+ Used in sealed form only.
* Classification based on R.P.S. calculations.

5.1.9. Table II gives the amounts of unsealed isotopes of the different classes which can be used at any one time in the three grades of laboratory, but not in wards. It must not be assumed that the ranges are fixed so precisely that no latitude is allowed in any circumstances. The Radiological Protection Adviser can, indeed, in exceptional cases, allow some flexibility in the amounts used.** Below the Table are given the values of the modifying factors for various procedures.

Examples

(i) Laboratory work involved in using I-131 in hospitals is regarded as a " simple wet operation", for which the appropriate modifying factor is 10. Since I-131 is a Class 2 isotope, this means that

**Since the hazard may depend on the chemical form, the Radiological Protection Adviser must decide when the amounts used should be restricted to levels lower than those given in Table II.

up to 1 curie of I-131 would be permitted in a Grade B laboratory.

(ii) The tipping of radioactive material (in solid form) from its can is regarded as a " simple dry operation ".

TABLE II

Grade of laboratory required for various quantities of isotopes of various radiotoxicities

Classification	Grade of laboratory required for unsealed isotopes at levels of activity specified below		
	C	B	A
High toxicity (Class 1) .	< 10 μc	10 μc – 1 mc	> 1 mc
Medium toxicity Upper Sub-Group A (Class 2) . . .	< 1 mc	1 mc– 100 mc	> 100 mc
Medium toxicity Lower Sub-Group B (Class 3) . . .	< 100 mc	100 mc–10 c	> 10 c
Low toxicity (Class 4) .	< 10 c	10 c–1000 c	> 1000 c

Modifying factors to be applied to the above quantities, according to the complexity of the procedure to be followed.

Procedure	*Modifying factor*
Storage (stock solutions)	× 100
Simple wet operations	× 10
Normal chemical operations	× 1
Complex wet operations with risk of spills Simple dry operations	× 0·1
Dry and dusty operations	× 0·01

5.2. *Design and facilities of laboratories and isotope clinics*

Lay-out

5.2.1. As far as possible, laboratories should be set aside for radioactive work and should not be used for other purposes. If, in a large laboratory, a section is used for radioactive work, this section should not be used for ordinary chemical work. In order to avoid cross contamination, laboratories should be designed and used so as to segregate widely different levels of activity. (See Tables I and II.) In particular, procedures involving the use of more than about one millicurie of any isotope should be kept away from counting rooms.

5.2.2. In the average hospital laboratory for the therapeutic and diagnostic applications of isotopes, space should be provided for

(i) isotope dispensary and store;

(ii) wash-up room;

(iii) excreta and specimen store, with measurement facilities and sluice room;

(iv) isotope surgery;

(v) clinical examination room;

(vi) laboratories (clinical, biochemical, counting, etc.); and

(vii) decontamination space.

While separate rooms for the above functions are desirable, (i) and (ii) and (iv) and (v) may be combined if relatively small activities are handled.

5.2.3. Washing facilities should be provided in the laboratory. In general, the usual laboratory sinks will suffice, though the taps should be operable by arm, foot or knee, so as not to contaminate them by the hands or gloves. If large quantities of isotopes are being dealt with, it is advisable to provide a shower in case of general body contamination of workers. In any laboratory where radioactive materials are discharged into the drains, another basin not used for radioactive materials should be available for the washing of hands.

5.2.4. The discharge of liquid radioactive waste should be limited to as small a number of points as possible and should be confined to the minimum section of the drainage system. Only approved sinks and drains should be used and these should be suitably marked. Drain pipes should be monitored from time to time.

Materials

5.2.5. Attention is drawn to the fact that floors may have to support large weights of shielding materials. Floors should have smooth, continuous and non-absorbent surfaces, and should be made of materials which can easily be cleaned and should, preferably, possess a surface which is easily removable. Floors should be cleaned by wet mopping or by the use of moist compound. Dry sweeping should be avoided.

5.2.6. Walls and ceilings should be finished with a non-porous washable surface, such as a good hard-gloss paint. Suitable materials for bench tops are waxed wood, laminated plastic sheets or glass. The working surface should always be protected by disposable covers of paper, bituminised paper, vinyl cloth, plastic-coated paper, or plastic sheets. To minimise the risks from spills, drip trays or double containers should always be used.

5.2.7. When the shielding of the worker from radiations is effected by vertical lead screens mounted on top of the bench between the worker and the source, adequate protection in other directions should be ensured. For example, γ - radiation may penetrate the bench top and reach the lower part of the worker's body or, if there are rooms below that in which the bench is installed, persons who may be working in such rooms.

Fume hoods

5.2.8. Adequate fume hood space should be provided. Several small hoods are usually more convenient than one large one. They can be constructed of wood and glass, provided that the former is protected by hard-gloss paint. The base can be of slate, or linoleum, or laminated sheet, the choice probably depending upon the type of work to be undertaken. The junctions between the base

and vertical walls of the hood should be adequately sealed.

5.2.9. The exhaust system should be sufficient to produce an air flow of about 100 linear feet per minute through the opening of the fume hood, when the window is closed to the working position. Smoke tests should be carried out to ensure that the draught is adequate under all circumstances (e.g. when there are " down draughts " or open windows and doors in the laboratory) to prevent radioactive dust and vapours being blown from the fume hood or external vent into the air of the laboratory or neighbouring rooms.

5.2.10. The extraction of air from the active area must be designed to prevent the movement of activity into inactive areas and measurement rooms. The exhaust air should be discharged through ducting to the outside of the building at a point preferably not lower than roof level. The possibility that the air, even when so vented, may be carried by down draughts into other rooms or buildings through nearby open windows should be carefully examined. When considering the design and erection of the exhaust ducting, ease of decontaminating it, as well as minimising the spread of contamination within buildings during the decontamination of the ducting should be borne in mind.

5.2.11. These restrictions on the design and use of fume hoods are adequate for simple wet and normal chemical operations in accordance with Table II. For other operations the additional precautions requiring closed boxes as outlined in Section 5.2.12 are necessary. Fume hoods should not be used for the storage of radio-isotopes.

Closed boxes

5.2.12. Closed boxes fitted with either long rubber gloves or remote-controlled manipulators are designed to avoid actual contact with radioactive materials and to prevent their dispersal. They are sometimes used for dealing with radioactive liquids, but are generally employed to prevent the inhalation of radioactive dust.

They should be used when dealing with α-emitting isotopes or with dry powdered or friable materials of specific activity of the order of 1 mc/g or upwards.

5.2.13. The closed box is fitted with an exhaust fan and filter and operated under slightly reduced pressure. Air-flow out of the box is only necessary to maintain the reduced pressure whilst using a transfer port or when changing gloves. Materials and equipment are introduced into the box through an air-lock.

Heating and ventilation

5.2.14. Special attention should be given during planning to such aspects as the mode of heating (e.g. enclosed wall heaters or under-floor heaters rather than the small wall radiators which are difficult to decontaminate), ventilation, design of drains and surface finishes. The use of closed boxes fitted with gloves or with remote-controlled manipulators will lead to a reduction in capital and running costs of heating and ventilation.

Other equipment

5.2.15. The following equipment should be supplied for work with unsealed isotopes

(i) laboratory coats or protective gowns of distinctive colour or marking; rubber (or plastic) gloves, caps, masks and overshoes;

(ii) tongs, forceps, trays and, for the higher levels of γ-activity, apparatus for remote handling;

(iii) (*a*) containers for active materials incorporating, where possible, the necessary shielding close to the source;

(*b*) double-walled containers (the outer wall being unbreakable) in which to keep liquid samples;

(iv) a suitable drip tray or some form of double container over which to carry out all manipulations, with a view to minimising the consequences of breakages or spills;

(v) compression bulbs for the pipetting of solutions or operation of wash-bottles; alternatively, hypodermic syringes to replace pipettes; and

(vi) radiation-monitoring equipment. (See Appendix D.)

5.3. *General procedures in laboratories and isotope clinics*

5.3.1. Working procedures should be designed to minimise the spread of contamination from the site of operations, not only in the interests of the safety of personnel but also to prevent cross-contamination of premises.

5.3.2. The details of procedures for radiation and contamination control are very dependent on the physical and organisational lay-out of the institution concerned and it is therefore essential for each institution to draw up its own detailed working instructions. Since these instructions cannot cover all eventualities, they must be supplemented by the careful training of staff at all levels.

5.3.3. Major changes in procedures and new procedures must be approved from the point of view of radiation safety by the Radiological Safety Officer and should, when necessary, be tried out by dummy runs with no or minimal radioactivity.

5.3.4. Because of the danger of direct transfer of contamination into the body, eating, drinking, smoking and the application of cosmetics in the active area must be forbidden.

5.3.5. The quantity of radioactive material chosen for a specific purpose should always be as small as practicable. If possible, solutions rather than dry materials should be used. The manipulation processes selected should be those which produce the minimum of dust or spray, and which avoid excessive transfers from one vessel to another.

5.3.6. Extreme care must be taken to avoid cuts or puncture wounds, especially when dealing with the more hazardous radioisotopes. To reduce the chances of injury, cracked or chipped vessels should not be employed.

5.3.7. Laboratory coats (or protective gowns) and surgical gloves* should be worn for all procedures involving unsealed isotopes. In addition, for work with higher activities, caps, masks and overshoes should be worn. Such protective clothing should not be worn outside the active area, even when only very low levels (tracer amounts) are used, in order to avoid contamination of other work. Surgical gloves for manipulating radioactive materials should not be used for handling other items, even in the active laboratory. Contaminated gloves should be washed before they are taken off. The method of putting on, and removing, gloves should be based on the surgical technique so as to avoid transferring activity to the hands or to the inner surfaces of the gloves. Regular systematic monitoring of the hands and gloves is necessary.

5.3.8. Workers should use the equipment which is provided for laboratory manipulations of unsealed isotopes. Such equipment should be confined to the isotope department. The use of mouth-operated pipettes and wash-bottles must be forbidden.

5.3.9. It is of great importance that the active area be kept thoroughly clean and tidy. Cleaning methods (including those for the floors) should be selected so as to avoid raising dust.

5.3.10. It is necessary to ensure the periodic maintenance of handling equipment and the examination, at frequent intervals, of protective clothing especially surgical gloves, so that items can be rejected as soon as possible after defects occur.

5.4. *Design and facilities of wards*

5.4.1. Patients containing therapeutic quantities of unsealed isotopes should not be placed in general wards in which there are patients whose treatment does not

Lay-out

* It should be noted that, while surgical gloves may provide adequate protection against soft β-emitters, such as H-3, C-14 and S-35, they do not stop hard β-rays. Accordingly, high doses may be received if sources are picked up even with gloved hands. (An average figure for the β-ray dose at 3 mm from 1μc of unsealed isotopes is 3 rad/h delivered to soft tissue.)

include the use of radioactive materials but should be placed in specially designed side wards. Such wards should preferably be of one or two beds. If of two beds it should be large enough to permit the beds to be spaced well apart. This procedure is aimed at simplifying the control of radiation hazards and simultaneously reducing the number of exposed persons.

5.4.2. The patients in such a ward or wards should be provided with a toilet and bathroom which should be contained in the same suite and which should not be available to staff or to patients whose treatment does not include the use of radioactive materials.

5.4.3. Where consistent or regular use (e.g. for metabolic studies) is made of tracer (diagnostic) quantities, it is very desirable in the interests of good technique to have wards set apart for this work.

Materials

5.4.4. Floors should have smooth, continuous and non-absorbent surfaces and should be made of materials that can easily be cleaned and preferably possess a surface which is easily removable.

5.4.5. Walls and ceilings should be finished with a non-porous washable surface, such as a good hard-gloss paint.

Heating and ventilation

5.4.6. During the planning stage of special wards, consideration should be given to methods of heating, such as by enclosed wall heaters or under-floor heaters, which simplify the cleaning of the wards.

5.4.7. Provision should be made in special wards for exhaust fans (window or wall-type mounting) for use in the event of spills or similar accidents. Such fans must exhaust to outside air.

Other equipment

5.4.8. There should be a safe storage area, not necessarily shielded, where low-activity samples of urine and faeces can be temporarily stored and reserve bottles kept available. A shielded container should be provided for the temporary storage of high-activity samples of

urine and faeces. Storage bins and waste bins should be provided for the temporary storage of radioactive contaminated linen and waste. The facilities indicated in this paragraph should be kept near the ward and should be clearly marked.

5.4.9. A stock of protective clothing, including surgical gloves, surgical gowns and boots, must be available for use in emergencies.

5.4.10. Separate bed-pans should be provided for each patient who has been given either therapeutic or tracer amounts of unsealed radioisotopes.

5.4.11. Radiation-monitoring equipment should be available. (See Appendix D.)

5.5. *General procedures in wards*

5.5.1. General rules should be issued to Ward Sisters and additional instruction sheets should be prepared for each new isotope technique. The instructions should indicate any limitations of the time that ward staff and visitors may spend in the proximity of patients, and should summarise the techniques to be followed by the staff. It must be impressed upon the staff that no nursing procedures which could be temporarily postponed should be adopted and that there should be the minimum handling of contaminated bed linen, clothing, towels, china, etc.

Protection of hospital staff, visitors and patients

5.5.2. The instructions for the protection of hospital staff, visitors and other patients in proximity to patients undergoing treatment with unsealed radioactive isotopes might be based on the following rules.

(i) Beds in which there are any such patients must carry a notice indicating the fact, and giving details of the nature and total amount of the radioisotope, the time and date of administration and relevant nursing instructions. (The standard symbol to indicate ionising radiations is shown in Appendix F.)

(ii) The Radiological Safety Officer must in each case

measure or estimate the gamma-ray dose-rate at a distance of 2 ft from the patient. If this dose-rate is greater than 10 mr/h, a special symbol must be attached to the bed, indicating that a radiation hazard exists, and the safety officer must give instructions regarding the daily time allowable for nursing procedures and visitors.

(iii) Such patients must not be permitted to leave the ward suite or treatment room without the approval of the appropriate medical officer. (For rules of discharge of such patients from hospital, see Section 7.)

(iv) During and following administration of unsealed radioisotopes for therapeutic purposes including external application, e.g. thorium-X, protective gowns and surgical gloves should be worn when handling the patient, his excreta, contaminated clothing or bed linen.

(v) The separate bed pan provided for each patient should be monitored by trained staff. Care should be taken that samples of urine collected from a patient given a tracer isotope cannot become contaminated by those from a patient who has received a different isotope or from one having a therapeutic administration.

5.5.3. Similar procedures to those required for treatment with unsealed radioisotopes may be necessary for patients containing diagnostic or tracer quantities of unsealed radioisotopes. Where only a few patients are involved each containing less than 10 μc, no special safety precautions in wards and clinics are necessary. However, even where there is no health hazard, steps may have to be taken to prevent cross-contamination, in which case local rules will be necessary.

5.5.4. For procedures which are unusually hazardous, the Radiological Safety Committee should lay down special rules and the Radiological Safety Officer should supervise their implementation.

5.6. *Environmental monitoring*

5.6.1. Provision must be made within each institution for a monitoring service (a) for testing the degree of radioactive contamination of personnel, clothing, equipment and installations (e.g. benches, sluices or drains), (b) for carrying out decontaminating procedures, and (c) for measuring external radiation levels in areas where unsealed radioactive isotopes are used and in the neighbourhood of patients containing such isotopes. Particular attention should be paid to the external application of unsealed radioisotopes, e.g. thorium-X.

5.6.2. The monitoring of wards, operating theatres, clinics and laboratories in which work with unsealed radioactive materials is undertaken must be carried out on a regular and systematic basis. The purpose of such monitoring is to establish the adequacy, from the point of view of radiation safety, of current working methods, and to provide experience in the light of which new techniques may be safely introduced. It is therefore important that monitoring results should be properly recorded for future reference.

5.6.3. Maximum permissible levels of external radiation and of contamination for α-, β- and γ-ray emitters are given in Appendices B and D.

Measurement of external radiation levels

5.6.4. Whenever work is undertaken with unsealed radioactive sources having activity greater than one millicurie, the working area must be regularly monitored for external beta and gamma radiations. Other areas in proximity to active areas, where persons may be exposed to radiation, such as adjoining rooms and places outside the building, must also be monitored periodically.

5.6.5. The most suitable instrument for this purpose is a portable battery-operated dose-rate meter of the ionisation chamber type which is sensitive to both beta and gamma radiations. The ionisation chamber should be provided with a thin window which may be closed for the assay of the gamma-ray component of the radiation.

The instrument should be capable of measuring dose-rates up to about 2 rad/h, with provision for switching to more sensitive ranges for lower dose-rate measurement.

5.6.6. In the circumstances where the dose-rates to be measured are only a few mrad/h, a G.M. counter and a suitable ratemeter may be used.

5.6.7. When high activity radiation sources are being used, the installation of instruments with visual and/or audible alarms should be considered.

Measurement of contamination

5.6.8. In wards, operating theatres, clinics and laboratories where unsealed sources of radioactive material are handled, the adequacy of the operating techniques in avoiding the spread of contamination should be checked by the regular monitoring of working surfaces, of operators' clothing and skin and, if necessary, of air. Such monitoring is important in the avoidance of health hazards, and is also valuable in providing information regarding faulty techniques and apparatus. It is also important for the avoidance of errors in measurement as a result of cross-contamination of samples.

(i) Contamination monitoring should cover all working surfaces including the floor of the laboratory or ward. Occasionally surveys of adjacent corridors may also be necessary. Equipment and other items should be monitored while situated in, and on being removed from, active areas.

Suitable instruments consist of portable or mains-operated ratemeters with interchangable probes. For alpha-emitters a scintillation type probe is most convenient; for beta-gamma surveys, a thin-walled G.M. type probe is suitable, fitted with a window which may be closed for measuring the gamma-ray component of the radiation.

Direct monitoring should be the rule, but when this is not practicable, smear testing may be

adopted. In such testing a conventional filter paper should be wiped over an area of the surface to be tested and then presented to the appropriate probe. Alternatively, the paper may be counted in a drawer assembly supplied with some types of contamination monitor.

(ii) Clothing, including shoes, of staff working in active areas should be regularly monitored particularly when leaving the active area. Any of the instruments mentioned in the previous section are suitable for this purpose. To encourage regular use, a monitoring instrument should be placed at the entrance to the laboratory. Contaminated laundry may also be monitored with any of the instruments mentioned in the previous section.

(iii) Staff working in active areas should ensure that their exposed skin surfaces are regularly monitored, particularly the hands, after work and before eating, smoking, or the application of cosmetics. To avoid unnecessary contamination of the hands, surgical gloves must always be worn when handling active materials and equipment, and the gloved hands should be washed thoroughly before removal of the gloves using surgical technique.

Care must be exercised in the measurement of skin contamination if the necessary sensitivity is to be achieved at the maximum permissible levels listed in Appendix D. An instrument for monitoring the hands should usually be available where hands are washed.

For other parts of the skin surface, ratemeters and interchangeable α- and β/γ- probes of the type mentioned in Section (i) may be used, but it is important to realise that with some types of probe the count rates equivalent to the maximum permissible levels may be satisfactorily measured only in low background areas.

(iv) As a general rule when diagnostic or tracer quantities of radioactive materials are used, air sampling is unlikely to be necessary.

When therapeutic quantities of unsealed radioactive materials are being handled in the laboratory other than in a fume hood or glove box, air monitoring for radioactive dust particles, vapours or gases may be necessary but this will depend on the activity and type of material being handled and the operating technique being used.

The concentration of active dusts in air is most conveniently measured by collecting the aerosol on filter paper supported on a vacuum-cleaner type of sampler and subsequently determining the retained activity by counting under an end-window G.M. counter or under a scintillation counter in the case of alpha-active samples. Glass fibre filter papers are suitable for dust particles larger than about 0·2 micron (μ) combining a low resistance to airflow with a high collection efficiency. For volatile contaminants such as radioiodine, a charcoal impregnated filter paper may be used; chemical traps can be employed as appropriate. For gases such as radon or thoron, the air is drawn through a filter paper to remove active dusts before the air is admitted for counting into a scintillation counter.

Monitoring instruments

5.6.9. In Appendix D are listed some A.E.R.E. type instruments or their commercial equivalents as an indication of the type of instrument required for the various purposes.

5.7. *Decontamination procedures*

Personnel

5.7.1. Those working with radioisotopes should wash their hands thoroughly with mild, pure soap and water before leaving active areas and especially before eating,

smoking or the application of cosmetics. Particular attention should be paid to the fingernails. After washing, the hands should be checked with a radiation monitoring instrument. The permissible levels of contamination of the hands and of other parts of the body are given in Appendix D.

5.7.2. If washing with soap and water fails to reduce the contamination to the required level, the application of carrier diluent may be beneficial, if applied quickly. Otherwise a detergent or, under instruction, titanium dioxide paste or lanolin should be tried. If this fails, treatment with a saturated solution of potassium permanganate, followed by decolourisation with 5 per cent sodium bisulphite, may be used. However, such treatment must only be carried out under the supervision of experienced persons. Chemical treatment should not be resorted to vigorously, as the skin becomes porous. Similarly, when using mild abrasives, or even when scrubbing, care should be taken not to injure the skin. Even when the contamination has not been reduced to the required level, these procedures should not be carried on to the stage of breaking the skin.

5.7.3. In the case of contamination of other skin areas (or of the hair), soap and water or, if necessary, a 2 per cent liquid detergent should first be used. Potassium permanganate should not be applied to contaminated hair as there is a risk of causing a semi-permanent change of hair colour.

5.7.4. When high-level contamination of parts of the body other than the hands is suspected, the Radiological Safety Officer and Head of the Department should be notified at once. It is a mistake for the subject to have a shower prior to such notification, as contamination from the " hot spot " may spread all over the body. Great care should also be taken, during decontamination of the face, that contaminated liquid does not fall on to the lips or enter the eyes. Equally, if the eye is being irrigated for contamination, it should be ascertained that the adjacent skin is not highly contaminated, as measures

must first be taken to prevent such contamination from being irrigated into the eye.

5.7.5. If the skin is accidentally broken in conditions when there is a risk of radioactive contamination, the wound should, if possible, be irrigated immediately with tap water, care being taken not to spread the contamination over the rest of the body. As soon as the first aid measures have been taken, all wounds should be reported to the Supervisory Medical Officer for further treatment including decontamination if necessary.

5.7.6. It is suggested that establishments might prepare a summary in tabular form of the above procedures for use in case of accidents or spills. (See Section 5.8.)

Equipment

5.7.7. The permissible levels of contamination of benches and floors of active laboratories and of glassware and laboratory tools are given in Appendix D. These levels apply to contamination not known to be fixed. For fixed contamination the levels should be such as will ensure that no person can receive an external radiation dose in excess of those permitted.

5.7.8. Scrupulous care in the cleaning of glassware and porcelain is necessary. After use, all vessels should be marked and segregated for special attention when cleaning. Glassware and porcelain can be cleaned by any of the normal chemical agents, of which chromic-sulphuric solution is probably the most useful. Other cleaning agents are concentrated nitric acid, ammonium citrate, pentasodium triphosphate and ammonium bifluoride. The solutions used for cleaning should not be returned to the stock bottle.

5.7.9. For vessels made of other material, e.g. plastic, care should be taken in the choice of cleaning agents.

5.7.10. All metal tools, trays, sinks and equipment should be surveyed to detect possible contamination. They may be cleaned by washing with a heavy duty detergent of the type used for laundering followed, if

necessary, by inhibited phosphoric acid, or by dilute sulphuric acid, or by mildly acid mixtures of citrates with EDTA and/or ammonium bifluoride. For stainless steel, acids should be avoided as they are likely to corrode the equipment, causing greater difficulty in future decontamination; stubborn contamination may often be removed by the use of a slightly abrasive polish. When all other procedures fail with stainless steel, a mixture of 6 per cent nitric acid with 1 per cent sodium fluoride may be used; this, in most cases, should prove more effective than hydrochloric acid but less corrosive to equipment.

5.7.11. Paint work can be cleaned with soap (or detergent) and water or, in extreme cases, removed with a paint remover. Polished linoleum and other floor coverings can be cleaned with soap and water. Linoleum should preferably be sealed with a varnish, e.g. polyurethane, and a water emulsion polish used to maintain it. Contaminated polish could then be removed using a hot solution of detergent. If activity still remains, the floor covering should be replaced or, in the case of short-lived isotopes, suitably covered temporarily until the radioactivity decays sufficiently.

5.7.12. If in the case of long-lived isotopes, after decontaminating procedures have been carried out, the levels of activity of equipment and glassware remain greater than those specified, the items should be regarded as radioactive waste. For short-lived isotopes, the equipment can be stored until the radioactivity decays sufficiently.

Clothing

5.7.13. Protective clothing and personal clothing of staff, or clothing or bedding of hospital patients who are being treated with radioisotopes, should be monitored at regular intervals spaced according to the radioactive hazard involved. Any article that is known to be, or suspected of being, contaminated, should be placed in a container provided for the purpose. The permissible levels of contamination are given in Appendix D.

Laundering

5.7.14. Contaminated clothing and bedding should not be released to public laundries unless the activities (assumed to be removable contamination), averaged over an area not exceeding 300 cm^2, are below the permissible levels given in column 3 of Table D I in Appendix D. If the activities exceed one tenth of these levels, the clothing and bedding should be sent in a specially labelled container.

5.7.15. For articles contaminated above these levels with short-lived radioactive isotopes, storage is recommended until the activity has fallen below the safe levels. Care must be taken to prevent airborne contamination during the movement of contaminated clothing and bedding. When storage is not practicable but special laundering facilities are available in a hospital, a contaminated garment or bedding with an activity above the permissible levels should be given a series of hot rinses. The article should then be given further rinses with soapy and clear water, followed by washing in a hot solution of 1·5 per cent citric acid and finishing with a series of cold rinses. The article should then be monitored and the procedure repeated if necessary. An automatic washing machine is very useful for this purpose.

Clothing which cannot be laundered satisfactorily or held for storage should be regarded as radioactive waste.

5.8 *Emergencies* (*accidents*, *spills*, *fires*)

5.8.1. The first concern in the event of an emergency likely to result in the dispersal of radioactive material must be the protection of the persons involved including patients (whether in the operating theatre or ward) as well as ward and laboratory staff. The second is to confine the contamination as far as possible to the area directly affected.

Preparatory procedures

5.8.2. Instructions on the action to be taken in an accident with, or spill of, or fire involving, radioactive material must be drawn up to cover the points dealt with in Section 5.8.7. to 5.8.9. They must be seen and read by all persons who may be concerned. The instructions should

be reviewed periodically and revised as necessary. Where possible, practical exercises should be held to test the effectiveness of the arrangements to deal with a serious spill and to ensure that all persons concerned know what action to take in an accident.

5.8.3. Care should be taken to ensure that there are adequate means of escape in the event of a fire or other emergency but the local rules should make clear the circumstances in which emergency exits are to be used. The local fire brigade (through the Chief Fire Officer*) should be afforded the opportunity of visiting the establishment to obtain information about the lay-out of the premises and about warning measures, symbols, etc. The Chief Fire Officer will also advise about first-aid fire-fighting equipment suitable for the risk in the area concerned.

5.8.4. Notices must be posted in or near every active area showing

(i) the system of warning persons in the vicinity;
(ii) the system of contacting the Radiological Safety Officer (or deputy) and the head of the department to whom the accident should be notified immediately;
(iii) arrangements for calling the fire brigade and medical services; and
(iv) the localisation and method of use of emergency equipment including fire-fighting equipment.

5.8.5. Arrangements must be made for the notification of the appropriate authorities by the Radiological Safety Officer or deputy in the event of an emergency. These may include the fire brigade, ambulance service, Supervisory Medical Officer, and, in the event of an area outside the establishment being affected, the police and local Medical Officer of Health.

5.8.6. An up-to-date list of all places in the establishment where there are radiation hazards, showing in particular

* In Scotland, the Firemaster. In Northern Ireland, the Fire Force Commander of the Northern Ireland Fire Authority or the Chief Officer of the Belfast Fire Brigade.

the exact location of, and means of access to, all rooms likely to contain radioactive materials should be kept where it is readily available in the event of fire or other emergency. The Chief Fire Officer should be given a copy of this list.

Action during an emergency

5.8.7. The best course of action in an emergency depends very much on local circumstances and the nature of the emergency. Local rules should incorporate the following requirements in a form best suited to the circumstances and the sort of emergency likely to arise.

5.8.8. An accident or spill may be regarded as serious when the quantity of isotope which has been spilt is more than the appropriate minimum quantity given for Grade B laboratories in Table II if wet, and more than one-tenth of this quantity if dry. In such circumstances, decontamination of personnel must take priority over other types of decontamination and, until a plan for dealing with the decontamination of the area has been worked out, only the minimum emergency action should be taken, for example

(i) evacuation of all non-essential staff and, if necessary, patients, ensuring that contamination is not carried to other areas on shoes or clothing;

(ii) notification of the Radiological Safety Officer and head of the department;

(iii) re-entry to carry out emergency measures only, with adequate protective equipment including respirator and rubber boots;

(iv) if the spill is on the skin, thorough flushing with tap water. (See Section 5.7.);

(v) if the spill is on clothing, immediate removal of protective and, if possible, outer clothing, which should be left in the affected room;

(vi) (*a*) except where there is radioactive gas or vapour to be dispersed, the switching off of all

laboratory services except lighting, but including mechanical ventilation and closing of all doors and windows;

(*b*) where radioactive gas or vapour is to be dispersed, the switching on of mechanical ventilation and, according to discretion, the opening of doors and windows.

5.8.9. Contaminated persons should not proceed far into any inactive area until they have been monitored and until any necessary steps to reduce surface contamination have been taken. (See Section 5.7.) The treatment of serious injuries must, however, take precedence over decontamination of personnel or containment of contamination.

Subsequent action

5.8.10. It is important to estimate the dose received by each person and to establish which part of the body is involved. The Controlling Authority must arrange for any special medical examinations of the affected persons which the Supervisory Medical Officer recommends. In some instances, it may be necessary to carry out tests on personnel involved in an accident or spill to determine the amount of radioactive material which has entered the body. (See Section 2.3.4.)

5.8.11. Before re-entering the area to effect decontamination measures, personnel involved should wear suitable protective clothing, gloves, footwear and respirators, according to the seriousness of the accident. These persons should, in due course, be submitted to the necessary decontamination and monitoring procedures.

5.8.12. Entry to the contaminated area must be restricted until radiation surveys have indicated that it is safe and the approval of the Radiological Safety Officer has been given.

Emergency trolley

5.8.13. In departments where quantities are used in excess of those permitted in Grade C laboratories for Classes 1, 2, and 3 isotopes and in excess of 100 mc

for Class 4 isotopes, a trolley should be kept permanently ready for use in dealing on site with the recovery of lost sources, the prevention of the spread of contamination resulting from spills of radioactive material and the decontamination of surfaces and of persons and equipment. It is recommended that the trolley be equipped with the following items, arranged in labelled containers.

(i) *Protective Clothing*

2 surgical (preferably plastic) gowns, caps, face masks, overshoes
Assorted pairs surgical gloves and polythene mittens
Respirator
Boiler suit
Rubber apron
Plastic aprons

(ii) *Decontamination equipment for persons*

Mild Soap
Titanium dioxide paste } with instruction sheet
Lanoline
Carrier solutions, particularly iodide and phosphate (e.g. 10 g per litre)
Plastic sponge
Soft brush

(iii) *Decontamination equipment for surfaces*

Plastic sponges
Polythene bucket
Detergent
Soap powders
Brush

(iv) *Sundries*

Polythene bags
Polythene sheet
Sellotape

(v) *Sundries* (*cont.*)

Blotting paper
Labels
Barrier creams
Iodide tablets
Wax cartons
Wax pencils
Simple first-aid equipment, i.e. plaster, bandages
2 lead pots
4 film badge holders
2 quartz fibre pocket dosemeters and charging unit
G.M. tube monitor
Torch
1 remote handling tool
2 pairs forceps
2 pairs tongs
Adhesive labels saying "Radioactivity" and warning notices
Chart showing maximum permissible levels of contamination of surfaces
Notebook
Films (to be drawn from normal stock)
List of contents of trolley

Emergency pack

5.8.14. In all departments where a decontamination problem could arise, an emergency pack containing items as under must be held in readiness in a clearly labelled suitcase or similar portable container.

1 surgical gown, cap, face mask, overshoes
Respirator
2 pairs polythene mittens
1 pair forceps
Polythene sheet
Blotting paper
Warning labels
Swabs
Polythene container for active waste
Decontamination substances as given under (ii) and (iii) of Section 5.8.13.

Mild soap, soft brush, paper towels
G.M. tube monitor
Torch
Chart showing maximum permissible levels of contamination of surfaces
Iodide tablets
Notebook
List of contents of pack

5.9. *Physical and metabolic factors and doses (in rems) to various organs and tissues per microcurie intake by ingestion or injection, for the isotopes at present being used in hospitals.*

For details see " Radiation doses from administered radio-nuclides ". J. Vennart and Margaret Minski, Brit J. Radiol, 1962, **35,** 372. or the Handbook of Radiological Data.

6. Protection of the Patient

6.1. *Introduction*

6.1.1. Patients exposed to radiation for diagnostic or therapeutic purposes may be subject to some personal hazard, and the direct or indirect irradiation of their gonads (testes and ovaries) may constitute a hazard to future generations. Consequently it is important to carry out only those radiological examinations and treatments that are strictly necessary and in doing so, to avoid all unnecessary irradiation.

6.1.2. In diagnostic procedures, if proper protective measures are employed, and if the irradiation of the patient is kept to the lowest limit consistent with the clinical needs of each case, the risks either to the individual or to successive generations can be regarded as small compared with the benefits obtained.

6.1.3. In therapeutic procedures considerably larger doses of radiation are necessarily given. Nevertheless every effort should be made to reduce the dose to parts not being treated.

6.1.4. Detailed surveys of radiological procedures were carried out under the auspices of the Adrian Committee on " Radiological Hazards to Patients " and the Committee's recommendations are to be found at Appendix H. The recommendations include the following main points.

6.2. *General*

6.2.1. Radiological examinations should not be made in the absence of clear-cut clinical indications or as part of general medical supervision. Unnecessary examinations are sometimes due to a failure to ascertain whether there are records of previous radiological examinations. Case sheets should have a section headed " Previous X-rays ".

6.2.2. Special consideration should be given (i) where extensive or repeated radiological examinations of young people are undertaken, (ii) before abdominal investigations and (iii) in the radiography of pregnant women.

6.2.3. Records of all radiotherapy should be maintained.

6.2.4. In the treatment of non-malignant conditions special consideration should always be given to alternative methods of treatment before undertaking radiotherapy.

6.3. *Techniques*

General diagnostic radiology

6.3.1. In every case the dose given should be the minimum necessary for the purpose. Considerable reductions can be achieved by strict limitation of field size and by adequate gonad shielding where this is feasible.

Radiography

6.3.2. The fastest films and screens consistent with satisfactory diagnostic results should be used and

automatic timing devices employed to keep exposures, and the necessity for repeated exposures, to a minimum.

Fluoroscopy

6.3.3. This technique should not be used if radiography or electronic metal-locating equipment can give the same or better information. Before undertaking any fluoroscopic examination, time for dark adaptation should be allowed. Unless image intensification is used this should be at least ten minutes. An automatic timing device should be fitted to the fluoroscopy machine. Especially in prolonged examinations more use should be made of image intensification.

Mass miniature radiography

6.3.4. This method should not be used for the chest examination of pregnant women. If used for children and adults of short stature, particular steps must be taken to exclude the gonads from the beam.

Radiotherapy

6.3.5. In the treatment of skin conditions the softest quality radiation should be used consistent with adequate irradiation of the tissues. Radiation should not be applied to the ovaries for the production of a temporary artificial menopause, or for the treatment of infertility. Adequate gonad shielding should be used where this does not interfere with the proposed treatment.

7. The Discharge of Hospital Patients during Treatment with Radioactive Materials

7.1. *Introduction*

7.1.1. Section 7 deals with the conditions under which both in-patients and out-patients who are undergoing treatment with radioactive materials may be allowed to leave hospital to return to their homes. It is intended to give general guidance to radiotherapists, who should use their discretion in regard to individual cases. Further information is given in Appendix I.

7.2. *General considerations*

7.2.1. Such patients may be permitted to leave hospital subject to the following conditions

(i) the activity of the radioactive material administered or applied is in accordance with the values given in Table III;

(ii) the likelihood of a sealed source being lost is remote; and

(iii) suitable instructions are given to the patients regarding their behaviour, personal activities and movements during an appropriate ensuing period. (Suggested instructions are given in Section 7.4.)

7.2.2. If the activity on discharge is such that instructions in accordance with Section 7.2.1. (iii) need to be given to a patient, the general practitioner must be informed and dates on which the various restrictions can be lifted should be given.

7.2.3. If the activity on discharge is in excess of the values given in paragraph 4 in Appendix J, dates should be specified before which, in the event of death, neither a post-mortem examination, nor embalming, nor cremation should take place without reference to the hospital authorities.

7.3. *Maximum activities of various isotopes for patients permitted to leave hospital*

7.3.1. Table III deals with two conditions and sets out the maximum activities of the commonest isotopes that may be allowed for patients (i) who propose to travel home by public transport and (ii) who are conveyed home by other means. Reference may be made to the Radiological Protection Service about corresponding activities for isotopes not included in Table III. Table III refers to patients in whose tissues implantations of short half-life sealed sources have been made or to whom unsealed radioactive materials have been internally

administered. A note on the conveyance by ambulance of patients containing radioactive materials is given in Appendix I.

TABLE III

Maximum activities of patients permitted to leave hospital

Isotope	Journey home by public transport	Journey home by other than public transport
I-131	15 mc	30 mc
Radon (sealed) . .	12 mc	12 mc
Y-90 or Au-198 (sealed) .	30 mc	30 mc
Y-90 or Au-198 (colloidal)	10 mc	30 mc (10 mc if possibility of leakage from patient)
P-32	30 mc	30 mc

7.4. *Instructions to patients*

7.4.1. The instructions given to patients should be based on the following considerations, which in general apply to activities at or near the maximum values given in Table III. If the activities are substantially less than those in Table III, suitable relaxations of these conditions can be applied. (For guidance see Appendix I.)

(i) Conditions should be specified under which subsequent journeys by public transport may be made. (For details see Appendix I.)

(ii) Visits to places of entertainment can be made.

(iii) For a week after leaving hospital, when levels of radioactivity may be high, particular care should be taken to avoid close contact with other members of the household, especially children and young people.

(iv) The patient should not return to work until the activity of the radioactive material within the body has fallen to one quarter of the appropriate level given in the third column of Table III.

8. Storage and Movement of Radioactive Materials

8.1. *Introduction*

8.1.1. By far the most frequent use of radioactive materials for medical and dental purposes occurs in large hospitals and associated clinics; but these materials are used to a limited extent in small hospitals and by consultants in private practice. The following recommendations have the purpose of ensuring that satisfactory standards of safety are maintained in all establishments using these materials, and although hospitals are specifically referred to, the recommendations apply equally to clinics and private practice, since it is important that the same standards of safety are maintained. Small users of radioactive materials may not find it necessary to appoint a specific person or persons to be responsible to the custodian. (See Sections 8.2.14. and 8.2.29.) In such cases the duties assigned in the Code to these persons will still need to be performed and it will be necessary to establish a procedure and to allocate responsibilities to ensure this.

8.2. *Storage and internal movement of radioactive materials*

General recommendations (sealed and unsealed sources)

8.2.1. In each hospital where radioactive sources are used, a custodian, who may be the Radiological Protection Adviser, must be nominated to be responsible, in

consultation with the Radiological Safety Committee of the hospital, for organising the security during storage and use of all types of radioactive material and for ensuring that all necessary records are kept.

8.2.2. Each hospital must be provided with one or more main stores for radioactive material which can be securely locked. A warning notice of the design illustrated in Appendix F must be displayed where it can easily be read outside the place of storage.

8.2.3. Full records must be kept of all radioactive material stored and of all material issued and received.

8.2.4. The stores must be maintained in an orderly fashion and should be inspected regularly by the custodian or by a responsible person nominated by him.

8.2.5. Stores for radioactive substances must be so sited and designed that sources can be both stored and transferred to and from a store without excessive exposure of any person. The protection provided within the stores for sealed and unsealed sources must be such that the person who transfers sources to and from the stores does not, in the performance of these duties during any working period, receive more than small fractions of each of the maximum permissible doses. To minimise exposure of staff resulting from transport of sources, stores should, where practicable, be located near the working areas, e.g. the radium store and laboratory should be near to the radium theatre. Data for the computation of shielding against both beta and gamma radiations are given in the Handbook of Radiological Data.

8.2.6. In providing shielding for radioactive sources consideration should be given to the scattered radiation. It is not sufficient to place large sources behind a barrier, no matter how thick, if the radiation scattered round it presents a hazard.

8.2.7. Where radioactive gases or vapours may be emitted by stored sources (e.g. radium containers,

iodine-131) the store must be adequately ventilated by mechanical means. Fans must be operated continuously while staff are present in the store room and also for a sufficient time before the room is entered.

8.2.8. The place of storage should be chosen and the store constructed so as to minimise the risk from fire and flooding. Advice on these matters may be sought from the Chief Fire Officer*.

8.2.9. Subsidiary protected stores, secure against tampering or theft, should be provided at all sites in the hospital (e.g. laboratories, radium theatre, wards) where radioactive material may have to be left for any significant period of time when not actually in use. These stores should be large enough to hold appliances carrying radioactive sources and containers for active fluids. A warning notice of the design illustrated in Appendix F must be displayed at each store.

8.2.10. Attention should be given to the radiation hazards which may arise from stored sources in the event of fire and flood. Plans for the handling and recovery of the sources in the event of fire should be worked out in consultation with the Chief Fire Officer*.

8.2.11. Radioactive material must be issued from a main store only by a person nominated for this purpose (see Sections 8.2.14. and 8.2.29) and thereafter, until its return or disposal, must be at all times in the care of responsible individuals. Local rules should be formulated for each hospital in order to define precisely the responsibility of such individuals at each stage of the movement of sources in the hospital and to other hospitals.

8.2.12. Radioactive sources must only be transported in the hospital in suitable containers provided for the purpose and distinguished by orange coloured markings. Such containers must be designed (i) to provide adequate protection of all persons during transport, loading and unloading, (ii) to prevent loss of sources, and (iii) to

* In Scotland, the Firemaster

minimise the risk of spilling unsealed radioactive material. All containers for radioactive materials must be labelled with a warning notice of the design illustrated in Appendix F.

8.2.13. If radioactive sources have to be transported outside hospitals adequate precautions must be taken. (See Section 8.3 and Appendix K.)

Special recommendations relating to sealed sources

8.2.14. A specific person or persons must be nominated to be directly responsible under the custodian of radioactive sources for the storage, maintenance, issue and receipt of sealed radioactive sources. The responsibilities of this person or persons must be defined in the local rules.

8.2.15. In the main storage safe a number of separate compartments should be provided (i.e. drawers or slides) so that the total stock of sources can be subdivided into a number of smaller groups. A separate compartment should be provided for each different type of source, while a number of compartments should be provided for sources of one type when the number of such sources is considerable. An individual compartment should not contain more than 20 sources, or whenever possible, an activity exceeding the gamma-ray equivalent of 100 mg radium. Each compartment should be so marked as to permit immediate and certain identification of its contents from the outside.

8.2.16. Where two or more types of source have a similar appearance it is necessary to adopt a satisfactory method of discrimination and to check regularly that the sources are correctly identified.

8.2.17. A Sealed Sources Register must be kept, showing full particulars of all sealed sources having a half-life greater than a few days. This Register must include all relevant information concerning the construction, content, dimensions and serial numbers of each type of source. Records of radon leak tests on radium containers and of all inspections of sources for damage,

together with records of repairs, must also be included in this Register.

8.2.18. Records must be kept of all sealed sources issued from or received at the main store. These records must be signed by the person or persons nominated in Section 8.2.14., and must be sufficiently detailed and so arranged that information concerning the precise whereabouts of every sealed source which has been issued, and its expected time of return, are immediately available. A means should also be provided for showing at any time the number of sources of each type actually in the store and available for issue. The possibility of supplementing written records with a convenient visual display system should be considered.

8.2.19. Whenever sealed sources are transferred from the care of one person to another, the recipient must sign a receipt for the same on a form provided for this purpose. This receipt must state the types, contents and number of sources, and the person or department from which they were received.

8.2.20. At regular and frequent intervals, the person or persons nominated in Section 8.2.14., must undertake an audit to account for every source listed in the Sealed Sources Register. Sources in the store must be actually counted (without checking serial numbers) except that a previous count may be accepted for a group of sources which have been stored in a sealed container since the previous audit. Sources which have left the store must be covered by a current receipt.

8.2.21. An annual check audit of all sealed sources must be undertaken by the custodian or by a senior officer nominated by him for this purpose.

8.2.22. Sealed sources must be inspected after use for evidence of damage before being returned to a main store. All such sources must also be regularly examined by a competent person with sufficient frequency to

permit the early detection of progressive damage which might lead to the loss of radioactive material; records must be kept of these examinations.

8.2.23. Every sealed source must be tested by a competent person for leakage at least once per year. Moreover, radium sources must be tested for leakage of radon whenever there is reason to believe that a source has been bent or otherwise damaged. Results of all tests for leakage must be recorded.

8.2.24. Whenever there are reasonable grounds for believing that radioactive material is leaking, or is liable to leak, from a sealed source, that source must be placed in a suitable airtight container forthwith pending repair by a competent person. Leaking radium sources must only be repaired by the Radiochemical Centre, Amersham, whose advice regarding the return of such sources should be sought.

8.2.25. When a sealed source is damaged to an extent which involves, or which might involve, the spilling of radioactive material, a competent person properly equipped for the purpose must be instructed to recover or remove the radioactive material. Until this has been done, all practicable measures must be taken to prevent the dispersal of the radioactive substance and for safeguarding all persons involved. These measures may include temporary vacation of contaminated premises. In this connection accidents to radium containers must be treated as serious emergencies.

8.2.26. Effective means must be provided to minimise the possibility of the loss and subsequent damage of sealed sources, e.g. it should not be possible for sources which might be mislaid or lost from a patient to find their way to the refuse incinerator or laundry. Dressings and excreta from patients receiving treatment with sealed sources should not be disposed of until it has been proved that there is no lost source present. All rubbish bins, soiled dressings bins, laundry baskets, etc., coming

from a ward or other area where sealed sources are employed, should be tested for radioactivity with a suitable instrument before the contents are disposed of. A double check can be provided by permanently installing a source alarm in an appropriate doorway or corridor through which outgoing bins, baskets and possibly food trolleys, etc., have to pass.

8.2.27. Local rules stating the actions to be taken in the event of the loss or suspected loss of a sealed source should be formulated by each Controlling Authority. The following points are important.

(i) The Radiological Safety Officer should be informed without delay. He should arrange for an immediate search for the lost source to be made by a competent person. The possibility that the lost source might have fallen into a gap in protective material should not be overlooked.

(ii) The person who is responsible in accordance with Section 8.2.11., should be informed without delay.

(iii) All possible means by which the lost source might move further astray must be eliminated, until the search referred to in Section 8.2.27(i) has been carried out. For example, there must be no sweeping of floors; no disturbing of furniture, sinks, sluices or toilets; no movement of staff or patients and no movement or disposal of soiled dressings, laundry or dust bins.

(iv) Pending the search referred to in Section 8.2.27 (i) any fires which might be involved should not be made up and the ashes must not be disturbed. No further rubbish should be thrown on the hospital incinerator fires.

(v) Should there be any reason to suspect that the lost source might have become damaged, the possibility of contamination by spilled radioactive material should be borne in mind. On the earliest suspicion of such contamination, rigorous

precautionary measures, such as those stated in Section 8.2.25., should be instituted at once.

8.2.28. Sealed sources should be cleaned before being returned to the safe, particular care being taken with thin walled sources. Methods similar to the following are suitable

(i) soaking for about an hour, if necessary, in a suitable disinfectant, or (if dried blood is present) in a solution of hydrogen peroxide, or (if mould material is adherent) in xylene,

(ii) thoroughly rinsing in warm or boiling water, or

(iii) if the containers are of steel, which might rust, rinsing in surgical spirits or alcohol prior to drying.

The use of ultrasonics is under investigation and the Radiochemical Centre, Amersham should be consulted before this method is used.

Abrasive substances (e.g. metal cleaners and polishes) must not be used, and sources must not be allowed to come into contact with mercury or mercury salts, iodine and solutions of hypochlorites.

Special recommendations relating to unsealed sources

8.2.29. In each department in which unsealed sources are stored there must be an authorised person or persons directly responsible, under the custodian of radioactive sources, for the storage, maintenance, issue and receipt of unsealed radioactive sources. The responsibilities of this person or persons must be clearly and precisely defined in the local rules.

8.2.30. In an unsealed sources store a number of separate compartments should be provided so that the total stock of sources can be subdivided into a number of smaller groups. A separate compartment should be provided for each different isotope, while a number of compartments should be provided for sources of one type when the number of such sources is considerable. Whenever possible an individual compartment should not contain an activity exceeding the gamma-ray

equivalent of 100 mg radium. Each compartment should be so marked as to permit immediate and certain identification of the contents from the outside.

8.2.31. In each department concerned, the person or persons authorised (see Section 8.2.29) must keep records of all sources received and issued. The purpose for which the source is issued must be recorded and the recipient must give a signed receipt.

8.2.32. Persons to whose custody sources are subsequently transferred must sign a receipt of an approved form.

8.2.33. The person or persons authorised (see Section 8.2.29) must at regular and frequent intervals inspect the stocks of sources in his department. Records must be kept showing all stocks present at the time of each inspection, and of all material disposed of from the store as active waste.

8.2.34. All containers must be clearly labelled, using a system whereby the contents can be readily identified.

8.2.35. Whenever practicable, fragile containers should be stored inside larger unbreakable ones.

8.2.36. The following special precautions concerning the storage of unsealed radioactive sources should be adopted.

(i) Active residues even at tracer levels should never be stored in Winchesters with glass or screw-on stoppers: polyethylene, rubber or cork stoppers should be used.

(ii) Chemically stable solutions containing radioactive material in excess of 5 millicuries of α-activity and 50 millicuries of β-activity should always be stored in properly vented containers. This amount of radioactivity may be expected to produce about 1 millilitre per month of gas at N.T.P. from radiation decomposition of water.

(iii) Chemically unstable solutions containing radioactive material, e.g. nitric acid, or other oxidising solutions containing traces of organic material, peroxides, chlorates, etc., should always be stored in vented containers.

(iv) Special care should be taken in opening old bottles of radioactive liquors to minimise the danger of bursting or frothing.

(v) Highly α-active solutions should not be left in thin glass vessels where the glass is liable to weaken under irradiation. It is not possible to set an activity level at which this becomes serious because the main danger is from dry deposits above the liquid surface. It should be borne in mind at levels of the order of 1 millicurie per millilitre.

8.2.37. Vessels holding radioactive materials must be transported within the hospital in containers having firmly fitting lids.

8.2.38. Any spills during storage or transport must be dealt with immediately as recommended in Section 5.8.

8.2.39. When a patient containing unsealed radioactive material is transported within the hospital, containers as described in Section 8.2.37. should be provided for the transport of any bottles containing radioactive urine. In the event of any spill occurring, or, for example, of the patient vomiting, immediate action must be taken as described in Section 5.8.

8.3. *Transport of radioactive materials outside hospitals*

8.3.1. The transport of radioactive materials outside hospital premises must be in accordance with the current regulations or codes of practice relating to the various means of transport used and it is the responsibility of the Radiological Safety Officer to ensure this.

8.3.2. At the present time the road transport of radioactive materials is under consideration while the regulations for rail transport are being revised. It is possible

that there will be differences in detail between the conditions required for these two modes of transport and that there will be further differences from the regulations for air transport. The Radiological Safety Officer must therefore familiarise himself with the relevant sections of the conditions for each form of transport that is used. Some general information is given in Appendix K.

8.4. *Sterilisation of small sealed sources*

8.4.1. It is most important that in sterilising small sealed sources (e.g., radium needles, gold grains etc.), adequate precautions should be taken to avoid (i) radiation exposure of nursing and other staff, (ii) damage to the sources and (iii) loss of sources. There are several satisfactory ways of carrying out such sterilisation, each having particular merit for certain types of work. Special precautions need to be taken with each of the techniques.

Sterilisation by boiling

8.4.2. (i) The design of the steriliser must ensure that the temperature cannot rise above 110 °C, even in the event of it boiling dry.

(ii) So far as is practicable, sterilisers should be screened with lead or other heavy protective material.

(iii) Sterilisers must be provided with traps or other means of preventing sources from being lost down the drainhole.

Chemical sterilisation

8.4.3. (i) Sources should be immersed in a sterilising solution for an appropriate time before being used.* The containers in which sources are stored during sterilisation should be adequately screened by lead or other heavy protective material.

(ii) Some sterilising solutions may attack the enamel used to identify some radium appliances and any

* A suitable solution consists of $\frac{1}{200}$ (0·5%) Chlorhexidine $+\frac{1}{100}$ (1·0%) Cetrimide in 70% methylated spirit. Appliances should be immersed for 5 minutes and then rinsed with sterile water.

damage of this type noted must be reported at once to the custodian.

Hot air sterilisation

8.4.4. Some sources, particularly gold grains in magazines, can be conveniently sterilised in hot air. This method must never be used for radium or radon. Hot air sterilising ovens should be so designed that the sources are completely enclosed by an adequate lead screen during sterilising procedures.

Sterilisation by radiation

8.4.5. It is possible that in the future some sterilisation by radiation will come into use.

9. Disposal of Radioactive Waste

9.1. *Explanation of legal implications*

9.1.1. The Radioactive Substances Act, 1960, requires in general that persons who keep or use radioactive materials on any premises which are used for the purposes of an undertaking must register with the Minister of Housing and Local Government (in Scotland, the Secretary of State and in Northern Ireland, the Minister of Health and Local Government).

National Health Service Hospitals are specifically exempted from this provision*, but arrangements have been made to ensure that these Ministers are kept informed of all such hospitals which keep or use radioactive materials. The exemption does not extend to other hospitals or premises.

9.1.2. The Act requires also that authorisations must be obtained from these Ministers for the accumulation and/or disposal of radioactive waste; and, unless the contrary is proved, accumulation is to be presumed if any substance resulting from the keeping or use of radioactive material is retained for more than three months. It is an offence to accumulate or to dispose of waste if an authorisation has not been given or, if one

* The corresponding hospitals in Northern Ireland are not exempted.

has been given, otherwise than in accordance with the conditions specified in it.

Unless the accumulation or disposal has been exempted by order made under the Act, National Health Service Hospitals must apply for an authorisation to the appropriate Minister, from whom advice on how to make the application can be obtained. Minor disposals of radioactive waste, including thorium-X, have, subject to certain conditions, been exempted by orders from the authorisation requirements; a summary of the effect of these orders is given in Section 9.3.

It will be the duty of the Controlling Authority to ensure that an authorisation is obtained, to specify internal hospital rules to ensure that its conditions are observed and to check periodically that the rules are being followed.

9.2. *General guidance*

9.2.1. The general government policy governing disposals has been propounded in the White Paper " The Control of Radioactive Wastes " (Cmnd. 884, H.M.S.O., 1959). Where it is safe and practicable to do so, local methods for disposal of ordinary waste should be used, since they are usually inexpensive and often give adequate dilution or dispersal. Where this is not possible, special disposal arrangements are available which utilise the disposal facilities of the United Kingdom Atomic Energy Authority. Details of these arrangements may be obtained from the Ministry of Housing and Local Government, the Scottish Development Department or the Ministry of Health and Local Government for Northern Ireland.

The White Paper gives some guidance on the levels of activity which can in general be disposed of with ordinary waste. The authorisations and the conditions imposed by the authorisations will be based on this general

guidance but they will have regard to the local conditions, which may affect permissible levels. Local conditions vary so widely that general conditions may frequently be modified.

9.2.2. It is convenient to recognise the following types of radioactive waste which may occur in hospitals

(i) sealed sources;

(ii) excreta from patients treated with radionuclides;

(iii) unwanted solutions of radionuclides intended for therapeutic use;

(iv) normal low-level liquid waste, e.g. from washing of apparatus;

(v) normal low-level solid waste, e.g. paper, glass;

(vi) waste from spills and decontamination; and

(vii) gases.

9.2.3. Waste sealed sources are easily contained and managed but may present a hazard if set aside unlabelled and forgotten. They should be clearly labelled and stored until by decay the activity is reduced to a level (say, about 10 microcuries) which permits disposal with ordinary waste or they should be disposed of at once by the special disposal service. It is important that a decision should be taken as soon as they are recognised as waste and action taken to implement the decision with reasonable speed.

9.2.4. The collection of radioactive excreta from patients and its storage occasion irradiation of nurses and other hospital workers and increase the risk of spills. The nature of this material makes its storage undesirable in hospitals, unless good reasons for storage can be adduced. In most cases, disposal to a sewerage system will afford sufficient dilution to make irradiation of sewer workers and sewage disposal workers negligible. Since most of the big cities in the United Kingdom drain to the sea, to estuaries and to rivers not used as drinking water supplies, there will not usually be any significant hazard. Accord-

ingly at the present levels of use of the relatively short-lived radionuclides now employed in hospitals, excreta from patients should be disposed of to the sewer.

A convenient number of water closets should be reserved for these patients and activity levels should be checked periodically. The drains serving the closets should be regarded as drains from a radioactive laboratory and if repairs are necessary, they should be done under the supervision of the Radiological Safety Officer and measurements of radiation levels should be made as the drain is opened up.

9.2.5. It may occasionally happen that rather larger amounts of activity, for example, of radioiodine and radiogold, are left over or unused. The solutions are in a readily manageable form and of sufficiently short half-life to render storage for decay convenient. They should be stored till their activity permits disposal to the sewer.

9.2.6. The liquid waste normally resulting from the simple operations involved in dispensing and making up solutions for hospital use is of low activity and suitable for disposal to the sewer.

9.2.7. The solid waste normally occurring, comprising paper tissues, swabs, glassware and similar materials, is of low activity, usually only a few microcuries, and suitable for disposal with ordinary refuse. Occasionally more active items arise, e.g. bed linen from incontinent patients and unwanted or broken applicators. Care should be taken to segregate contaminated clothing and linen for treatment as indicated in Section 5.7.14. Applicators should be stored till decay permits disposal in accordance with the authorisation or be disposed of by the special disposal service.

9.2.8. The nature and consequences of spills and accidents can hardly be foreseen and useful general rules are not readily formulated. So far as is practicable, consistent with the safety of the staff involved and the urgency of the decontamination measures, some thought

should be given to the radioactive waste resulting from the operations. Heavily contaminated swabs and other items should be set aside for storage or special disposal.

9.2.9. Generally the only significant gaseous wastes resulting from normal hospital use of radioactive materials are exhausts from stores, especially radium stores, and from fume cupboards and emissions from incinerators. It is important that the points of release to the atmosphere should be carefully sited. They should not be in positions where the radioactive wastes can be carried into occupied rooms, e.g. by eddy currents. Preferably they should be above eaves level. Radiation and contamination levels near them should be checked periodically by the Radiological Safety Officer. (See Section 5.2.8. to 5.2.11., regarding the provision of fume hoods.)

9.2.10. In some hospitals research activities may create wastes outside the categories listed in Section 9.2.2. Often the research may involve only tracer levels of radionuclides and normal methods of refuse disposal may be adequate, e.g., incineration of combustible waste contaminated by carbon-14, tritium and even millicurie amounts of iodine-131 with ordinary refuse may provide conditions for adequate dispersal of the radionuclides in the atmosphere.

Incineration of refuse containing non-volatile radionuclides concentrates the activity in the ash and ash of undesirably high activity in a not easily controllable state may be produced. For wastes which cannot be disposed of by normal methods, the special disposal service should be used.

9.3. *Exemption Orders*

9.3.1. A summary of the Exemption Orders* which have been made under the Radioactive Substances Act, 1960, relating to minor discharges of radioactive wastes from hospitals and to the use of thorium-X is given below.

9.3.2. Under the Hospitals' Waste Exemption Orders, radioactive waste arising on the premises of a hospital from the medical treatment of human beings, being waste containing no alpha-emitters and no strontium-90, may be disposed of without authorisation

(i) by means of the local authority refuse disposal service or to a tip used normally for inactive refuse provided that in any container at the time of disposal the activity is not greater than 10 microcuries, that the activity of any article is not greater than 1 microcurie and that the volume of refuse is not less than 3 cubic feet;

(ii) by burning on the premises, provided the activity burnt is not greater than 30 microcuries in any day; and

(iii) by discharge to the foul water drainage system provided that in any four consecutive weeks the activity does not exceed 10 millicuries if the system connects to a public sewer or 2 millicuries if it does not.

It is a condition of exemption that records of the amounts disposed of are kept; the amounts may be estimated in any generally accepted manner.

*The Radioactive Substances (Hospitals' Waste) Exemption Order 1963 (S.I.1963/1833).
The Radioactive Substances (Hospitals' Waste) Exemption (Scotland) Order 1963 (S.I. 1963/1879. (S.96)).
The Radioactive Substances (Hospitals' Waste) Exemption Order (Northern Ireland) 1963 (S.R. & O. (NI) 1963 No. 217)
The Radioactive Substances (Thorium-X) Exemption Order 1963 (S.I. 1963/1834)
The Radioactive Substances (Thorium-X) Exemption (Scotland) Order 1963 (S.I. 1963/1880 (S.97)).
The Radioactive Substances (Thorium-X) Exemption Order (Northern Ireland) 1963. S.R. & O. (NI) 1963 No. 221).

9.3.3. The Thorium-X Exemption Orders provide that radioactive waste arising on the premises of a hospital from the use of ointments or solutions of thorium-X for the medical treatment of human beings may be disposed of without authorisation

(i) by means of the local authority refuse disposal service or to a tip used normally for inactive refuse provided the activity does not exceed 10 microcuries of thorium-X in any week;

(ii) by burning on the premises without condition (but the disposal of incinerator ash is subject to the previous limit); and

(iii) by discharge to the foul water drainage system provided the activity does not exceed 100 microcuries of thorium-X in any week.

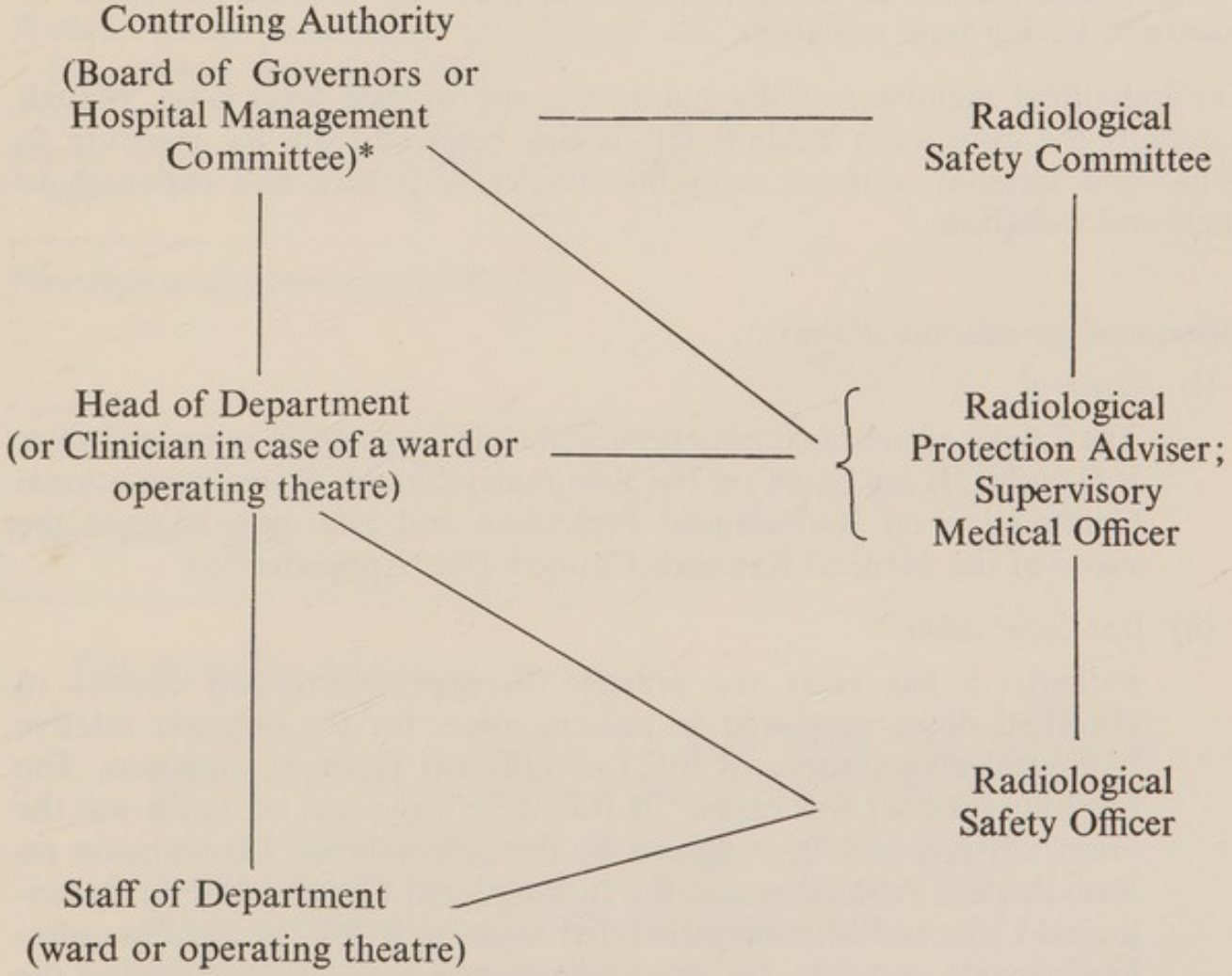
These conditions also apply to premises of medical practioners and of pharmacists.

The appropriate orders should be consulted for the precise conditions subject to which exemption is granted.

Appendix A

Responsibility for Radiological Safety Arrangements

The example below indicates the type of administrative organisation suitable in large National Health Service Hospitals. Some modification may be necessary in smaller hospitals.



* In Scotland, Board of Management.

Appendix B

Maximum Permissible Doses

1. *Additivity of doses*

For the levels of exposure given in Tables B II and B III, the total dose in any organ or tissue due to exposure of "designated persons" or "other staff" while at work must comprise the dose received from external sources during working hours and the dose contributed by internal sources taken into the body during working hours. The total dose must not include any medical exposure or exposure to background radiation.

For individual members of the public the appropriate total dose, though numerically the same as in Table B III, is that received from all exposure to external and internal sources, excepting medical exposure and exposure to background radiation.

2. *Maximum permissible doses*

(i) *General*

The values of the maximum permissible doses given in rems in Tables B II and B III are based on the Recommendations of the International Commission on Radiological Protection and take into account the views of the Medical Research Council. (See Appendix N.)

(ii) *Dose equivalent*

Hitherto it has been the practice to apply correction factors to absorbed doses measured in rads to allow for the different relative biological effectiveness (R.B.E.) of different types of radiation. The resulting product was called "R.B.E. dose", the unit of which was the "rem". It has now been agreed by the International Commission on Radiological Protection and the International Commission on Radiological Units and Measurements that the term R.B.E. be used in radiobiology only and that, for protection purposes, the factor be called the "quality factor" (QF). It has also been agreed that for protection purposes, it is useful to define a quantity which will be termed the "dose equivalent" (DE),where DE is the product of the absorbed dose, the quality factor, a dose distribution factor (DF) which expresses the

modification of biological effect due to non-uniform distribution of internally deposited isotopes and other necessary modifying factors. The unit of dose equivalent is the "rem".

In Table B I are given the values of QF for certain types of radiation.

TABLE B I

Values of quality factor used in defining maximum permissible doses

Type of radiation	Quality factor
X-rays; γ-rays; electrons; and β-rays with E_{max} greater than 0·03 MeV	1·0
β-rays with E_{max} not greater than 0·03 MeV	1·7
Neutrons and protons up to 10 MeV	10 (30 in the case of irradiation of the eyes)
Naturally occurring α-particles	10
Heavy recoil nuclei	20

(iii) *Doses for designated persons*

The values of the maximum permissible doses for various body organs and tissues of designated persons are given in Table B II.

If no information is available as to the doses that a designated person has received during any periods of employment in that category it must be assumed that the person has received the maximum doses permitted during those periods. Persons who were exposed in accordance with former I.C.R.P. values for maximum permissible weekly dose and who may, therefore, have accumulated a dose higher than that permitted by the formula in Table B II must not be exposed at a rate higher than 5 rems in any one year.

TABLE B II

Maximum permissible doses for designated persons

Exposed part of body	Persons over 18 years of age	Persons between 16 and 18 years of age
Whole body, blood-forming organs, and gonads	Cumulative dose = 5 (N-18) rems where N is age in years;* 3 rems/calendar quarter**	1·5 rems/year***
Bone, thyroid and skin of whole body	8 rems/calendar quarter; 30 rems/year	3 rems/year
Any single organ (excluding blood-forming organs, gonads, bone, thyroid and skin of whole body)	4 rems/calendar quarter; 15 rems/year	1·5 rems/year
Hands, forearms, feet and ankles	20 rems/calendar quarter; 75 rems/year	7·5 rems/year

*This formula indicates an average dose to the whole body, blood forming organs and gonads of 5 rems per year. Provided the cumulative dose permitted by the formula is not exceeded, a designated person may receive a dose not in excess of 3 rems during any calendar quarter. If necessary, the 3 rems may be received as a single dose but this practice should be avoided as far as practicable, especially in the case of women of reproductive age.

**If there is reason to suppose that doses are being accumulated at grossly irregular rates, a period of 13 consecutive weeks should be used instead of a calendar quarter.

***Exposure of the whole body, blood-forming organs and gonads subsequent to the period 16 to 18 years of age should be controlled so that the dose accumulated up to 30 years of age does not exceed 60 rems.

The dose to the whole body, blood-forming organs and gonads from all *accidental exposure* must be added to the occupational dose received up to the time of the accident. If the sum then exceeds that permitted in the light of the person's age, the excess must be redressed by lowering the subsequent exposure rate so that within a period not exceeding 5 years the accumulated dose will conform with the limit set by the person's age.

Work involving *emergency exposure* above the normal permissible limits must be planned on the basis that the individual will not receive a dose to the whole-body, blood-forming organs and gonads in excess of 12 rems. This must be added to the occupational dose accumulated

up to the time of the emergency. If the sum then exceeds that permissible in the light of the person's age, the excess must be redressed by lowering the subsequent exposure so that within a period not exceeding 5 years, the accumulated dose will conform with the limit set by the person's age. Women of reproductive age must not be subjected to such emergency exposure.

(iv) *Doses for "other staff"*

A person who is classified as a member of other staff must not receive, in any one year, doses in excess of the values listed in Table B III.

TABLE B III

Maximum permissible doses for other staff

Exposed part of body	Dose in 1 year (in rems)
Whole body, blood-forming organs and gonads	1·5
Bone, thyroid and skin of whole body	3
Any single organ excluding blood-forming organs, gonads, bone, thyroid or skin of whole body	1·5
Hands, forearms, feet and ankles	7·5

(v) *Doses for patients*

The normal concept of "maximum permissible dose" is not applicable in the case of patients undergoing diagnostic examination or therapy with ionising radiations. It is nevertheless desirable to limit the exposure of patients to the minimum value consistent with medical requirements.

(vi) *Doses for persons not included in (iii), (iv) and (v).*

Persons in this category must not receive, in any one year, doses in excess of the values permitted to the various body organs and tissues of persons classified as other staff (Table B III).

Appendix C

Maximum Permissible Body Burdens and Maximum Permissible Concentrations in Air and Water of the Various Radionuclides at present being used in Hospitals

As indicated by the International Commission on Radiological Protection, the assessment of the maximum permissible body burden and maximum permissible concentration in air and in water of any particular radionuclide should ideally be based on clinical studies of human beings who have been exposed to that radionuclide under working conditions for an extended period of time comparable with that which typifies average occupational exposure. However, only in the case of radium is there clinical evidence of effects on human beings for as long as 50 years, which is the appropriate period for selecting values for long-term exposure. This has to some extent been supplemented by the knowledge gained from the therapeutic administration of radionuclides or from accidents in which radionuclides have been taken into the body. For the majority of radionuclides human data are lacking, but for those radionuclides which have been used in animal experiments, the I.C.R.P. has extrapolated the data to man.

In Table C I are given the recommended values of maximum permissible body burdens and of the maximum permissible concentrations in air and in water of the various radionuclides at present in use in hospitals. Most of these values are taken from the Recommendations of the I.C.R.P., listing those organs for which the values for soluble and insoluble compounds are lowest. Where no I.C.R.P. value is available, assessments have been made, using the I.C.R.P. concepts.

TABLE C I

Maximum permissible body burdens and maximum permissible concentrations (40-hour week) in air and water

Radionuclide	Critical Organ	Maximum permissible body burden (in μc)	Maximum permissible concentrations (in μc/cm³)	
			In air	In water
H-3				
As tritiated water (sol)	Body tissue	10^3	5×10^{-6}	0·1
As tritium gas (submersion)	Skin	—	2×10^{-3}	—
C-14 as CO_2 (sol)	Fat	300	4×10^{-6}	0·02
(submersion)	Total Body	—	5×10^{-5}	—
*0-15 (sol)	Total Body	14	10^{-3}	—
(insol)	Lung	—	9×10^{-3}	9
F-18 (sol)	G.I. (SI)	—	—	0·02
(insol)	G.I. (ULI)	—	—	0·01
Na-22 (sol)	Total Body	10	2×10^{-7}	10^{-3}
(insol)	Lung	—	9×10^{-9}	—
	G.I. (LLI)	—	—	9×10^{-4}
Na-24 (sol)	G.I. (SI)	—	10^{-6}	6×10^{-3}
(insol)	G.I. (LLI)	—	10^{-7}	8×10^{-4}
P-32 (sol)	Bone	6	7×10^{-8}	5×10^{-4}
(insol)	Lung	—	8×10^{-8}	—
	G.I. (LLI)	—	—	7×10^{-4}
S-35 (sol)	Testis	90	3×10^{-7}	2×10^{-3}
(insol)	Lung	—	3×10^{-7}	—
	G.I. (LLI)	—	—	8×10^{-3}
Cl-36 (sol)	Total Body	80	4×10^{-7}	2×10^{-3}
(insol)	Lung	—	2×10^{-8}	—
	G.I. (LLI)	—	—	2×10^{-3}
Cl-38 (sol)	G.I. (S)	—	3×10^{-6}	0·01
(insol)	G.I. (S)	—	2×10^{-6}	0·01
K-42 (sol)	G.I. (S)	—	2×10^{-6}	9×10^{-3}
(insol)	G.I. (S)	—	10^{-7}	6×10^{-4}

* Assessed by the Radiological Protection Service.

Radionuclide		Critical Organ	Maximum permissible body burden (in μc)	Maximum permissible concentrations (in μc/cm³)	
				In air	In water
*K-43	(sol)	Total Body	20	3×10^{-6}	2×10^{-2}
	(insol)	G.I. (S)	—	10^{-6}	2×10^{-5}
Ca-45	(sol)	Bone	30	3×10^{-8}	3×10^{-4}
	(insol)	Lung	—	10^{-7}	—
		G.I. (LLI)	—	—	5×10^{-3}
Ca-47	(sol)	Bone	5	2×10^{-7}	10^{-3}
	(insol)	Lung	—	2×10^{-7}	—
		G.I. (LLI)	—	2×10^{-7}	10^{-3}
Cr-51	(sol)	G.I. (LLI)	—	10^{-5}	0·05
		Total Body	800	10^{-5}	—
	(insol)	Lung	—	2×10^{-6}	—
		G.I. (LLI)	—	—	0·05
*Fe-52	(sol)	G.I. (ULI)	—	—	9×10^{-4}
	(insol)	G.I. (ULI)	—	10^{-7}	8×10^{-4}
		Lung	—	5×10^{-6}	—
Fe-55	(sol)	Spleen	10^3	9×10^{-7}	0·02
	(insol)	Lung	—	10^{-6}	—
		G.I. (LLI)	—	—	0·07
Fe-59	(sol)	Spleen	20	10^{-7}	—
		G.I. (LLI)	—	—	2×10^{-3}
	(insol)	Lung	—	5×10^{-8}	—
		G.I. (LLI)	—	—	2×10^{-3}
*Co-56	(sol)	G.I. (LLI)	—	—	2×10^{-3}
	(insol)	G.I. (LLI)	—	—	10^{-3}
		Lung	—	3×10^{-8}	—
Co-57	(sol)	G.I. (LLI)	—	3×10^{-6}	0·02
	(insol)	Lung	—	2×10^{-7}	—
		G.I. (LLI)	—	—	0·01
Co-58	(sol)	G.I. (LLI)	—	8×10^{-7}	4×10^{-3}
	(insol)	Lung	—	5×10^{-8}	—
		G.I. (LLI)	—	—	3×10^{-3}
Co-60	(sol)	G.I. (LLI)	—	3×10^{-7}	10^{-3}
	(insol)	Lung	—	9×10^{-9}	—
		G.I. (LLI)	—	—	10^{-3}
Ni-65	(sol)	G.I. (ULI)	—	9×10^{-7}	4×10^{-3}
	(insol)		—	5×10^{-7}	3×10^{-3}

* Assessed by the Radiological Protection Service.

Radionuclide		Critical Organ	Maximum permissible body burden (in μc)	Maximum permissible concentrations (in μc/cm³)	
				In air	In water
Cu-64	(sol)	G.I. (LLI)	—	2×10^{-6}	0·01
	(insol)		—	10^{-6}	6×10^{-3}
Zn-65	(sol)	Total Body	60	10^{-7}	3×10^{-3}
		Prostate	70	10^{-7}	—
		Liver	80	10^{-7}	—
	(insol)	Lung	—	6×10^{-8}	—
		G.I. (LLI)	—	—	5×10^{-3}
Ge-71	(sol)	G.I. (LLI)	—	10^{-5}	0·05
	(insol)	Lung	—	6×10^{-6}	—
		G.I. (LLI)	—	—	0·05
As-74	(sol)	G.I. (LLI)	—	3×10^{-7}	2×10^{-3}
	(insol)	Lung	—	10^{-7}	—
		G.I. (LLI)	—	—	2×10^{-3}
As-76	(sol)	G.I. (LLI)	—	10^{-7}	6×10^{-4}
	(insol)		—	10^{-7}	6×10^{-4}
Br-82	(sol)	Total Body	10	10^{-6}	8×10^{-3}
	(insol)	G.I. (LLI)	—	2×10^{-7}	10^{-3}
Kr-85	(submersion)	Total Body	—	10^{-5}	—
Rb-86	(sol)	Total Body	30	3×10^{-7}	2×10^{-3}
		Pancreas	30	3×10^{-7}	2×10^{-3}
	(insol)	Lung	—	7×10^{-8}	—
		G.I. (LLI)	—	—	7×10^{-4}
Sr-85	(sol)	Total Body	60	2×10^{-7}	3×10^{-3}
	(insol)	Lung	—	10^{-7}	—
		G.I. (LLI)	—	—	5×10^{-3}
Sr-90	(sol)	Bone	2	3×10^{-10}	4×10^{-6}
	(insol)	Lung	—	5×10^{-9}	—
		G.I. (LLI)	—	—	10^{-3}
Y-90	(sol)	G.I. (LLI)	—	10^{-7}	6×10^{-4}
	(insol)			10^{-7}	6×10^{-4}
Nb-95	(sol)	Total Body	40	5×10^{-7}	—
		G.I. (LLI)	—	—	3×10^{-3}
	(insol)	Lung	—	10^{-7}	—
		G.I. (LLI)	—	—	3×10^{-3}

Radionuclide		Critical Organ	Maximum permissible body burden (in μc)	Maximum permissible concentrations (in μc/cm³)	
				In air	In water
Ru-103	(sol)	G.I. (LLI)	—	5×10^{-7}	2×10^{-3}
	(insol)	Lung	—	8×10^{-8}	—
		G.I. (LLI)	—	—	2×10^{-3}
Ag-110 m	(sol)	G.I. (LLI)	—	2×10^{-7}	9×10^{-4}
	(insol)	Lung	—	10^{-8}	—
		G.I. (LLI)	—	—	9×10^{-4}
Ag-111	(sol)	G.I. (LLI)	—	3×10^{-7}	10^{-3}
	(insol)		—	2×10^{-7}	10^{-3}
Te-132	(sol)	G.I. (LLI)	—	2×10^{-7}	9×10^{-4}
	(insol)		—	10^{-7}	6×10^{-4}
*I-124	(sol)	Thyroid	0·7	10^{-8}	10^{-4}
	(insol)	G.I. (LLI)	—	4×10^{-7}	2×10^{-3}
*I-130	(sol)	Thyroid	0·4	6×10^{-8}	4×10^{-4}
	(insol)	G.I. (ULI)	—	2×10^{-6}	10^{-3}
I-131	(sol)	Thyroid	0·7	9×10^{-9}	6×10^{-5}
	(insol)	G.I. (LLI)	—	3×10^{-7}	2×10^{-3}
		Lung	—	3×10^{-7}	—
I-132	(sol)	Thyroid	0·3	2×10^{-7}	2×10^{-3}
	(insol)	G.I. (ULI)	—	9×10^{-7}	5×10^{-3}
Xe-133	(submersion)	Total Body	—	10^{-5}	—
Cs-134	(sol)	Total Body	20	4×10^{-8}	3×10^{-4}
	(insol)	Lung	—	10^{-8}	—
		G.I. (LLI)	—	—	10^{-3}
Cs-137	(sol)	Total Body	30	6×10^{-8}	4×10^{-4}
	(insol)	Lung	—	10^{-8}	—
		G.I. (LLI)	—	—	10^{-3}
Ba-140	(sol)	Bone	4	10^{-7}	—
		G.I. (LLI)	—	—	8×10^{-4}
	(insol)	Lung	—	4×10^{-8}	—
		G.I. (LLI)	—	—	7×10^{-4}
La-140	(sol)	G.I. (LLI)	—	2×10^{-7}	7×10^{-4}
	(insol)		—	10^{-7}	7×10^{-4}

* Assessed by the Radiological Protection Service.

Radionuclide		Critical Organ	Maximum permissible body burden (in μc)	Maximum permissible concentrations (in μc/cm³)	
				In air	In water
Ce-141	(sol)	Liver	30	4×10^{-7}	—
		G.I. (LLI)	—	—	3×10^{-3}
	(insol)	Lung	—	2×10^{-7}	—
		G.I. (LLI)	—	—	3×10^{-3}
Ce-144	(sol)	Bone	5	10^{-8}	—
		G.I. (LLI)	—	—	3×10^{-4}
	(insol)	Lung	—	6×10^{-9}	—
		G.I. (LLI)	—	—	3×10^{-4}
Pm-147	(sol)	Bone	60	6×10^{-8}	—
		G.I. (LLI)	—	—	6×10^{-3}
	(insol)	Lung	—	10^{-7}	—
		G.I. (LLI)	—	—	6×10^{-3}
Tm-170	(sol)	Bone	9	4×10^{-8}	—
		G.I. (LLI)	—	—	10^{-3}
	(insol)	Lung	—	3×10^{-8}	—
		G.I. (LLI)	—	—	10^{-3}
Lu-177	(sol)	G.I. (LLI)	—	6×10^{-7}	3×10^{-3}
	(insol)		—	5×10^{-7}	3×10^{-3}
Ta-182	(sol)	Liver	7	4×10^{-8}	—
		G.I. (LLI)	—	—	10^{-3}
	(insol)	Lung	—	2×10^{-8}	—
		G.I. (LLI)	—	—	10^{-3}
Ir-192	(sol)	Kidney	6	10^{-7}	—
		G.I. (LLI)	—	—	10^{-3}
	(insol)	Lung	—	3×10^{-8}	—
		G.I. (LLI)	—	—	10^{-3}
Au-198	(sol)	G.I. (LLI)	—	3×10^{-7}	2×10^{-3}
	(insol)		—	2×10^{-7}	10^{-3}
Hg-203	(sol)	Kidney	4	7×10^{-8}	5×10^{-4}
	(insol)	Lung	—	10^{-7}	—
		G.I. (LLI)	—	—	3×10^{-3}
Tl-204	(sol)	Kidney	10	6×10^{-7}	—
		G.I. (LLI)	—	—	3×10^{-3}
	(insol)	Lung	—	3×10^{-8}	—
		G.I. (LLI)	—	—	2×10^{-3}
Rn-222		Lung	—	3×10^{-8}	—

Radionuclide		Critical Organ	Maximum permissible body burden (in μc)	Maximum permissible concentrations (in μc/cm³)	
				In air	In water
Ra-224 (Th-X)	(sol)	Bone	0·06	5×10^{-9}	7×10^{-5}
	(insol)	Lung	—	7×10^{-10}	—
		G.I. (LLI)	—	—	2×10^{-4}
Ra-226	(sol)	Bone	0·06	3×10^{-11}	4×10^{-7}
	(insol)	Lung	—	4×10^{-11}	—
		G.I. (LLI)	—	—	7×10^{-4}

Appendix D

Permissible Levels of Contamination

1. The maximum permissible level of contamination so fixed that it cannot be removed by normal cleaning must be such as will ensure that no person can receive any radiation doses in excess of those permitted.

The maximum permissible levels of contamination not known to be fixed to the surface must be as follows:

TABLE D I

Maximum permissible levels of contamination

Class of radioactive isotope (See Table I)	Site	
	Parts of body; personal clothing; hospital bedding; "inactive" areas	Personal protective equipment; "active" areas; glassware; tools*
1	*a*-emitters: $10^{-5}\mu c/cm^2$ β-emitters: $10^{-4}\mu c/cm^2$	*a*-emitters: $10^{-4}\mu c/cm^2$ β-emitters: $10^{-3}\mu c/cm^2$
2 3 4	$10^{-4}\mu c/cm^2$	$10^{-3}\mu c/cm^2$

*The contamination levels given in the last column of the table do not apply in the case of surfaces or equipment inside fume cupboards and closed boxes. In such cases the contamination level should be kept to the minimum that is practicable.

Results may be averaged over an area not exceeding 100 cm^2 for parts of the body (300 cm^2 in the case of the hands), over an area not exceeding 1000 cm^2 for floors, walls and ceilings, and over an area not exceeding 300 cm^2 in other cases.

In close contact with a contaminated surface, a β-activity of $10^{-4}\mu c/cm^2$ gives about 1 mrad/h (delivered to soft tissue).

2. Examples of instruments required for various monitoring purposes are given below:

(i) *Ionisation chamber dose-rate meter:—*
An instrument is available commercially, which has ranges of 0 to 3

mrad/h, 0 to 30 mrad/h and 0 to 300 mrad/h and has a reasonably uniform response to X- and γ- radiations down to energies of about 15 keV.

(ii) *Contamination monitors with* α- *and* β-*probes*:—
A.E.R.E. Type Nos. 1320 and 1650.

(*Note:* A.E.R.E. Type No. 1021 is no longer available, being replaced by A.E.R.E. Type No. 1650 which is commercially available).

There is also available commercially a portable contamination monitor for simultaneous monitoring of alpha and beta/gamma contamination. This has a range of 0 to 5000 counts/sec.

(iii) *Hand and clothing monitor:*—

Floor standing hand and clothing monitors are available commercially.

A bench-mounted single-hand monitor is also available.

(iv) *Air Monitor:*—

Portable sampler—A.E.R.E. Type No. 1355

Appendix E

Transfer Record for Designated Persons

1. Full names of worker
2. Sex
3. Private address of worker
4. Date of birth of worker
5. National Insurance number
6. Name of employer
7. Address of place of employment
   (6 and 7 refer to the employment which the worker is about to leave)
8. *Periods during which:

(*a*) The worker was in employment as designated person or former equivalent status		(*b*) External radiation doses were recorded	
From	To	From	To

*These must include work as a designated person or former equivalent status prior to the work the person concerned is leaving.

9. External dose record (whole body):

	X, γ and β (rads in air)*	X and γ (rads in air)*	neutrons (rems)
Cumulative total dose from commencement of first employment as designated person up to the end of the last completed calendar quarter			
Dose received during the current calendar quarter			

*Please state dose units used if they are not " rads in air ". Also indicate what allowance has been made for periods when employed as a designated person, or former equivalent status, but not subjected to dose measurements.

10. External dose record (for parts of body other than the trunk).
If the designated person has any record (additional to that given in section 9) of doses received by hands, forearms, feet and ankles, please state these doses in the same way as in section 9.

11. Please give any information available under the following sections:

(i) Any record of doses estimated from past or present deposition in the body of radioactive material.

(ii) Any occurrence of exposure in excess of the values of maximum permissible doses given in Appendix B.

(iii) Any other relevant information.

Date.....

Signed.....

(on behalf of
Employing Authority).....

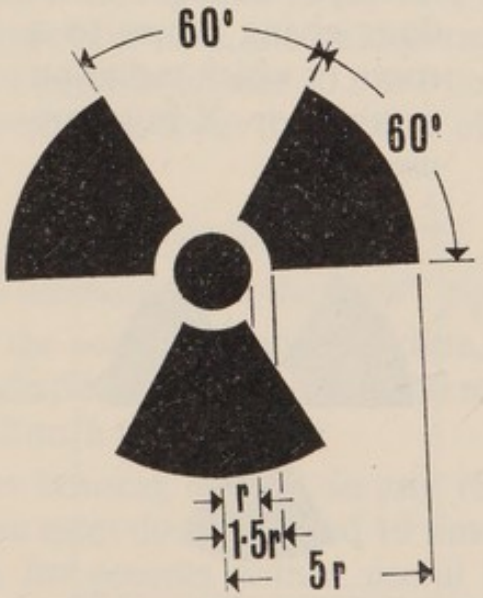
Appendix F

Symbol to Indicate Ionising Radiations

A British Standard specification for symbols to denote the actual or potential presence of ionising radiations and to identify objects, devices, materials or combinations of materials which emit ionising radiations has been drawn up. The Standard does not specify any radiation levels at which symbols are to be used.

Shape and proportions

The basic symbol is of the following design:—



Colours

The areas above shown shaded are coloured black. The symbol must be placed on a yellow background, of a colour approximating to colour No. 309 of B.S.381C*, of sufficient area for it to be distinctive.

Application to medical and dental use

The standard allows appropriate wording or other symbols to be used in association with the basic symbol, but for medical and dental use it is recommended that words only should be added. Wording might be used to indicate the nature of the source of radiation, the type of radiation, the limits of time which may be spent in the proximity, etc.

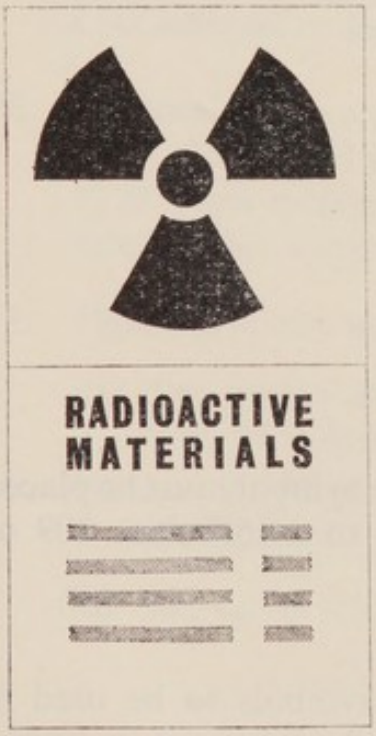
* B.S.381C—Colours for ready-mixed paints

General

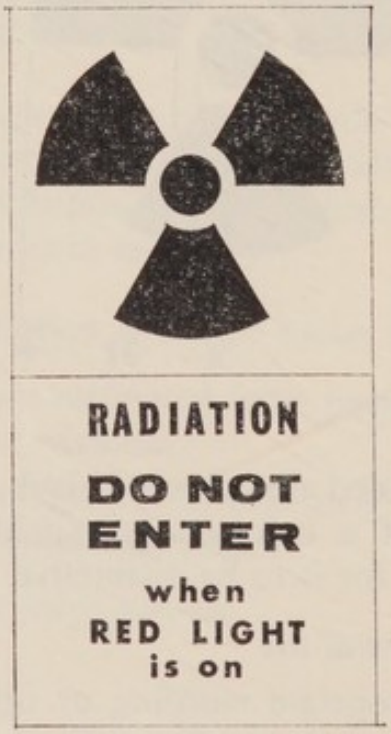
The basic symbol must be used only to signify the actual or potential presence of ionising radiations. It must be as prominent as is practical, and of a size consistent with the size of the equipment or material to which it is affixed or attached, providing that the proportions shown above are maintained. The symbol must be recognisable from a safe distance. There is no preferred orientation: it may be used with "one blade up" or "two blades up", as convenient. Any wording added to the symbol must not detract from its clarity, e.g. by being larger or more brightly coloured. No lettering should be superimposed on the symbol, and any wording used must be kept to the minimum necessary.

The following are some applications of the symbol:—

Example 1. Sign on a storage cabinet for radioactive materials.



Example 2. Sign on a door giving access to a room in which radiation sources or X-rays are used.



Example 3. Label on a bottle containing radioactive solution.

Appropriate words may be added as indicated

Appendix G
Tube and Source Housings

1. *Diagnostic-type tube housing* (see Section 3.11.1.)

The protective housing of a diagnostic X-ray tube should be so constructed that, at every specified rating of the tube, the leakage radiation at a focal distance of 1 metre, does not exceed 100 mr in 1 hour.

(X-ray tubes are now available in which the leakage does not exceed 10 mr in 1 hour at 1 metre. As old tubes are replaced, new tubes of this standard should be installed).

2. *Therapeutic-type tube housing* (see Section 4.1.1.)

The protective housing of a therapeutic X-ray tube should be so constructed that, at every specified rating of the tube, the leakage radiation at a focal distance of 1 metre does not exceed 1 r in 1 hour, nor 30 r in 1 hour at any point accessible to the patient at a distance of 5 cm from the surface of the housing or its accessory equipment.

3. *Teletherapy-type source housing* (see Section 4.2.1.)

(i) With the beam control mechanism in the "OFF" position

(a) at 1 metre from the source, in any direction, the maximum dose-rate of the leakage radiation does not exceed 10 mr/h nor does the average dose-rate exceed 2 mr/h and

(b) at 5 cm from the housing surface, in any readily accessible position the respective dose rates do not exceed 10 times the above values in the case of housings for sources with a useful beam dose-rate of more than 100 r/h at 1 metre from the source, or do not exceed 20 times the above values, in the case of housings for sources with a useful beam dose-rate of less than 100 r/h at 1 metre from the source.

(ii) With the beam control mechanism in the "ON" position

(a) in the case of housings for sources with a useful beam dose-rate of more than 100 r/h at 1 metre from the source, the maximum dose-rate of the leakage radiation at a source distance of 1 metre does not exceed either 1 r/h or 0.1 per cent of the useful beam dose-rate at 1 metre from the source, whichever is the greater and

(b) in the case of housings for sources with a useful beam dose-rate of less than 100 r/h at 1 metre from the source, no values are recommended but in the design and use of such housings, consideration should be given to minimising the integral dose to the patient from leakage radiation.

Appendix H

Protection of Patients

(See Section 6)

(Recommendations of the Second Report of the Adrian Committee on "Radiological Hazards to Patients" H.M.S.O., 1960)

1. GENERAL

(i) There should be clear-cut clinical indications before any X-ray examination is undertaken, and it should be ascertained whether there has been any previous radiological examination which would make further examination unnecessary. For this purpose the case sheet should have a section labelled "previous X-rays".

(ii) To reduce unnecessary examinations, arrangements should be made for the ready availability of previous films and for the routine transfer of films from one hospital to another.

(iii) All requests for examinations should state precisely the clinical indications and the information required.

(iv) There should be consultation between clinician and radiologist before extensive or repeated radiological examinations of young individuals are undertaken. It must be realised that radiological exposure is just as much the responsibility of the clinician as of the radiologist.

(v) To reduce the necessity for repeat investigation strict attention should be paid to adequate preparation of the patient before abdominal investigation.

(vi) Special precautions should be adopted in the radiography of pregnant women. Only essential examinations should be carried out during pregnancy and particular care should be taken to avoid irradiation of the foetus whenever possible. In all women of child-bearing age the clinician requesting the examination should never overlook the possibility of early pregnancy.

(vii) Any previous history of radiotherapy should be ascertained before a new course of treatment is undertaken. Permanent records of all radiotherapy should be maintained and be readily available for transfer from one hospital to another.

(viii) Consideration should always be given to alternative methods of treatment before radiotherapy for non-malignant conditions is undertaken.

2. TECHNIQUES

In every radiological examination, care should be taken to reduce to a minimum the irradiation of the gonads. The steps necessary to this end are discussed throughout the Report.

In particular, strict attention should be paid to the following:—

(i) *General to all forms of radiology*

(a) *Limitation of field size*

Strict limitation of field size to the area necessary for the particular examination or treatment should be routinely practised. In diagnostic radiology, this should be done by fitting light beam diaphragms rather than circular cones, particularly when a large field size is used.

(b) *Beam direction*

Whenever possible, the beam should not be directed towards the gonads and this should be borne in mind particularly in examinations or treatments of the limbs, especially of the hands with the patient in the sitting position.

(c) *Gonad shields*

Adequate gonad shields should invariably be used in examinations or treatments which are likely to give a high gonad dose, unless they interfere with the proposed examination or treatment.

(d) *Immobilising devices*

In the examination or treatment of children or patients who need support, mechanical devices to ensure immobilisation should be used.

(ii) *Particular to radiography*

(a) *High speed films and screens*

The use of the fastest films and screens consistent with satisfactory diagnostic value is strongly recommended.

(b) *Automatic timing devices*

Repeat exposures should be kept to a minimum by the use of photoelectric timers or similar devices. Where these are not practicable, accurately preset timing devices should be readily available.

(iii) *Particular to fluoroscopy*

(a) *Limitation of Use*

Fluoroscopy should not be undertaken if the same information can be obtained by radiography. It should not be used for locating metallic foreign bodies at operations as electronic metal-locating equipment is now available.

(b) *Dark adaptation*

No fluoroscopic examination should be undertaken without adequate dark adaptation on the part of the clinician undertaking the examination (at least 10 minutes).

(c) *Automatic switches*

All fluoroscopy machines should be fitted with a clock, or other timing device, which automatically cuts off the beam after a certain time or a certain dose.

(d) *Image intensification*

More general use should be made of image intensification in such examinations as cardiac catheterisation.

There is urgent need for more research into the problems of image intensification for medical purposes.

(iv) *Particular to mass miniature radiography*

In accordance with the recommendations of our Interim Report, chest examinations of pregnant women should not be carried out with mass miniature techniques, but by full size films with strict limitation of field size. For the chest radiography of children and adults of short stature either technique may be used, so long as adequate steps can be taken to exclude the gonads from the X-ray beam; otherwise large films should be used.

(v) *Particular to radiotherapy*

(a) In the treatment of skin conditions, use should always be made of the softest quality of radiation consistent with adequate irradiation of the tissues to be treated.

(b) Radiation should not be applied to the ovaries for the production of a temporary artificial menopause, or for the treatment of infertility.

3. EQUIPMENT

(i) Checks should be made regularly to ensure that all radiological equipment is maintained to the standard laid down in the Code of Practice for the Protection of Persons Exposed to Ionising Radiations*. Obsolete and erratic equipment should be replaced immediately.

(ii) The development of automatic devices, and particularly those which reduce the risks of human error, should be actively encouraged.

4. STAFF and TRAINING

(i) Attention should be given to the provision at all times of adequate medical and technical staff in radiological departments.

(ii) In sparsely populated areas where radiologists or radiographers are not available, training in the safe use of equipment should be given to the general practitioners or nurses who have to carry out any minor X-ray examinations.

(iii) Adequate instruction should be given in the medical and dental undergraduate curricula on the uses and hazards of ionising radiations.

5. SURVEILLANCE

The genetic dose to the population from diagnostic and therapeutic radiology should be kept under effective review by the Health Departments.

* H.M.S.O. 1957. Replaced by this Code.

Appendix I

Discharge of Hospital Patients during Treatment with Radioactive Materials

1. *Introduction*

Details are given below of the basis of the recommendations of Section 7 of the Code and further guidance is given regarding the conditions under which patients being treated with radioactive materials may leave hospital and return to their homes. Information on postmortem examinations, embalming and cremation is given in Appendix J.

2. *Protection Criteria*

The recommendations are based on considerations of the maximum permissible doses for members of the public and the possibility of damage to undeveloped photographic materials. The conditions given in the Code are such that the doses received from any one patient are unlikely to exceed acceptable amounts and it is considered that the chance of any member of the public becoming closely involved with more than one patient is very small indeed. In these circumstances the doses received will be but a small fraction of the permissible doses that may be accumulated over a period of years by individual members of the population.

As regards the drivers of ambulances, their assistants and members of the hospital car service who may be required to convey numbers of radioactive patients each year from treatment centres to their homes, calculations have shown that it is extremely unlikely that the doses recommended for "other staff" (see Appendix B) will be exceeded. If, however, in exceptional circumstances there is a possibility of higher doses being received, it is the responsibility of the Radiological Protection Adviser to advise on the precautions to be adopted.

3. *Journey times*

The recommendations regarding travel home by public transport have been based on a journey time in any one vehicle of 1 hour. If it is known that a journey of substantially longer duration is involved, either the activity on discharge should be limited in proportion, or the patient should return home by other means.

Subsequent journeys by public transport should be limited in duration in accordance with the diminishing activity of the radioactive material. Restrictions can be removed when the activity within the body has fallen to one quarter of the appropriate value in column 2 of Table III. (See Section 7.)

4. *Conduct at home*

On the basis of some simple assumptions as to the time spent at various distances from the patient by members of the family and friends, an estimate can be obtained of the doses likely to be received by these people if the patient were given no instructions as to his subsequent conduct.

Based on the activities given in column 3 of Table III, these calculations yield the following conclusions.

(i) Visitors are unlikely to receive more than 20 mrads from any one of the different types of treatment.

(ii) Children could receive about 1·5 to 2 rads to their eyes and about 200 mrads to their gonads from a patient treated with a superficial implant. Much the greater part of this dose is due to the assumption that unless instructed to the contrary, the patient might play with, nurse or fondle young children. (Patients receiving other types of treatment are considered likely to be too ill to be bothered with children.)

From this it appears that there is no hazard for visitors, but that patients treated with superficial implants should not play with, nurse or fondle children. With regard to the spouse it seems advisable to recommend that he or she, if still of reproductive age, should not share the same bed as the patient. Both these restrictions can be removed when the activity has fallen to one quarter of the appropriate value given in column 3 of Table III.

5. *Visits to places of entertainment*

The only patients likely to wish to visit places of entertainment while the activity of the radioactive material is significant are those treated with superficial implants. During such a visit, a neighbouring person might receive about 20 to 30 mrads. It is considered that no restrictions are necessary.

6. *Return to work*

A patient treated with a superficial implant may feel well enough to return to work. In doing so, the source could deliver up to about 200 mrads

to a nearby workmate during the treatment period. This could cause difficulties in view of the doses permitted in the Factories (Sealed Sources) Regulations*. It is therefore recommended that these patients should not return to work during the treatment period until the activity of the implant has fallen to one quarter of the level given in column 3 of Table III.

7. *Disposal of excreta*

The excreta from patients discharged in accordance with the limits given in Table III can be disposed of via the normal drains. It is felt that normal standards of hygiene will prevent the handling of bed pans or contaminated bed linen from constituting a hazard. Contamination arising from incontinence of the patient is also considered not to constitute a hazard.

8. *Loss of sealed source*

The loss of a sealed source such as a gold grain might constitute a hazard if it is caught up in a person's clothing or if it is picked up by a person ignorant of its nature. For example, a gold grain of activity 100 μc will deliver at 1 cm a γ-ray dose of about 20 rads to complete decay and the β-ray dose rate in contact with such a source will be about 13 rads/h, the total β-ray dose to complete decay being about 1250 rads. Patients with superficial implants of gold grains should only be discharged from hospital when the radiotherapist is satisfied that the nature of the treatment and the dressings are such that the risk of loss of a gold grain is remote. This condition does not apply when the activity of every grain in the implant is less than 10 μc.

* S.I. 1961. No. 1470. Factories—The Ionising Radiations (Sealed Sources) Regulations 1961. S.R. & O. (N.I.) 1962 No. 124. Factories—Ionising Regulations (Sealed Sources) Regulations (Northern Ireland) 1962.

Appendix J

Radiation Hazards During the Disposal of Radioactive Corpses

These hazards were first considered by a Panel set up by the Radioactive Substances Advisory Committee and the recommendations, which were issued in 1959, form the basis of this Appendix.

1. The Radiological Safety Officer of the hospital at which the treatment with radioactive isotopes was given should be consulted on the radiation problems of the disposal of radioactive corpses and on post-mortem procedures.

2. The hazards associated with diagnostic or tracer amounts of radioactive materials are negligible, and no special precautions need be taken.

3. No special precautions are necessary in the direct burial, without embalming, of deceased persons who have received therapeutic doses of radioisotopes.

4. No special precautions are necessary for the post-mortem examination outside treatment centres or the embalming of corpses containing not more than 5 mc radon or colloidal Y-90 or Au-198, 10 mc P-32 or 15 mc I-131 or sealed Y-90 or Au-198.

5. Corpses containing greater activities than those specified in paragraph 4 should not normally be embalmed, but if there are special reasons for doing so in a particular case, the embalmer should first consult the hospital where the treatment was given.

6. The activities given in paragraph 4 are not necessarily applicable to post-mortem examinations at the treatment centre where the cases might be more frequent and the activities greater. At such centres the pathologist should, in consultation with the Radiological Safety Officer, familiarise himself with the radiation levels likely to be encountered and with the hazards involved. The methods employed and the precautions adopted

should be chosen accordingly. Consideration should be given to the classification as designated persons of such pathologists and their assistants.

7. No special precautions are necessary for the cremation of corpses containing up to 30 mc Y-90, I-131, Au-198 or radon or 10 mc P-32.

8. Temporary implants of isotopes should be removed from corpses before their release from hospitals.

9. The possibility exists that a post-mortem examination might be carried out, without the knowledge of the general practitioner concerned, on a corpse having an activity greater than those specified in paragraph 4, in which circumstances the pathologist will not be aware of the presence of radioactive material. These occurrences are likely to be exceedingly rare and the probability that any pathologist will receive sufficient numbers of such corpses as to constitute a hazard is regarded as being negligible.

10. The Radiological Protection Service is available for consultation in cases of isotopes other than those referred to above.

Appendix K

Transport of Radioactive Materials Outside Hospitals

1. In this Appendix is given an outline of the regulations or conditions likely to be required by bodies responsible for the various modes of transport. It is emphasised that this information is presented only as a guide and that each Radiological Safety Officer, responsible for the transport of radioactive materials outside hospitals, must seek authoritative advice regarding the modes of transport he wishes to employ. Such advice* can be obtained from the following:—

   Road— Ministry of Transport,
   Rail — British Railways Board,
   Air — Ministry of Aviation,
   Sea — Ministry of Transport.

2. Detailed " Regulations for the Safe Transport of Radioactive Materials " have been published by the International Atomic Energy Agency, on which it is intended all U.K. Transport Regulations will be based.

3. All conditions for transport require certain standards of packaging. The most important of these are that the containers for radioactive material must be:—

   (i) not less than 4 in. (10 cm) cube,
   (ii) leak proof,
   (iii) securely closed,
   (iv) supplied with appropriate shielding,
   (v) designed with consideration of the following:

   (*a*) action of shocks and water
   (*b*) corrosion by the contents
   (*c*) ease of decontamination.

* In Northern Ireland advice can be obtained from Ministry of Commerce for air or sea transport and from Ministry of Home Affairs for road or rail.

Subject to the above, two standards of packaging are acceptable, (i) Type A, capable of withstanding conditions normally incident to transport and minor accidents, and (ii) Type B, capable of withstanding a major accident (including fire) bearing in mind the mode of transport used. The amounts of radioactive material that are permitted in a package are dependent upon the radiotoxicity of the radioisotope, its physical form and on the standard of packaging employed.

At the present time it is not possible to give precise information regarding the permissible amounts of radioactive material in each type of package, for each mode of transport, but a general indication of the position is given in Table K I.

TABLE K I

Package Standard \ Radiotoxicity Group	Group I	Group II	Group III	Group IV	Special Form
Type A	1 mc	50 mc	3 c	20 c*	20 c
Type B	20 c	20 c	200 c	200 c	5000 c

*Special (higher) limits are applicable to certain isotopes in Group IV.

The toxicity groups referred to in the above Table differ from those given in Table 1 Section 5 of the Code. The radioisotopes indicated in that Section as being used in hospitals are classified in the present context as in Table K II. By " special form " is meant radioactive material, regardless of toxicity group, which, in addition to having other specified properties, is in the form of a massive non-friable solid of melting point greater than 540°C (1000°F), virtually non-soluble in water and non-reactive with both air and water, or encapsulated so as to meet the above conditions.

TABLE K II

Classification of isotopes into radiotoxicity groups for transport purposes

Radioactive materials are, for the purpose of the transport regulations, divided into the following four groups:

Group I: very high radiotoxicity

Group II: high radiotoxicity

Group III: moderate radiotoxicity

Group IV: low radiotoxicity

Group I Ra-226

Group II Sr-90, Ra-224 (Th-X), Rn-222.

Group III Na-22, Cl-36, K-43, Co-56, Co-60, Ag-110m, I-124, I-131, Cs-134, Ba-140, Ce-144, Tm-170, Lu-177, Ta-182, Ir-192, Tl-204.

Group IV H-3, C-14, F-18, Na-24, P-32, S-35, Cl-38, K-42, Ca-45, Ca-47, Cr-51, Fe-55, Fe-59, Co-57, Co-58, Ni-65, Cu-64, Zn-65, Ge-71, As-74, As-76, Br-82, Kr-85, Rb-86, Sr-85, Y-90, Nb-95, Ru-103, Ag-111, Te-132, I-132, Xe-133, Cs-137, La-140, Ce-141, Pm-147, Au-198, Hg-203.

Certain radioisotopes used in hospitals are not at present classified. They are:— O-15, Fe-52 and I-130. However, in accordance with a formula applicable to transport, they can each be allocated to Group III.

4. The external dose rate from packages is subject to limitations which enable two main classes of package to be defined, regardless of whether they are of Type A or Type B as defined above.

These classes are:

(i) packages with an external surface dose rate of not more than 10 mrads per 24 hours; and

(ii) packages which are defined both by a surface dose rate, which may have various values up to 200 mrads per hour, and a dose rate at a metre from the surface which may have various values up to 10 mrads per hour.

The class of package is identified by the colour of the labels which are white and yellow respectively for surface transport and blue and red respectively for air transport.

5. The contamination by loose radioactive material of the outer surfaces of packages is limited to not more than 10^{-5} μc/cm^2 for alpha emitters and 10^{-4} μc/cm^2 for beta emitters. These values apply to averages obtained over any area of 300 cm^2.

6. Limitations are to be expected on the number of individual packages of various types and classes that can be loaded into a road vehicle and on the dose rate on the surface of the vehicle. Furthermore it will be necessary to take steps to minimise the possibility of loss or pilfering and to make arrangements for the notification of responsible persons in the event of any untoward occurrence.

7. Small amounts of radioisotopes are exempted from the various sets of conditions but these cannot be specified at the present time.

8. Packages containing radioactive materials may be conveyed by passenger or merchandise train but only in accordance with the relevant regulations. They are prohibited on the London Underground System and in Public Service Vehicles (buses, trolley buses, tramcars, etc.).

9. It is anticipated that, subject to the conditions regarding packaging and labelling and limitations on numbers of packages, it will be permissible to transport radioactive materials in private cars, shooting brakes, taxis and the like, provided they are accompanied by a person who is aware of the precautions to be adopted, and in ambulances, provided they are accompanied by a person nominated by a Radiological Safety Officer of the hospital. The Radiological Safety Officer must also satisfy himself that the doses received by all concerned are at acceptable levels and that satisfactory arrangements have been made to summon and supply assistance in the event of an accident or other emergency.

10. If circumstances arise which make it difficult to comply with all the regulations or conditions pertaining to a particular form of transport there is generally provision for making special arrangements on application to the transport authority concerned. This is not to be regarded as a means of avoiding compliance with the normal conditions, and the special arrangements will be aimed at ensuring that the movement is as safe as if it complied with the normal conditions in every respect.

Appendix L

Classification of Isotopes according to Relative Radiotoxicity per Unit Activity

TABLE L I

High Toxicity (Class 1)

Sr-90[+], Ra-226[+], Pb-210, Po-210, Ra-223, Ra-228, Ac-227, Th-227, Th-228, Th-230, Pa-231, U-230, U-232, U-233, U-234, Np-237, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Am-243, Cm-242, Cm-243, Cm-244, Cm-245, Cm-246, Cf-249, Cf-250, Cf-252.

Medium Toxicity

Upper Sub-group A (Class 2)

Na-22, Cl-36, Ca-45, Co-56*, Co-60[×], Ag-110m, I-124*, I-131, Cs-134[+], Cs-137[+], Ba-140, Ce–144[+], Tm-170[+], Ta-182, Ir-192, Tl-204, Ra-224 (Th-X), Sc-46, Mn-54, Sr-89, Y-91, Zr-95, Ru-106, Cd-115m, In-114m, Sb-124, Sb-125, Te-127m, Te-129m, I-126, I-133, Eu-152 (13 years), Eu-154, Tb-160, Hf-181, Bi-207, Bi-210, At-211, Pb-212, Ac-228, Pa-230, Th-234, U-236, Bk-249.

Lower Sub-group B (Class 3)

C-14, F-18, Na-24, P-32, S-35, Cl-38, K-42, K-43*, Ca-47, Cr-51, Fe-52*, Fe-55, Fe-59, Co-57, Co-58, Ni-65, Cu-64, Zn-65, As-74, As-76, Br-82, Rb-86, Sr-85, Y-90[×], Nb-95, Ru-103[+], Ag-111, Te-132, I-130*, I-132, La-140, Ce-141[+], Pm-147, Lu-177, Au-198[×], Hg-203, Rn-222[+], Be-7, Si-31, Ar-41, Sc-47, Sc-48, V-48, Mn-52, Mn-56, Ni-63, Zn-69m, Ga-72, As-73, As-77, Se-75, Kr-85m, Kr-87, Sr-91, Sr-92, Y-92, Y-93, Zr-97, Nb-93m, Mo-99, Tc-96, Tc-97m, Tc-97, Tc-99, Ru-97, Ru-105, Rh-105, Pd-103, Pd-109, Ag-105, Cd-109, Cd-115, In-115m, Sn-113, Sn-125, Sb-122, Te-125m, Te-127, Te-129, Te-131m, I-134, I-135, Xe-135, Cs-131, Cs-136, Ba-131, Ce-143, Pr-142, Pr-143, Nd-147, Nd-149, Pm-149, Sm-151, Sm-153, Eu-152 (9·2 hours), Eu-155, Gd-153, Gd-159, Dy-165, Dy-166, Ho-166,

Lower Sub-group B (Class 3) (*cont.*)

Er-169, Er-171, Tm-171, Yb-175, W-181, W-185, W-187, Re-183, Re-186, Re-188, Os-185, Os-191, Os-193, Ir-190, Ir-194, Pt-191, Pt-193, Pt-197, Au-196, Au-199, Hg-197, Hg-197m, Tl-200, Tl-201, Tl-202, Pb-203, Bi-206, Bi-212, Rn-220, Th-231, Pa-233, Np-239.

Low Toxicity (Class 4)

H-3, O-15*, Ge-71, Kr-85, Xe-133, Ar-37, Co-58m, Ni-59, Zn-69, Sr-85m, Rb-87, Y-91m, Zr-93, Nb-97, Tc-96m, Tc-99m, Rh-103m, In-113m, In-115, I-129, Xe-131m, Cs-134m, Cs-135, Sm-147, Re-187, Os-191m, Pt-193m, Pt-197m, Th-232, Th-Nat, U-235, U-238, U-Nat.

× Used in hospitals in both sealed and unsealed form.

\+ Used in hospitals in sealed form only.

Other isotopes underlined are used in hospitals in unsealed form only. Remainder of isotopes in the table are not at present used in hospitals.

* Toxicity classification based on R.P.S. calculations.

Appendix M

Definitions of Terms

Active area: area in which there is, or under normal operating conditions is liable to be, contamination in excess of levels given in the second column of Table D I. (Appendix D.)

Atomic number: number of orbital electrons in a neutral atom, or the electric charge on the nucleus of an atom, or the number of protons in the nucleus of an atom.

Bremsstrahlung: secondary photon radiation having a continuous energy spectrum and arising from the retardation of charged particles passing through matter.

Contamination (radioactive): deposition of radioactive material where it is not desired, for example, on any surface including the skin, hair and clothing of persons and any part of absorbent objects or materials.

Controlling Authority: body or person or persons ultimately responsible for the control of the establishment. In the case of hospitals, the controlling authority is the Board of Governors or Hospital Management Committee (in Scotland, the Board of Management).

Curie (c): activity of a quantity of a radionuclide disintegrating at the rate of $3 \cdot 7 \times 10^{10}$ atoms per second. Several fractions of the curie are in common use:—

Millicurie (mc): One thousandth of a curie.
Microcurie (μc): One millionth of a curie.

Daughter (radioactive): synonym for radioactive decay product.

Dose: term commonly used hitherto to express three types of dose defined by the International Commission on Radiological Units and Measurements, namely, " exposure dose " (used to specify quantities, in röntgens, of X- or γ-rays of energy up to 3 MeV), " absorbed dose " (used to define quantities, in rads, of energy imparted to matter by ionising radiations of all types) and " R.B.E. dose " (used to define and add effective biological doses, in rems, of identical absorbed doses of different types of radiations). The term " dose " used in the Code follows this common usage. However,

recently, the International Commission on Radiological Units and Measurements has changed the terms " exposure dose " and " R.B.E. dose " and has re-defined the latter. The three concepts and corresponding units now advocated by the Commission are:—

(1) *Absorbed dose* of any ionising radiation: amount of energy imparted to matter by ionising particles per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad.

(2) *Dose equivalent:* quantity used for protection purposes as the product of absorbed dose, quality factor, dose distribution factor and other modifying factors to express the biological effect of identical absorbed doses of different types of ionising radiations. The unit of dose equivalent is the " rem ". (The term " dose equivalent " replaces the term " R.B.E. dose ").

(3) *Exposure:* quantity of X- or γ-radiation based upon the ability of the radiation to produce ionisation in matter through which it passes. The unit of exposure is the röntgen.

Dosemeter (ionisation): instrument used to detect and measure doses of ionising radiations.

Dose-rate: radiation dose received per unit time.

Dose-rate meter: instrument used to measure dose-rate.

Electron-volt (eV): unit of energy. The kinetic energy of an electron when it is freely accelerated through a potential difference of 1 volt. One eV is equivalent to $1 \cdot 602 \times 10^{-12}$ erg.

Kilo-electron-volt (keV): 1000 eV

Mega-electron-volt or million electron-volt (MeV): 1,000,000 eV.

Film badge: a pack comprising a photographic film and appropriate filters used to measure exposure to ionising radiations.

Filtration, inherent (X-rays): filtration introduced by the wall of the X-ray tube and any permanent tube enclosure; to be distinguished from added filters.

G. M. counter: instrument comprising a highly-sensitive, gas-filled tube (Geiger-Muller tube or G. M. tube) and associated electronic circuits for enumerating ionising events produced in the irradiated tube.

Half-life

(1) *Biological half-life:* time required for the body to eliminate, by normal processes, 50% of any substance deposited in body tissues.

(2) *Effective half-life:* time required for a radioactive substance deposited in body tissues to be reduced to 50% as a result of the combined action of biological elimination and radioactive decay.

(3) *Radioactive half-life:* time required for a radioactive substance to lose 50% of its activity by radioactive decay.

Ionisation: process or result of a process by which an electron is removed or added to a neutral atom or molecule.

Ionising radiations: electromagnetic radiation (X- or gamma-rays) or corpuscular radiation (α-particles, β-particles, electrons, protons, neutrons or heavy particles), capable of producing ions.

Isotope: one of several nuclides having same number of protons in their nuclei (i.e. same atomic number) but differing in the number of neutrons and therefore in their mass numbers.

Lead equivalent: thickness of lead affording the same protection under specified conditions of irradiation as the material in question.

Mass number: number of nucleons (that is, protons and neutrons) in the nucleus of an atom.

Micron (μ)*:* one millionth of a metre.

Nuclide (radionuclide): particular variety of atom having a nucleus characterised by its atomic number, mass number and energy state.

Occupancy factor: factor by which the work-load should be multiplied to correct for the degree of occupancy of the area in question.

Quality factor (QF): term now advocated by the International Commission on Radiological Protection and the International Commission on Radiological Units and Measurements to replace " R.B.E. " for protection purposes.

Rad: unit of absorbed dose, which is 100 ergs per gramme of any medium.

Millirad (mrad): one thousandth of a rad.

Radiation:

(1) *Annihilation radiation:* photons produced when an electron and a positron unite and cease to exist. The annihilation of an electron-positron pair results in the production of two photons each of 0·51 MeV energy.

(2) *Background radiation:* radiation from natural radioactivity in the environment, plus cosmic rays.

(3) *External radiation:* ionising radiations received from a source located outside the body and penetrating into deeper tissue.

(4) *Internal radiation:* ionising radiations received from radionuclides deposited in body tissues.

(5) *Primary radiation:*

(*a*) *X-rays:* all radiation coming direct from the target of an X-ray tube. Except for the useful beam, the bulk of the primary radiation is absorbed in the tube housing.

(*b*) β- *and* γ-*rays, neutrons and electrons:* radiation coming direct from the radiation source.

(6) *Scattered radiation:* radiation which, during passage through matter, has been deviated in direction. It may also have been modified by a change in photon or particle energy.

(7) *Secondary radiation:* radiation, other than the primary, emitted by irradiated matter.

(8) *Stray radiation:* radiation not serving any useful purpose.

(9) *Useful beam:* that part of the primary radiation which passes through the aperture, cone or other device for collimating the beam; and any primary radiation from a small sealed radioactive source.

Radiation survey: investigation of those factors associated with an installation or process which could give rise to a radiation hazard.

Radioactive substance: strictly, any substance containing a radionuclide. However, since all substances are radioactive to some degree, it is desirable to define a limit below which the radioactivity can be ignored.

There is general agreement that a substance is radioactive if it consists of or contains any radioactive chemical element whose specific activity exceeds 0·002 of a microcurie of parent radioactive chemical element per gramme of substance. (*Note.* This definition is not in the same terms as that used in the Radioactive Substances Act, 1960, for the purposes of disposal of radioactive waste.)

Radioactivity: spontaneous disintegration of an unstable (radioactive) nuclide with the emission of a particle or a photon, to form a different nuclide.

Rem: formerly the unit of R.B.E. dose which was the product of absorbed dose and a factor for the relative biological effectiveness (R.B.E.) of the radiation under consideration. Now the unit of " dose equivalent ".

Millirem (mrem): one thousandth of a rem.

Röntgen (r): formerly the unit of " exposure dose ", now of " exposure ", and defined as that quantity of X- or γ-radiation such that the associated corpuscular emission per 0·001293 g of air produces, in air, 1 e.s.u. of quantity of electricity of either sign.

Milliröntgen (mr): one thousandth of a röntgen.

Scintillation counter (or scintillation-type probe): instrument comprising a phosphor, photomultiplier tube and associated electronic circuits for counting light emissions produced in the irradiated phosphor.

Sealed source: any radioactive substance sealed in a container or bonded wholly within material (other than solely for the purpose of storage, transport or disposal) including the immediate container or bonding.

Specific activity: total radioactivity of a radionuclide per gramme of radionuclide, or element or compound.

Use factor: fraction of the work-load during which the useful beam is pointed in the direction under consideration.

Work-load: a measure in suitable units of the amount of use of radiation equipment. It might be expressed in mA. min per week for X-ray sources and röntgens per week at 1 metre for gamma-ray sources.

Appendix N

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(20/1/64). 90342. Wt. 3939–9585. K84. 21/9/64. 401.

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