CODE OF PRACTICE FOR RADIATION PROTECTION (MEDICAL X-RAY DIAGNOSIS)
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Committee representation

This Malaysian Standard Code of Practice was prepared by the Radiation Protection Unit of the Ministry of Health, Malaysia with the assistance of a panel comprising representatives from the following organizations:

Ir. A. Sekarajasekaran (Chairman) Ministry of Health
Prof. Dr. Ismail Saad Malaysian Radiological Society
Prof. Madya Dr. Ahmad Kamal b. Mohd. Alif Universiti Kebangsaan Malaysia
Prof. Madya Dr. Yeoh Poh Hong Malaysian Medical Association
Dr. Charanpal Singh General Hospital, Kuala Lumpur
Encik Abdul Rahman b. Abdul Attorney General
Encik Khoo Boo Huat University Hospital
Encik Idris b. Haji Hussein Society of Radiographers
FOREWORD

This Malaysian Standard Code of Practice was prepared by the Radiation Protection Unit of the Ministry of Health, Malaysia with the assistance of a panel of representatives from academic organizations in Malaysia.

With the passing of the Radioactive Substances Act (1968) and the subsequent regulations gazetted in 1974, operators of X-ray machines including medical personnel are required to comply with the requirements of these regulations. The regulations established under the Radioactive Substances Act are aimed at licensing the use of X-ray machines and regulating radiological safety. However, they do not provide information on proper procedures and operations of equipment necessary to attain a high standard of performance in X-ray examination.

The medical profession, in its effort to provide better standard of services and safety had made numerous enquiries on such information. In response to this need, a code of practice was drawn up. The object of this code is to provide necessary references for the present X-ray machine operators, the general practitioners, medical officers, radiologists and other medical specialists who wish to acquire X-ray facilities or improve on their present X-ray techniques. It is hoped that users operating X-ray machines for medical diagnosis, whether from the private or public sector will fully comply with this code of practice.

In the preparation of this code, references had been made to various international codes of practice and procedures. In addition, local conditions have been taken into consideration.

A list of bibliography of the reference materials is included at the end of this standard.

In the preparation of this code, considerable assistance and valuable advice had been derived from a panel of experts from various local academic institutions and societies and such assistance is hereby acknowledged.
PART 1: INTRODUCTION

1. SCOPE

1.1 This code provides criteria for the safe use of X-rays in medical diagnosis. It applies to administrative and working procedures, shielding requirements for X-ray rooms, and technical specifications for X-ray systems with respect to safety and performance. The requirements listed in this code are subject to amendments as are deemed necessary for the protection of public health and safety.

1.3 An X-ray system consists of the following components:

(a) X-ray tube housing assemblies including light beam collimators, X-ray controls and X-ray high-voltage generators.

(b) Fluoroscopic screening assemblies and attachments.

(c) Spool-film devices, image intensifiers, television displays and other viewing facilities.

(d) Devices for special procedures (e.g. cephalometric devices).

(e) Image receptor support devices including tables, cradles, film changers and cassette holders.

(f) Darkroom facilities including processors, chemicals, film, identification apparatus, cassettes and grids.

1.3 The supplier shall provide all technical data and instructions as are necessary to comply with part IV of this code. The users shall keep all records necessary for compliance with this code.

1.4 Throughout this code, the word ‘shall’ refers to measures which are considered necessary, and the word ‘should’ refers to measures which are desirable for achieving satisfactory protection.

2. DEFINITIONS

2.1 ‘Absorbed dose’ means the energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the joule per kilogramme (J kg⁻¹) given the special name gray (Gy). 1 Gy = 1 J kg⁻¹ = 100 rad.

2.2 ‘Aluminium equivalent’ means the thickness of aluminium affording the same attenuation under specified conditions as the material in question.
2.3 'Automatic exposure control' means a device which automatically controls one or more technique factors in order to obtain at a preselected location(s) a required quantity of radiation.

2.4 'Beam axis' means a line from the source through the centre of the X-ray field.

2.5 'Beam collimating device' means a device which provides a means to restrict the dimensions of the X-ray field.

2.6 'Coefficient of variation' means the ratio of the standard deviation of the sample to the mean value of the sample, for any sample of observations:

\[ C = \frac{S}{\bar{X}} \]

\[ = \frac{1}{\bar{X}} \left[ \sum_{i=1}^{n} \left( \frac{X_i - \bar{X}}{n} \right)^2 \right]^{1/2} \]

where,

- \( C \) is the coefficient of variation;
- \( S \) is the sample standard deviation;
- \( \bar{X} \) is the sample mean;
- \( n \) is the number of observations in the sample;
- \( X_i \) is the \( i \)th observation in the sample.

2.7 'Dose equivalent (H)' means the product of the absorbed dose at the point of interest and factors which take account of the biological effects of the particular type of radiation. The unit of dose equivalent is the sievert (Sv). 1 Sv = 1J kg\(^{-1}\) = 100 rem.

2.8 'Exposure' means a measure of the ionization produced in air by X-rays or gamma radiation. The exposure, \( X \) is the quotient \( dQ/dm \) where \( dQ \) is the absolute value of the total charge of the ions of one sign produced in air when all the electrons liberated by photons in a volume element of air having mass \( dm \) are completely stopped in air. The unit of exposure is coulomb per kilogramme (C kg\(^{-1}\)) and the special unit Roentgen (R) is equal to 2.58 x 10\(^{-4}\) C kg\(^{-1}\).

2.9 'Filter' means a sheet of material usually a metal, in the primary X-ray beam and intended to differentially absorb the less penetrating components of the X-ray beam.

2.10 'Fluoroscopy imaging assembly' means that imaging receptor in which X-ray photons are received to form a fluoroscopic image. It includes a fluorescent screen and/or image intensifier, a primary protective barrier, and any structural material by which it is ganged to the X-ray tube assembly.

2.11 'Half value layer (HVL)' means the thickness of material required to reduce the exposure rate in an X-ray beam of radiation to one-half.

2.12 'Image intensifier' means a device, installed in its housing, which instantaneously converts an X-ray pattern into a corresponding light image of higher energy density.

2.13 'Image receptor' means any device such as the fluorescent screen, radiographic film, etc. which transforms incident X-ray photons into a visible image or into another form which can be converted into a visible image or analogue thereof by further transformation.

2.14 'Inherent filtration' means the filtration in the beam provided by the structural components of the X-ray tube head.

2.15 'Lead equivalence' means the protective value of a specified thickness of any materials expressed in terms of the thickness of the lead which would provide an equivalent value. Where the protective material concerned is not itself lead, or a lead compound (such as PbO\(_2\)) the kilovoltage at which the lead equivalence was determined should be stated.
2.16 ‘Leakage radiation’ means X-rays emerging from the X-ray system in any direction, other than that of the useful beam and scattered radiation from the useful beam.

2.17 ‘Mobile X-ray machine’ means an X-ray machine which may be moved to another location on its own wheels. It cannot be readily carried to another location. Mobile X-ray machines are commonly used for ward and theatre radiography.

2.18 Occupancy factor (T) means the factor by which the workload shall be multiplied to correct for the degree of occupancy of the area in question while the source is ‘on’.

2.19 ‘Opaque medium’ means a substance of atomic number or density sufficiently greater than the material being examined with X-rays to provide a significant degree of contrast in the image, the opaque medium appearing as light density in the image, i.e. an opaqueness.

2.20 ‘Portable X-ray machine’ means an X-ray machine which may be disassembled and carried to another location. Some portable machines may have their own wheels and be used as mobile machines.

2.21 ‘Primary barrier’ means a barrier sufficient to attenuate the primary beam to the required degree.

2.22 ‘Primary protective barrier’ means the material, excluding filters, placed in the useful beam to reduce the radiation exposure for protection purposes.

2.23 ‘Radiation worker’ means a person who operates an irradiating apparatus and any other person who assists in the X-ray room.

2.24 ‘Scattered radiation’ means radiation which is produced due to change of direction and energy of X-ray photons after interaction mainly with electrons of atoms in their path.

2.26 ‘Source’ means the focal spot of the X-ray tube.

2.26 ‘Source-image receptor distance (SID)’ means the distance from the source to the centre of the input surface of the image receptor.

2.27 ‘Technique factors’ means the conditions of operation. They are specified as follows:

(a) For capacitor energy storage equipment, peak tube potential in kVp and quantity of charge in mAs.

(b) For field emission equipment rated for pulsed operation, peak tube potential in kVp and the number of X-ray pulses.

(c) For all other equipment, peak tube potential in kVp and either tube current in mA and exposure time in seconds, or the product of tube current and exposure time in mAs.

2.28 ‘Tube housing assembly’ means the tube housing with the tube installed. It includes high-voltage and/or filament transformers and other appropriate elements when they are contained within the tube housing.

2.29 ‘Tube rating chart’ means the set of curves which specify the rated limits of operation of the tube in terms of the technique factors.

2.30 ‘Use factor (U) or (beam direction factor)’ means fraction of the work-load during which the useful beam is directed at the barrier under consideration.

2.31 ‘Useful beam’ means the radiation which passes through the tube housing port and the aperture of the beam-collimating devices when the exposure switch or timer is activated.
2.32  'Workload (W)' means the degree of use of an X-ray source. It is usually, expressed in milliampere minutes per week.

PART II: RADIOLOGICAL SAFETY

3. PROTECTION OF THE PATIENT

3.1  A basic principle of protection in diagnostic radiology is that an X-ray examination should not be performed unless the benefits accruing to the patient outweigh any radiation risks. Judgement of whether benefits outweigh risks should be a matter for the radiologist or medical practitioner in each case. The simple question of whether the X-ray examination is necessary for adequate diagnosis should always be examined. In many cases, examinations may routinely be requested to exclude the possibility of unsuspected causes or conditions and not be based on clear-cut clinical indications. Routine chest radiography in life insurance and some pre-employment or post-employment X-ray examinations are examples of X-ray exposure with no clinical indications of necessity.

3.2  Implicitly the diagnosis provided by medical radiography determines subsequent patient management. If management is expected to be unaffected by the result of an X-ray examination then the need for the examination may be questioned. There are many instances where patients referred elsewhere are subjected to the same X-ray examination at both the referring and admitting institutions. This practice increases patient dosage, and should be avoided by improvements in administrative routine where such is the reason for the additional exposure. All films taken at the referring institution should accompany the patient and be reviewed before further X-ray examinations are requested.

3.3  The radiologist shall limit, cancel or defer the X-ray examination if he considers the expected information to be irrelevant or already available.

3.4  Experienced radiographers should draw the attention of the clinician involved to cases where the necessity for the X-ray examination, or number of views involved may be reviewed. This may particularly apply in hospitals in which no radiologist is available.

3.5  Minimising need for repeated X-ray examinations. The need for repeating an X-ray examination should be avoided when it adds to the radiation dose to the patient without also contributing to the diagnostic information.

3.6  The operation conditions for bedside radiography are frequently difficult and correct positioning and beam limitation require a great deal of thought and care. It is likely that in these conditions, the patient will receive more radiation than necessary, and other patients in adjacent accommodation may also be irradiated. Bedside radiography should therefore strongly be discouraged unless it is very necessary. Where the volume of work is sufficiently high, the use of apparatus designed for specific radiography, for example in operating theatres, may be advantageous.

3.7  Protective clothing of at least 0.25 mm lead equivalent shall be worn and precautions shall be taken to ensure that no other person is exposed unnecessarily if bedside radiography is performed.
3.8 For radiography in the ward, the minimum distance of:

(a) the operator from the tube and patient;

(b) the other patients (who shall not be in the path of the X-ray beam) from the tube and the patient being radiographed; shall be 2 m.

3.9 Standard methods of control of doses to patients

(a) Restriction of the useful X-ray beam to the area of clinical interest in any case not exceeding the effective-cross-section of the image receptor.

(b) Use of the highest practicable kilovoltage. The use of higher kilovoltage reduces the dose to the patient.

(c) Use of fastest image-recording device compatible with optimal image quality.

(d) Avoidance of short source-image receptor distance (SID).

(e) Avoidance of repeats for technical or administrative reasons.

(f) Use of specific organ shielding.

3.10 Protection of the embryo/foetus

(a) Irradiation of the foetus shall be minimised. Where irradiation of the foetus is necessary it shall be held to the minimum consistent with images of good diagnostic quality. As far as it is possible care shall be taken to avoid X-ray examinations involving the pelvic and lower abdominal regions of patients who are pregnant unless such examinations are of importance in connection with present management of the patients.

(b) Where the X-ray examination being requested does not directly relate to investigation of the patient’s current complaint and does involve potential irradiation of the uterus the referring practitioner should where practicable arrange that the examination be performed in the 10-day period following the onset of menstruation.

(c) X-ray examinations performed during the course of pregnancy and in connection with it shall require full justification on clinical grounds.

3.11 X-ray examinations performed during the course of pregnancy and not involving the abdominal or pelvic regions should keep the useful X-ray beam well-collimated to the area of interest (i.e. to avoid irradiation of the foetus). Where the useful beam angulation is such that it may incidentally irradiate the abdominal region, that region should be shielded with a lead apron. The apron should have a lead equivalence of not less than 0.5 mm.

3.12 Protection of the gonads

(a) With the objective of minimising the genetic effect of radiation to the population, gonad doses to patients undergoing diagnostic X-ray examinations shall be kept as low as is reasonably achievable.

(b) Wherever the gonads or the immediate region of the body in which they lie are not required to be demonstrated in the image, the X-ray beam shall be so collimated as to exclude the gonads. Light beam diaphragms and optical beam delineators in accurate alignment are the more efficient means of achieving this objective.

(c) Where the gonads lie in or very close to the useful X-ray beam, and collimation cannot be used to avoid their irradiation, the gonads should be shielded unless such shielding would obscure structures relevant to the examination.
(d) If gonad shielding is found difficult to apply in a few instances, its omission would have no detectable effect on population genetic dose. Undue perseverance with shielding may however result in the need for repeat exposure which would add appreciably to the patient's general dose.

3.13 Grids interposed between the patient and the recording device are necessary to reduce the amount of scattered radiation reaching the latter but at the same time allowing the maximum possible transmission of the emerging primary radiation constituting the image-forming pattern. In some grids the lead strips are parallel, but in most grids they are positioned to offer minimum obstruction to primary radiation from a particular point above the centre of the grid. Special care is needed to ensure that the X-ray focus is properly aligned to the grid, particularly when ultra fine line grids or cross-line grids are used, and that the focus-grid distance falls within the range for which the grid is designed.

4. PROTECTION OF PERSONNEL

4.1 The exposure of radiation workers shall not exceed the dose equivalent limits and should not exceed one-tenth of the dose equivalent limits. The dose equivalent limits are given in schedule 1.

4.2 Only those personnel required to assist, or in the course of training, should be present during the performance of X-ray examinations.

4.3 Personnel required to be present during the X-ray examination shall wear a lead apron having a lead equivalence not less than 0.25 mm, and shall not remain any closer to the patient and X-ray tube than is necessary. A double-sided apron should be worn by personnel who may receive radiation posteriorly and laterally as well as anteriorly.

4.4 No person shall hold a patient, X-ray film cassette, other imaging device or X-ray tubehead in position during exposures unless it is otherwise impossible to obtain a diagnostically useful image.

4.5 Motion restricting devices shall be applied to the patient insofar as it is practicable; and devices for remote holding of the film cassette shall be used wherever feasible.

4.6 Holding of patients or X-ray film cassettes during exposures shall be done by persons accompanying the patient in preference to non X-ray personnel; and by non X-ray personnel in preference to X-ray personnel. Non X-ray personnel should be chosen on a roster basis, i.e. it should not always be the same person who does the holding. No pregnant women or young persons should do any holding.

4.7 Any person holding patients or film cassettes in position during exposures shall wear a lead apron and wherever practicable, lead gloves. They should ensure as far as is practicable that no part of their body, even if covered with protective clothing, is in the useful beam.

4.8 Personnel not required to be in attendance shall not remain in the fluoroscopy room. Personnel required to be in the X-ray room during fluoroscopy shall as much as is reasonably achievable be protected from exposure to scattered radiation. The fluoroscopist shall wear a lead apron having a lead equivalence which shall be not less than 0.25 mm and should be 0.5 mm.

4.9 The fluoroscopist shall not be exposed to the unattenuated useful X-ray beam in virtue of his close proximity to the patient.
4.10 The fluoroscopist shall wear a lead glove on any hand used to palpate the patient. The glove shall have a lead equivalence of not less than 0.25 mm, and should have a lead equivalence of 0.5 mm.

4.11 For special procedures, specialists in radiation protection should be consulted regarding requirements on radiation safety.

Special procedures are X-ray examinations generally in the class ‘angiography’, a principal example being cardiac angiography. Other special examinations such as foetal blood transfusions may be included.

PART III: STRUCTURAL SHIELDING AND LAY-OUT

5. GENERAL REQUIREMENTS

5.1 The final plans for new installations or for modifications of existing installations involving structural shielding and lay-out of X-ray systems shall be vetted and approved by a qualified person before construction commences. Copies of the plans of the installation, including shielding specifications and lay-out of the X-ray system shall be made available for inspection. All particulars pertaining to the design, construction and installation of primary and secondary barriers shall be indicated on the plan.

5.2 Before any installation is put into operation, surveys and tests shall be carried out in order to establish that the approved plans have been followed and that shielding and operating conditions are in accordance with the requirements set out in part III of this code.

5.3 The materials of construction of every diagnostic X-ray room shall be such that the exposure rate at every occupied position outside the room and at the position normally occupied by the operator at the X-ray controls, is as low as is reasonably achievable, social and economic considerations being taken into account, and the materials shall be such that the exposure rate at every such position does not exceed $2.58 \times 10^{-6}$ Ckg$^{-1}$ per week (10 mR per week). In most circumstances ‘as low as is reasonably achievable, economic and social considerations being taken into account’ means of the order $2.58 \times 10^{-7}$ Ckg$^{-1}$ per week (1 mR per week).

5.4 Warning signs and lights should be installed at entrances to X-ray rooms. All entrances to the X-ray room shall be marked with a sign as shown in fig. 1 to warn the presence of X-rays. All entrances to X-ray rooms shall have a light that is illuminated prior to exposure or when fluoroscopy is in progress. The warning light should be red in colour but yellow or amber may be used.

6. STRUCTURAL SHIELDING

6.1 In calculating the shielding required against leakage and scattered radiation, the anticipated conditions of use which give rise to the maximum leakage radiation from the equipment and the maximum scattered radiation shall be assumed. Removable objects such as patients, phantoms and castings by which the beam may be partly absorbed shall not be taken into account in the calculations.

6.2 Secondary protective barriers shall be provided in all walls, ceilings and floor areas not having primary barriers. All barriers shall have a minimum height of 2 m above the floor.

6.3 Lead sheets should be mounted in such a
manner that they will not crinkle or creep under their own weight, and they should be protected from physical damage. Lead sheet joints should overlap by 1.5 cm or, if butted, should be welded or covered with 2.5 cm strips of lead of the same lead equivalence as the barrier.

6.4 Doors and windows shall have the same lead equivalence as that required for the wall. If the X-ray room is located above the ground floor, a protective barrier of 1.5 mm lead equivalence in thickness and 1.2 m by 2.5 m in area shall be provided in the floor area beneath the X-ray examination table.

6.5 The structural shielding required for the control cubicle (see fig. 2) shall be as follows:

(a) Radiographic X-ray systems capable of operating at maximum potentials up to 100 kVp.

The shield shall have minimum thickness of 1.5 mm lead equivalence and shall have dimensions as shown in fig. 2. It shall be at least 2 m in height and have a lead glass observation window at eye level. The lead glass observation window shall have a minimum thickness of 1.5 mm lead equivalence and minimum dimensions of 35 cm (width) by 30 cm (height). The value of the lead equivalence at 100 kVp shall be permanently marked on the glass.

(b) General radiographic X-ray systems capable of operating at potentials above 100 kVp.

The provisions stated in 6.5 (a) shall apply except for the size of the lead glass window which shall have minimum dimensions of 75 cm (width) by 45 cm (height).

(c) Fluoroscopic X-ray systems capable of operating at 100 kVp and above.

The shield shall have a minimum thickness of 1 mm lead equivalence and dimensions of at least 1 m wide and 2 m in height. The lead glass observation window shall have a minimum thickness of 1 mm lead equivalence and minimum dimensions of 25 cm (width) by 20 cm (height).

6.6 The door of the film pass-through hatch shall be lead lined with at least 1 mm lead thickness.

6.7 Data for shielding calculation is given in schedule 2(a) and 2(b).

7. LAY-OUT AND DIMENSIONS OF X-RAY ROOM

7.1 The X-ray tube shall be positioned such that the useful beam is not directed at the control cubicle, darkroom, doors or windows.

7.2 The control cubicle shall be at least 2 m from the examination table (the nearest end) and should be as far away as practicable.

7.3 The wall directly behind the chest stand (1.2 m x 1.2 m at chest level) shall have a lead equivalence thickness of at least 2 mm.

7.4 Where applicable the table should be positioned parallel with a long wall of the room (see fig. 3). A line drawn down the centre of the table should be in alignment with a similar line drawn up the middle of the chest stand. When the X-ray tube is positioned directly over the end of the table nearer to the chest stand, it shall be at least 1.0 m from the chest stand.

7.5 Where applicable the distance between the X-ray tube support and the nearest wall of the
room shall be at least 60 cm. This is usually the wall opposite the door through which patients enter. If the X-ray tube column is mounted on rails, the rails should be located between this wall and the table. The space between the door and the table should remain free of obstructions on the floor.

7.6 The X-ray system shall be designed and installed so as to be accessible for inspection and servicing.

7.7 The useful beam should not be directed towards adjacent occupied areas.

7.8 For X-ray systems operating at maximum 100 kVp, the dimensions of the X-ray room should not be less than 3.5 m (length) by 2.5 m (width) by 3.0 m (height).

7.9 For general radiography X-ray systems operating at 150 kVp maximum, the dimensions of the X-ray room should not be less than 5 m (length) by 3 m (width) by 3 m (height).

7.10 For fluoroscopic X-ray systems operating at 150 kVp maximum, the dimensions of the X-ray room should not be less than 6 m (length) by 4 m (width) by 3 m (height).

PART IV: SAFETY AND PERFORMANCE REQUIREMENTS OF X-RAY SYSTEMS

8. GENERAL REQUIREMENTS

8.1 Suppliers shall provide manuals (including circuit diagrams) on operation, installation, servicing, safety, and other technical matters.

8.2 Markings
X-ray systems shall carry the following markings:

(a) Name and trademark of the manufacturer or supplier of each component of the X-ray system.
(b) Type and serial number of each component of the X-ray system.
(c) Position and size of the focal spot(s).
(d) Source to image receptor distance on a scale.

9. PERFORMANCE CRITERIA

9.1(i) All X-ray systems should be tropicalized.
(ii) For X-ray systems that are not tropicalized, suppliers of X-ray equipment could advise the user as to what suitable temperature and relative humidity should be kept.

9.2 Accuracy

(a) The deviation of actual peak kilovoltages from indicated or preset peak kilovoltages during exposure shall not exceed 5% (or 5 kV whichever is greater) of the indicated or preset value at any X-ray tube current, for which the X-ray machine is properly operable.

(b) The deviation of the actual exposure time from preset exposure time shall not exceed 10% of the preset time when the set time is 0.2 seconds or greater.

9.3 Reproducibility. The reproducibility shall be assessed in terms of the coefficient of variation for specified combinations of selected technique factors. The coefficient of variation of a series of at least 10 consecutive radiation exposures shall not exceed 0.10 and preferably should not exceed 0.05.

9.4 Linearity. The average ratios of exposure to the set milliampere-seconds product (mR/mAs) obtained at any two consecutive tube current settings shall not differ by more than 0.10 times their sum. This is:

$$|\bar{x}_1 - \bar{x}_2| \leq 0.10 (\bar{x}_1 + \bar{x}_2)$$

where $\bar{x}_1$ and $\bar{x}_2$ are the average mR/mAs values obtained at each of two
consecutive tube current settings.

9.5 Assessments of performance criteria

(a) Assessments of performance criteria shall be based on at least 10 consecutive measurements taken within a period of one hour.

(b) All variable controls for technique factors shall be adjusted to alternate settings and reset to the test setting after each measurement.

(c) For these assessments the X-ray machine shall be connected to an electrical power supply as specified for that machine.

(d) Measurements shall be made with radiation dosemeters and other equipment that are properly calibrated.

10. X-RAY BEAM LIMITATION

10.1 The X-ray system shall be fitted with an adjustable light beam collimator.

10.2 It shall be attached to the tube housing so that it cannot become detached without the use of tools. If the collimator is designed to be rotated around the centre of the X-ray beam, the rotational movement shall not cause the collimator to become loose or detached.

10.3 The minimum field size at an SID of 100 cm shall be equal to or less than 5 cm by 5 cm.

10.4 The area illuminated by the light beam collimator and the area to be irradiated shall be coincident. The total misalignment of the edges of the visually defined field with the respective edges of the X-ray field along either the length or width of the visually defined field shall not exceed 2% of the distance from the source to the centre of the visually defined field when the surface upon which it appears is perpendicular to the axis of the X-ray beam.

10.5 The illumination of the light beam shall be not less than 160 lux at 100 cm or at the maximum SID whichever is less. The light beam should be switched off by an automatic device after an elapsed time of not more than 2 minutes. It should be necessary to initiate manually a further period of illumination.

10.6 The visually defined field (light field) shall contain cross wires or other acceptable mode of indicating the centre of the X-ray beam. The centre of the X-ray beam and indicated centre of the light beam shall correspond to an accuracy of within 2% of the distance from the source to the point on the illuminated surface at which it appears.

10.7 Additional requirements for equipment manufactured after 1980.

(a) When the angle between the image receptor and the beam axis of the X-ray beam is variable, means shall be provided to indicate when the axis of the X-ray beam is perpendicular to the plane of the image receptor, and to align the centre of the X-ray field with respect to the centre of the image receptor. Radiographic equipment designed for only one image receptor size at a fixed SID shall be provided with means to limit the field at the plane of the image receptor to dimensions no greater than those of the image receptor, and to align the centre of the X-ray field with the centre of the image receptor to within 2% of the SID.

(b) Non-image intensified fluoroscopy. The X-ray field produced by non-image intensified fluoroscopic equipment shall not extend beyond the entire visible area of the image receptor. Means shall be provided for stepless adjustment of the field size. The minimum field size at the
11. FILTRATION IN THE X-RAY BEAM

11.1 The total filtration in the useful beam shall be not less than the values given in table 1.

Table 1. Useful beam filtration requirements

<table>
<thead>
<tr>
<th>Where the X-ray machine is normally operated:</th>
<th>Total filtration in the useful beam shall be not less than:</th>
</tr>
</thead>
<tbody>
<tr>
<td>below 70 kVP</td>
<td>1.5 mm aluminium equivalent</td>
</tr>
<tr>
<td>in the range 70 kVP to 100 kVP</td>
<td>2.0 mm aluminium equivalent</td>
</tr>
<tr>
<td>above 100 kVP</td>
<td>2.5 mm aluminium equivalent</td>
</tr>
</tbody>
</table>

11.2 The total filtration in the useful beam from materials it traverses in the X-ray tube and its housing (i.e. the inherent filtration) shall be permanently marked on the X-ray tube housing as thickness of aluminium equivalent at a nominated kilovoltage. The nominated kilovoltage should be 70 kVP or 100 kVP (or both).

11.3 The filtration in materials in the path traversed by the useful X-ray beam through X-ray collimation devices and the like attached to the X-ray tube shall be permanently marked on the outer cover of the device as thickness of aluminium equivalent at a nominated kilovoltage. The nominated kilovoltage should be 70 kVP or 100 kVP (or both).

11.4 Any filter which may be added as required to the useful X-ray beam shall where practicable be permanently labelled in such a manner that the labels may be read when the filter is in the useful X-ray beam. The labels shall state the material of which the filter is composed and its thickness.

11.5 Mammography techniques which employ soft X-rays shall retain at least a total of 0.5 mm aluminium equivalent filtration in the useful beam. Mammography and other low kilovoltage techniques shall be performed on X-ray equipment designed for that purpose.

11.6 On fixed fluoroscopic X-ray installations the total filtration in the useful beam shall be not less than 3 mm of aluminium equivalent at 100 kVP. On mobile fluoroscopic X-ray machines (mobile image intensifiers) the total filtration shall be not less than 2 mm aluminium equivalent at 70 kVP and should be not less than 2.5 mm aluminium equivalent at 70 kVP.

11.7 The total filtration in the useful X-ray beam on mass miniature chest photofluorographic units shall be not less than 2.5 mm aluminium equivalent at 70 kVP.

11.8 For the purpose of assessing compliance with 11.1. the HVL of the useful X-ray beam shall be not less than as shown in table 2.

11.9 For capacitor energy storage equipment, compliance shall be determined with the
maximum quantity of charge per exposure.

11.10 The aluminium equivalent of each of the items listed in table 3 which are used between the patient and image receptor, shall not exceed the indicated limits. Compliance shall be determined by X-ray measurements made at a potential of 100 kVp and with an X-ray beam which has a half value layer of 2.7 mm of aluminium. This requirement is applicable to front panels of cassette holders and film changers provided by the manufacturer for the purposes of patient support and/or to prevent foreign object intrusions. It does not apply to such items as screens and associated mechanical support panels or grids.

<table>
<thead>
<tr>
<th>Table 3. Aluminium equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
</tr>
<tr>
<td>Front panel(s) of cassette holder (total of all)</td>
</tr>
<tr>
<td>Front panel(s) of film changer (total of all)</td>
</tr>
<tr>
<td>Stationary tabletop</td>
</tr>
<tr>
<td>Movable tabletop (including stationary subtop)</td>
</tr>
<tr>
<td>Cradle</td>
</tr>
</tbody>
</table>

11.11 Interlocking of filters. Systems operating with more than one thickness of filtration should employ a filter interlock system combined with the kilovoltage selector, to prevent X-ray emission if the minimum required filtration is not in position.

12. LEAKAGE RADIATION

12.1 Every X-ray tube used for diagnostic purpose shall be enclosed in a housing such that the exposure from the leakage radiation at a distance of 1 m from the source shall not exceed $2.58 \times 10^{-6}$ C kg (100 mR) and should not exceed $2.58 \times 10^{-6}$ C kg (10 mR) in an hour at every rating specified by the manufacturer for that tube in that housing. Collimating devices shall be so constructed that in combination with the X-ray tube housing the whole assembly (i.e. the X-ray tube assembly) conforms with this criterion. Unless otherwise known, the ratings of X-ray tubes on fixed diagnostic machines may be taken for the purposes of leakage assessment to be 200 mA-
min in an hour. On portable diagnostic X-ray machines and on dental X-ray machines a rating of 20 mA- min in an hour may be used. A single suitable rating for mobile diagnostic machines cannot be selected since this vary considerably in applied voltage waveform, type of X-ray tube, power of generator, etc. Mobile diagnostic X-ray machines with rotating anode tubes may be assumed to have the same rating as fixed X-ray machines (in few cases in practice would actual workloads approach these levels).

12.2 Capacitor discharge X-ray machines. Leakage radiation from the X-ray tube housing assembly when the exposure device is not activated shall not exceed $5.16 \times 10^{-3}$ C kg$^{-1}$ (2 mR) in one hour at 50 mm from any accessible surface of the X-ray tube assembly with the X-ray beam collimating device fully open and with the maximum voltage on the capacitors.

12.3 Radiation from components other than the X-ray tube assembly. The radiation emitted from any component other than the X-ray tube assembly and which is an integral part of the X-ray machine shall not exceed $5.16 \times 10^{-5}$ C kg$^{-1}$ (2 mR) in one hour at 50 mm from the surface of the component, when the component is located at a place which is readily and properly accessible to any person during the operation of the X-ray machine.

12.4 Compliance shall be determined by measurement averaged over an area of 100 cm$^2$ with no linear dimension greater than 200 mm. The significance of narrow leakage beams shall however be investigated.

13. X-RADIATION EMISSION FROM TELEVISION MONITORS AND OTHER ELECTRONIC EQUIPMENT

13.1 X-rays emitted from any television monitor used in presenting video images either during the X-ray examination or subsequently, whether in the X-ray room or elsewhere, shall be less than $0.5 \times 10^{-5}$ Sv h$^{-1}$ (0.5 mrem h$^{-1}$) at any accessible point around the television receiver.

13.2 Any imaging device, cathode-ray tube, or other device which contains or acts as part of an electronic circuit but is ancillary to it, shall not emit X-rays which would result in dose rates to any person at any point around the device in excess of $0.5 \times 10^{-5}$ Sv h$^{-1}$ (0.5 mrem h$^{-1}$).

13.3 'Any accessible point' may conveniently be taken to mean at a distance of 50 mm from any point to the surface of the television monitor or electronic equipment being measured.

13.4 For the purpose of dose rate assessment $0.5 \times 10^{-5}$ Sv h$^{-1}$ (0.5 mrem h$^{-1}$) may be taken as equivalent to an exposure rate of $1.29 \times 10^{-2}$ C kg$^{-1}$ h$^{-1}$ (0.5 mR h$^{-1}$) averaged over a cross-sectional area of $10^4$ mm$^2$ in the region of maximum X-ray emission.

14. LIGHTS AND INDICATORS AT CONTROL PANEL

14.1 Warning lights at the X-ray control. There shall be a prominent light on the X-ray control panel which is illuminated when the X-ray machine is switched on to the electrical mains. The colour of the light may be blue or green. Alternatively the meters, indicators, etc. of the X-ray control panel may generally become illuminated when the electrical mains are switched on to the X-ray machine.

14.2 There shall be a prominent light on the X-ray control panel which is illuminated green when the X-ray exposure is in 'preparation' mode and another which is illuminated red during the period when X-rays are being produced.
14.3 Where there are more than one tube connected to the generator, the tube selector switch at the X-ray control panel shall be clearly and unambiguously labelled and the X-ray tube presently connected shall be indicated by an illuminated sign close to the selector switch or by other clear and unmistakable means.

14.4 When more than one patient may be examined at the same time in the same room or in adjacent rooms using general X-ray tubes connected to the same generator, each tube shall have a prominent warning light switch which becomes illuminated when that tube is connected to the generator. This will indicate that an exposure is likely to be made or is being made. The warning light should be red.

14.5 Control and indication of technique factors

(a) Visual indication. The technique factors to be used during an exposure shall be indicated before the exposure begins, except when automatic exposure controls are used, in which case the technique factors which are set prior to the exposure shall be indicated. On equipment having fixed techniques this requirement may be met by permanent markings. Indication of technique factors shall be visible from the operator position except in the case of spot films made by the fluoroscopist.

14.6 Regular inspections shall be performed and recorded to verify that all warning signs remain in place and warning lights are operating properly.

15. EXPOSURE SWITCHES AND TIMERS

15.1 Means shall be provided to terminate the exposure at a preset time interval, preset product of current and time, a preset number of pulses, or a preset radiation exposure to the image receptor.

15.2 Except during serial radiography, the operator shall be able to terminate the exposure at any time during and exposure of greater than half a second. Termination of exposure shall cause automatic resetting of the timer to its initial setting or to zero. It shall not be possible to make an exposure when the timer is set to a zero or off position if either position is provided.

15.3 During serial radiography, the operator shall be able to terminate the X-ray exposures at any time, but means may be provided to permit completion of any single exposure of the series in process.

15.4 The exposure-switch shall be so arranged that it can be operated from a safe position only, in the case of a spot film device, and in the case of special techniques when it is necessary to control the irradiation from the examination equipment or elsewhere, the switch shall be located so that it can be operated personally by the user. In all cases, the switch shall be so constructed and connected that the operator will be able to terminate the irradiation at any time and it should, wherever practicable, be a dead-man switch.

16. ADDITIONAL REQUIREMENTS FOR FLUOROSCOPY

16.1 The provisions of this section apply to equipment for fluoroscopy and radiography and for the recording of images through an image intensifier.

16.2 Primary protective barrier. The fluoroscopic imaging assembly shall be provided with a primary protective barrier which intercepts the entire cross-section of the useful beam at any SID. The X-ray tube used for fluoroscopy shall not
produce X-rays unless the barrier is in position to intercept the entire useful beam. The exposure-rate due to transmission through the barrier with the attenuation block in the useful beam combined with radiation from the image intensifier if provided, shall not exceed mR h⁻¹ at 10 cm from any accessible surface of the fluoroscopic imaging assembly beyond the plane of the image receptor for each R min⁻¹ of entrance exposure rate. This may be achieved by using lead glass of lead equivalence equal to:

(a) 2 mm for apparatus capable of operating up to 100 kVp;

(b) an additional 0.01 mm per kVp above 100 kVp.

16.3 The entrance exposure rate shall be measured in accordance with 16.5. The exposure rate due to transmission through the primary barrier combined with radiation from the image intensifier shall be determined by measurement averaged over an area of 100 cm² with no linear dimension greater than 20 cm. If the source is below the tabletop, the measurement shall be made with the input surface of the fluoroscopic imaging assembly positioned 30 cm above the tabletop. If the source is above the tabletop and the SID is variable, the measurement shall be made with the end of the beam-limiting device or spacer as close to the tabletop as it can be placed, provided that it shall not be closer than 30 cm. Movable grids and compression devices shall be removed from the useful beam during the measurement. For all measurements the attenuation block shall be positioned in the useful beam 10 cm from the point of measurement of the entrance exposure rate and between this point and the input surface of the fluoroscopic imaging assembly.

16.4 The central axis of the useful X-ray beam shall pass through the geometric centre of the fluorescent screen or other image receptor of the fluoroscopic imaging assembly.

16.5 Entrance exposure rate limits

(a) Equipment with automatic exposure rate control. Fluoroscopic equipment which is provided with automatic exposure-rate control shall not be operable at any combination of tube potential and current which will result in an exposure-rate in excess of 10 R min⁻¹ at the point where the centre of the useful beam enters the patient, except:

(i) during recording of fluoroscopic images, or

(ii) when an optional high level control is provided. When so provided, the equipment shall not be operable at any combination of tube potential and current which will result in an exposure rate in excess of 5 R min⁻¹ at the point where the centre of the useful beam enters the patient unless the high level control is activated. Special means of activation of high level controls shall be required. The high level control shall only be operable when continuous manual activation is provided by the operator. A continuous signal audible to the fluoroscopist shall indicate that the high level control is being employed.

(b) Equipment without automatic exposure rate control. Fluoroscopic equipment which is not provided with automatic exposure-rate control shall not be operable at any combination of tube potential and current which will result in an exposure-rate in excess of 5 R min⁻¹ at the point where the centre of the useful beam enters the patient, except:

(i) during recording of fluoroscopic images, or

(ii) when an optional high level control is activated. Special means of activation of high level control shall be required. The high level control shall only be operable when continuous
manual activation is provided by the operator. A continuous signal audible to the fluoroscopist shall indicate that the high level control is being employed.

16.6 Compliance with 16.5 shall be determined as follows:

(a) If the source is below the table, exposure rate shall be measured 1 cm above the tabletop or cradle.

(b) If the source is above the table, the exposure rate shall be measured 30 cm above the tabletop with the end of the beam limiting device or spacer positioned as closely as possible to the point of measurement.

(c) In a C-arm type of fluoroscope, the exposure rate shall be measured 30 cm from the input surface of the fluoroscopic imaging assembly.

16.7 Indication of potential and current. During fluoroscopy and cine-fluorography X-ray tube potential and current shall be continuously indicated. Deviation of X-ray tube potential and current from the indicated values shall not exceed the maximum deviation as stated by the supplier in accordance with clause 9.

16.8 Source-skin distance. Means shall be provided to limit the source-skin distance such that in fluoroscopy with mobile equipment, the source-skin distance shall not be less than 30 cm and with stationary equipment, the source-skin distance shall not be less than 30 cm and preferably should not be less than 45 cm.

16.9 Fluoroscopic timer. Means shall be provided to preset the cumulative on-time of the fluoroscopic tube. The maximum cumulative time of the timing device shall not exceed 5 minutes without resetting. A signal audible to the fluoroscopist shall indicate the completion of any preset cumulative on-time. Such signal shall continue to sound while X-rays are produced until the timing device is reset.

16.10 Activation of tube. X-ray production in the fluoroscopic mode shall be controlled by a device which requires continuous pressure by the operator for the entire time of any exposure. When recording serial fluoroscopic images, the operator shall be able to terminate the X-ray exposures at any time, but means may be provided to permit completion of any single exposure of the series in process.

16.11 Protective materials shall be affixed to the X-ray equipment or otherwise installed in such a way as to be interposed between sources of scattered radiation and X-ray personnel. These materials shall have a lead equivalence of not less than 0.5 mm over the fluoroscopy range of kilovoltages. Protective materials shall be effective in any position of the fluorescent screen assembly. They shall not obstruct palpation or other necessary manipulation of the patient. The usual example is a set of lead curtains hung from the fluorescent screen assembly.

16.12 The side of the X-ray couch nearer the fluoroscopist including the bucky slot should be closed or otherwise shielded to protect the legs and feet of the fluoroscopist. Where the couch is open-sided or lightly covered then a shielded enclosure should be extended from the undercouch X-ray tube and collimating device to the underside of the panel of the X-ray couch.

16.13 The circuit on the primary side of the equipment shall be so constructed that currents in the X-ray tube do not exceed 5 mA during fluoroscopy. A separate switch shall be provided when the tube currents exceed 5 mA, for example, in cinefluoroscopy.

16.14 The X-ray tube assembly and fluoroscopic imaging assembly shall be ganged together such that there can be no lateral movement of the
one with respect to the other. Where the ganging is disconnected it shall no longer be possible to perform fluoroscopy.

17. MECHANICAL REQUIREMENTS

17.1 Support and immobilization devices. Support and immobilization devices shall comply with the following requirements:

(a) Equipment and parts serving for support and/or immobilization of patients shall be designed and manufactured so that physical injuries are avoided; fixings cannot become loose as a result of movements of the patient or of the equipment, and the patient shall not be at risk.

(b) The mechanical strength of supporting parts for adult human patients shall be appropriate for a patient mass of at least 135 kg. All such supporting parts shall be firmly fixed or anchored to a part of the building fabric and shall remain stable under normal conditions of use.

(c) Where power-operated variable compression devices are installed, the amount of force shall not exceed 50 N. In the event of equipment movement relative to the patient during manual or power-operated compression, the compression locks or power-operation shall be released.

(d) For myelography, a lock shall be provided to prevent inadvertent compression of the patient. In this mode of operation, it shall be possible to move the patient relative to the compression device.

17.2 Moving parts. All moving parts shall be adequately protected by means of suitable guards or enclosures so that under normal conditions of operation no parts of the body can enter into these parts. Such guards shall be of sufficient strength and rigidity to serve their purposes and shall be removable only by the use of tools.

17.3 Expellable parts. If there is a risk of parts being expelled, special precautions shall be taken, e.g. the use of protective casings or guards.

17.4 Vibration and noise. Equipment should not cause vibration or noise disturbing to the operator or patient or such as would render radiographs unsharp.

17.5 Suspension system. Suspended assemblies such as ceiling-mounted tube suspensions, image intensifier assemblies and other equipment suspended over the operational area represent a potential hazard to both staff and patients, and special attention shall be given to the security of such suspensions under static and dynamic conditions, as follows:

(a) All supporting parts shall be effectively secured.

(b) Dual suspension should be used with cables or chains. Where a single suspension is employed, it shall incorporate an automatic locking device to prevent a suspended assembly from falling through the failure of the suspension cable or chain.

(c) The total safety factor of the suspension system as calculated from the following formula shall be not less than 4:

\[
\text{Total safety factor} = \frac{\text{Safe working load}}{\text{Maximum static load}}
\]

(d) Safety measures employed in suspension systems shall ensure that:

(i) where suspension components are duplicated for reasons of safety, each shall be capable of carrying the load imposed upon it in
the event of failure of the other:

(ii) dual suspensions shall each be separately anchored to fixed and moving components.

(e) Counterweighting mechanisms employing wire ropes or chains shall be designed so that the pulleys or sprockets for such mechanisms are of a radius appropriate to the rope or chain employed in order to provide proper guidance and to prevent the rope or chain from jumping off.

(f) All counterweighting systems shall be provided with adequate covers, and shall be accessible for service and inspection.

(g) Where any suspended equipment is installed, care shall be taken in respect of its balance, and in particular on the release of detachable parts.

17.6 Hydraulic and pneumatic power. Hydraulic equipment and pneumatic powered devices in equipment shall be designed so that they are safe during normal use and that no hazards may arise. Particular attention shall be paid to the following:

(a) Pressure or loss of pressure exceeding a safe limit.

(b) Escape of gas or fluids under pressure.

(c) Protection of hydraulic and pneumatic devices against external hazardous influences.

17.7 Stops and brakes. On all equipment in which there are provisions for mechanical movement, mechanical stops shall be provided to arrest such movement at the limits. Such stops shall be located appropriately to the moving mass, and shall be securely attached. Where appropriate, such stops should have a shock-absorbing action. Mechanical stops should not cause undue stresses on the equipment. Where mechanical or electromechanical brakes are fitted, they shall also be securely attached.

18. ELECTRICAL REQUIREMENTS

18.1 All electrical installations shall comply with the existing National Electricity Board statutory requirements. Wherever necessary, the X-ray systems shall have independent power supply.

18.2 Immunity to supply failure. All equipment shall be designed and/or installed in such a way that the cessation or interruption of the whole or part of the mains supply or a reduction in voltage below the specified limits for normal operation cannot cause a hazard to patients or staff, except that which might arise indirectly for patients through the consequent premature termination of a medical procedure being performed.

18.3 Electric cables. Cables shall be used within their electrical, mechanical and environmental rating and shall be suitably protected with particular concern for protection against undue wear, accidental damage, excessive temperature, the effects of ionising and non-ionising radiation and chemical attack. Cable entries to conduit and trunking systems shall be effectively bushed or flared to obviate abrasion. Unenclosed cables shall be provided with effective strain relief at connection points and all cables shall be of adequate length to prevent strain arising in any available configuration of the equipment.

18.4 Each movement in which motion is intended to be stopped in normal operation at a stage observed by the operator while motion is in progress, shall be controlled in such a way that motion is not possible except by the continuous actuation of a controlling device (e.g. a switch wired to the 'stop' position).
18.5 In all systems in which a failure could result in a patient being trapped or suspended in a position from which he could not quickly and safely be removed from the equipment, means should be provided to enable the configuration to be suitably adjusted under manual control.

18.6 All controls, instruments and indicating devices shall be permanently and clearly marked to indicate their functions. Markings in plain language shall be in English or Bahasa Malaysia. Markings by symbols should follow established international practice and their meanings shall be described in the operating instructions.

18.7 Every sealed housing containing an X-ray tube insert shall be fitted with a switch actuated either by the pressure within the housing or by the movement of a device provided to accommodate changes of volume within the housing, and arranged to open in increasing pressure or volume.

18.8 The switch shall be connected so that, on opening, all electrical supplies to the housing are disconnected, except that a supply connected directly and exclusively to a filament or a control grid of the X-ray tube insert may remain connected.

18.9 The switch shall open at a level of pressure or volume such that the attainment of an unsafe pressure in the housing is prevented by the disconnection of supplies in accordance with 18.8.

19. AUTOMATIC FILM PROCESSING UNITS

19.1 Thermal cut-outs. Every system employing a heating element shall be provided with a thermal cut-out in addition to any device used to maintain normal operating temperatures, arranged to disconnect the supply to the element in order to prevent danger or damage in the event of absence (or partial absence) of liquid or reduction of air flow or modification of any other condition on which the maintenance of normal temperatures is dependent. The cut-out may be of a self-resetting type but the circuit should be such that restoration of the disconnected supply is possible only by the deliberate operation of a control.

19.2 Prevention of contact with moving parts. Film processors shall be constructed so that no danger arises from accidental contact with moving parts or the opening of covers which are provided to give access without the aid of tools for routine procedures such as film clearance, replenishment or cleaning. Protection may be afforded by shielding of the moving parts or by appropriate interlocking to inhibit movement when the covers are not fully closed.

19.3 Access covers. Every cover, the opening of which could cause films in the course of processing to be spoiled, shall be latched in the closed position to discourage casual opening, unless it is a cover to which other means of fixing are applicable.

19.4 Control of water flow. Where correct operation requires a particular flow-rate of water, the means to maintain the flow-rate automatically within the required limits should be included in the installation.

19.5 Electrical isolation. The means for isolating the electrical supply to a film processor shall be accessible to operators at both the input and the output sections of the processor.

20. DARKROOM

20.1 The darkroom shall be ventilated by a
ventilating fan or by air-conditioning.

20.2 The darkroom shall be light proof such that it should not be possible to see any light from outside after twenty minutes dark adaptation from daylight.

20.3 There shall be adequate arrangements for processing films. This includes the provision of a thermometer (preferably non-mercury type), a suitable timer, suitable processing tanks, correct safe-lights and other fittings.

20.4 The developer and fixer should be replaced at regular intervals, even though not many films have been processed. This interval shall not exceed a period of two months.

20.5 The floor should be durable, easily cleaned, impervious and not slippery.

21. INSTALLATION REQUIREMENTS

21.1 The supplier shall specify any required pre-installation work including the provision of electrical and other supply points, electrical interconnections, ceiling fixings and floor mounting, and all features necessary to enable the installation to comply with this code. The supplier shall determine whether the electrical power supply is adequate and sufficiently stable for each X-ray machine which is to be installed and wherever necessary the X-ray system shall have independent power supply.

21.2 The supplier shall not proceed with an installation if he believes or has reason to suspect that the pre-installation work is incompatible with safety and reliability, and that it will affect the performance of the X-ray system in the completed installation.

21.3 To ensure the safety and security of clamped, bolted or screwed devices, they shall be positive in action and not subject to rapid wear. They shall employ positive locking devices such as washers, stiff nuts, split pins, forged screens or forged pins, screen-locking compounds and grub-screw indents. All rough surfaces, sharp corners and edges which may cause injury or damage shall be avoided and particular attention should be paid to flanges for frame edges and to the removal of burrs.

21.4 The supplier, when installing an X-ray tube or tubehead, shall ensure that any necessary additional filter is fitted to provide the appropriate total filtration for the maximum tube voltage at which the equipment is rated to be used.

21.5 The X-ray system shall be installed so as to be accessible for inspection and servicing.

21.6 After installation, the X-ray system shall be serviced in such a way that when the servicing is completed, the X-ray system complies with this code or any local radiation protection rules promulgated by the users.

PART V: RECORDS AND REPORTS OF X-RAY SYSTEMS

22. GENERAL REQUIREMENTS

22.1 Records and reports required for X-ray systems as listed in 1.3 shall include information on all components which may affect the quantity and quality or direction of radiation emissions.

22.2 All reports and records including data and product descriptions shall be signed. Reports of subsequent additions to the X-ray system shall be
made within 90 days after the additions are made.

22.3 The report shall be distinctly marked 'Report of (Name of supplier)' and shall:

(a) State the model of the X-ray system including the name of the manufacturer and the year of manufacture.

(b) Identify each model of the X-ray system with sufficient information concerning the manufacturer's code or other system of labelling to determine the place of manufacture.

23. INITIAL REPORTS BEFORE INSTALLATION

23.1 Initial reports shall:

(a) Describe the function, operational characteristic affecting radiation emission, and intended and known uses of each model of the X-ray system.

(b) State the standards or design specifications if any for each model with respect to radiation safety.

(c) Describe the physical or electrical characteristics such as shielding, or electronic circuitry, etc. incorporated into the X-ray system in order that the standards or specifications reported pursuant to 23.1 (b) are met.

23.2 Tube housing assemblies. For each tube housing assembly, there shall be provided:

(a) Statements of the leakage technique factors for all combinations of tube housing assemblies and beam limiting devices for which the tube housing assembly manufacturer states compatibility, the minimum filtration permanently in the useful beam expressed as millimeters of aluminium equivalent, and the peak tube potential at which the alúminium equivalent was obtained.

(b) Cooling curves for the anode and tube housing.

(c) Tube rating charts.

23.3 If the tube is designed to operate from different types of X-ray high-voltage generators (such as single-phase self-rectified, single-phase half-wave rectified, single-phase full-wave rectified, three-phase six pulse, three-phase 12 pulse, constant potential, capacitor energy storage) or other modes of operation such as alternate focal spots or speeds of anode rotation which may affect its rating, specific identification of the difference in rating shall be noted.

23.4 X-ray controls and generators. For the X-ray control and associated X-ray high-voltage generator there shall be provided:

(a) A statement of the rated line voltage and the range of line-voltage regulation for operation at maximum line current.

(b) A statement of the maximum line current of the X-ray system based on the maximum input voltage and current characteristics of the tube housing assembly compatible with rated output voltage and rated output current characteristics of the X-ray control and associated high-voltage generator.

(c) A statement of the technique factors that constitute the maximum line current condition described in 23.4 (b).

(d) A statement of the generator rating and duty cycle.
(e) A statement of the maximum deviation from the indication given by labelled control settings and/or meters during any exposure when the equipment is connected to a power supply as described in accordance with this paragraph. In the case of fixed technique factors, the maximum deviation from the nominal fixed value of each factory shall be stated.

(f) A statement defining the measurement basis (or bases) upon which the exposure time, peak tube potential, tube current, and/or other technique factors are stated pursuant to 23.4 (c).

23.5 Initial reports shall describe the methods and procedures employed, if any, in testing and measuring each model with respect to radiation safety including the control of unnecessary, secondary, or leakage radiation, the applicable quality control procedures used, and the basis for selecting such testing and quality control procedures.

23.6 For X-ray systems which may produce increased radiation with age, initial reports shall describe the methods and procedures used, and frequency of testing for durability and stability with respect to radiation safety.

23.7 Initial reports shall provide sufficient results of the testing and measuring of radiation safety and of the quality control procedures described in accordance with 23.1 (c) and 23.2 of this code to determine the effectiveness of the methods and procedures used to accomplish the stated purposes.

23.8 Initial reports shall report all warning signs, labels and instructions for installation, operation, and use which relate to radiation safety.

23.9 Initial reports shall provide upon request such other information as may be reasonably required to determine whether the supplier has acted or is acting in compliance with the code.

24. REPORTS AFTER INSTALLATION

24.1 Certification tag. The supplier shall certify that the X-ray system conforms to this code. The certification shall be in the form of a label or tag permanently affixed to or inscribed on the X-ray system so as to be legible and readily accessible to view when the X-ray system is fully assembled for use.

24.2 A supplier who installs an X-ray system shall file a report of such assembly. Completed reports shall be submitted within 15 days following completion of the assembly. The details of the report shall include the following:

(a) The full name of the assembler and the date of assembly or installation.

(b) The name and address of the purchaser and the location and specific identification of the X-ray system or sub-system.

(c) An affirmation that all instruction manuals and other information as required by this code have been delivered to the purchaser.

(d) A statement of the type and intended use of the X-ray system or sub-system into which the certified components were assembled or installed, such as ‘radiographic-stationary general purpose’.

(e) A list of all components which were assembled or installed into the X-ray system or sub-system in accordance with the instructions
of the manufacturers, identifying the components by type, manufacturer, model number and serial number.

(f) An affirmation that all components installed in the system conform with this code.

24.3 Defects.

(a) For the purpose of this section, an X-ray system shall be considered to have a defect if:

(i) It is a component of the X-ray system which does not utilize the emission of radiation in order to accomplish its purpose, and from which such emissions are unintended, and as a result of its design, production or assembly (1) it emits radiation which created a risk of injury, including genetic injury, to any person, or (2) it fails to conform to its design specifications relating to radiation emission;

(ii) It is a product which utilizes radiation to accomplish its primary purpose and from which such emissions are intended and as a result of its design, production or assembly it (1) fails to conform to its design specifications relating to the emission of radiation, or (2) without regard to the design specifications of the product, emits radiation unnecessary to the accomplishment of its primary purpose which creates a risk of injury including genetic injury to any person, or (3) fails to accomplish the intended purpose.

(b) Any supplier who discovers that any component of the X-ray system assembled or imported by him, which has left its place of manufacture and has a defect or fails to comply with this code, shall immediately furnish notification with reasonable promptness to the purchaser of such X-ray system or any subsequent transferee of such X-ray system.

(c) The notification shall be confirmed in writing and, in addition to other relevant information which may be required shall include the following:

(i) Identification of the component(s) involved.

(ii) The expected usage of the component if known to the manufacturer.

(iii) A description of the defect in the component or the manner in which the component fails to comply with the code.

(iv) An evaluation of the hazards reasonably related to the defect or the failure to comply with the code.

(v) A statement of the measures to be taken to repair such defect or to bring the product into compliance with the code.

(vi) The date and circumstances under which the defect was discovered.

(vii) The identification of any trade secret or information which the supplier desires to be kept confidential.

(d) If any component(s) of an X-ray system fails to comply with this code or has a defect and the notification specified in this code is required to be furnished, the supplier of such component(s) shall (1) without charge, bring such component(s) into conformity with this code or remedy such defect, and provide reimbursement for any expenses for transportation of such component(s) incurred in connection with having such product brought into conformity or having such defect remedied or (2) replace such component(s) with a like or equivalent component(s) which comply with the code and has no defect relating to the safety of its use or (3)
make a refund at cost of the component(s) to the purchaser.

(e) Reports for remedying such defects in the component(s) shall include:

(i) Identification of the components involved.

(ii) The specific modifications, alterations, changes, repairs, corrections or adjustments made to bring the components into conformity.

(iii) The technical data, test results or studies demonstrating the effectiveness of the remedial action.

24.4 Repairs, replacements and services on the X-ray system.

(a) A report is required for the repair, replacement and service on the X-ray system already installed and in operation.

(b) Such reports shall include the following:

(i) The identification of the X-ray system involved.

(ii) The specific job descriptions, modifications, alterations, changes, repairs, corrections or adjustments made to bring the X-ray system into conformity or to remedy any defect or for the purpose of routine maintenance service.

(iii) The manner in which the operations described in 24.4 (b) (ii) is accomplished.

(iv) The technical data, test results or studies demonstrating the completion of the job or remedial action.

25. COMPUTED TOMOGRAPHY (CT) SCANNER SYSTEMS USING TRANSMITTED X-RAYS

25.1 Reports, records and certifications as provided in Part 4 of this code shall include the following additional parameters.

(a) Physical parameters

(i) Image noise
(ii) Pixel size
(iii) Spatial resolution (tomographic plane)
(iv) Slice width (z-axis spatial resolution)
(v) Radiation dose
   (1) Axial dose profile (single scan)
   (2) Multi-slice dose
(vi) Spatial non-uniformity of CT values for uniform water phantom
(vii) Spatial non-uniformity of CT values for high atomic number material
(viii) Structured noise
(ix) Linearity of CT values
(x) Accuracy of patient positioning devices
(xi) Figure of merit

(b) Technical and clinical parameters

(i) Scanning geometry and detector systems

(1) Number of detectors
(2) Type and geometry
(3) Scanning times available
(4) Size of scan and slice widths, their methods of selection
(5) Digital radiographic facilities
(6) Arrangements for mechanical up-dates

(ii) X-ray generator design

(1) Range of kVp, mA or mAs available
(2) Type of tube
(3) Limitations due to tube loading
(4) X-ray beam geometry including focal spot size and shape
(5) Tube warm-up procedures

(iii) Size and shape of gantry aperture

(1) Ease of patient handling
(2) Gantry and couch movements, angulation
(3) Quickness of operation

(iv) Control and viewing

(1) Simplicity of main controls and viewing systems
(2) Facilities available during scanning, e.g. viewing

(v) Software

(1) Number and size of calculation and display pixels
(2) Reconstruction times (partial, total)
(3) Range of data processing algorithms and post-reconstruction programmes
(4) Disc picture capacity (processed and unprocessed)
(5) Arrangements for software updates
(6) Ease of implementing own software

(vi) Hard copy facilities

(1) Polaroid film, bromide paper, X-ray film
(2) Multiformat imager, line printer, camera

(vii) Archival store

(1) Magnetic tape, floppy disc, film

(viii) Additional facilities

(1) Facilities of independent consoles including additional software
(2) Data transfer from main machine
(3) Radiotherapy packages

(ix) Room environment

(1) Air conditioning requirements
(2) Humidity requirements
(3) Overall space required

(x) Maintenance and servicing

(1) Requirements for calibration, ease with which it is achieved
(2) Time involved, how often it is to be done
(3) Ease of servicing and maintenance arrangements, e.g. tube-life
(4) Guarantees, training of local technical staff
(5) Availability of machine diagnostic programme

25.2 Definitions as applied to CT scanners are as follows:

(a) Image noise. When a uniform material is imaged on a CT scanner and the CT values for a localized area of this image are examined, the CT values are not all the same but vary around a mean value. This random discrepancy is known as image noise. Image noise is expressed as the normalized standard deviation of an array of CT values at the centre of a single scan of a uniform water phantom. The standard deviation, $\sigma_{\text{water}}$, is defined as:

$$\sigma_{\text{water}} = \sqrt{\frac{1}{N-1} \left( \sum_{j,k} \alpha_{(j,k)} \right)^2 - \frac{1}{N} \left( \sum_{j,k} \alpha_{(j,k)} \right)^2}$$

where,

$\alpha_{(j,k)}$ is the CT value of the pixel at position $j, k$; $N$ is the number of pixels in the sample area.

(b) Pixel. A pixel is the individual element of an image matrix.

(c) Spatial resolution (tomographic plane). Spatial resolution in the plane of the CT image (tomographic plane) is measured as the Full-Width-Half-Maximum (FWHM) and the Full-Width-Tenth-Maximum (FWTM) of the Line Spread Function (LSF) derived from an edge, at specified positions within the defined phantoms. The percentage undershoot and overshoot is also measured when appropriate.

(d) Slice width (x-axis resolution). Slice width (or axial sensitivity profile of z-axis spatial resolution) is the effective thickness of the
tomographic section. It is measured as the Full-Width-Half-Maximum (FWHM) and the Full-Width-Tenth-Maximum (FWTM) of the axial (z-axis) sensitivity profile at the centre and towards the edge of the defined phantoms.

(e) Radiation dose. An estimate is required of the total dose (integral dose) and the maximum dose during a series of scans of contiguous slices. Due to the size and shape of the body and the X-ray beam energies normally used, the maximum absorbed dose is on the surface of the body. The average surface dose round the body can be used as an estimate of the integral dose.

(f) Spatial non-uniformity of CT values for uniform water phantom. The gradual variations of CT number across the image of a water-filled phantom.

(g) Spatial non-uniformity of CT values for high atomic number material. The changing CT values for a sample of high atomic number material as it is moved from place to place in a uniform water phantom.

(h) Linearity of CT values. The CT value ($H_n$) of a sample of materials is defined by the expression.

\[ H_n = K \frac{\mu_w (E) - \mu_x (E)}{\mu_w (E)} \]

Where $\mu_w (E)$ and $\mu_x (E)$ are the linear attenuation coefficients at the 'effective energy' of the X-ray beam at the point of measurement for water and the scanned sample respectively. $K$ is a constant, which has a value of 1000 if the CT value scale is to be in Hounsfield units.

(i) Figure of merit

Figure of merit, $Q = \sqrt{\frac{1000}{R^2 DZ S^2}} \text{mm}^{-2} \text{Gy}^{-1/2}$

where,

- $R$ is the FWHM of LSF in the image plane in mm;
- $D$ is the average multi-slice dose around the surface of the phantom in mGy;
- $Z$ is the nominal or measured slice width in mm;
- $S$ is the normalized standard deviation given by

\[ S = \frac{d_{\text{water}} \times 100}{CT \text{(scale)}} \]

Where CT (scale) = CT (water) - CT (air) and where CT (water) and CT (air) are the CT values obtained from the CT scanner for water and air respectively. By definition water has a value zero and air a value of - 1000 when measured in Hounfield units.

(k) Availability of spare parts for a minimum of ten years after installation.

PART VI: ADMINISTRATIVE REQUIREMENTS

26. ADMINISTRATIVE REQUIREMENTS

26.1 Part VI of this code should be read in conjunction with the Radioactive Substances Act 1968 and Rules made under the Act. It is not intended as a substitute for reading the Act or Rules and does not purport to be a legal interpretation of the Act or Rules.

26.2 A permit from the Director General of the Ministry of Health is required for the use of X-ray systems in medical diagnosis.

26.3 Permits for medical diagnostic purposes
are issued to registered medical practitioners.

26.4 Registered medical practitioners shall confine their radiological examinations to plain X-rays of the chest, abdomen and extremities, excluding the axial skeleton.

26.5 Persons operating X-ray systems under the supervision and instruction of the medical practitioner shall be given relevant training.

26.6 Persons operating X-ray systems shall perform only radiographic techniques for which they are competent.

26.7 The medical practitioner shall be responsible for all provisions required for complying with this code unless otherwise stated. For practical purposes a radiation protection officer may be appointed to ensure that the provisions of this code are continuously carried out. This officer shall be responsible to the medical practitioner only.

26.8 All persons operating or assisting in the operation of X-ray systems shall be provided with monitoring devices. A film badge pocket dosimeter or thermo-luminescent detector badge shall be used.

26.9 Instances of excessive exposure to radiation such as in an accident and any suspected leakage of X-rays from the X-ray system or X-ray room shall be reported to the Radiation Protection Unit.

26.10 A personal record shall be kept for all workers involved in the operation of the X-ray system. This record shall include personal details, duties performed, results of medical examinations and results of personal monitoring.

26.11 Persons involved in the operating of the X-ray system shall be provided with a pre-employment medical examination and annual medical examinations. The medical examination shall include a full blood examination.

26.12 A register shall be kept for all patients undergoing X-ray examinations.

26.13 A record shall be kept for all films and processing chemicals acquired.
Where R is the radius of the inner circle and 5R is not less than 7.5 cm.

Figure 1. Radiation warning sign
Observation window (Lead glass)

Observation window

Figure 2. Typical designs of control stations
(Minimum floor-area 1.5 m²)
Figure 3. An example of X-ray room
Schedule 1

Dose equivalent limits

The dose equivalent limits which are derived from recommendations of the International Commission on Radiological Protection (ICRP) are as follows:

(a) The dose limit for the whole body is 50 mSv/yr (5 rem/yr) and this must also be the limit for the sum of the dose-equivalent limits to all tissues. In order to achieve this, weighting factors are assigned to each tissue:

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Weighting Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gonads</td>
<td>0.25</td>
</tr>
<tr>
<td>Breast</td>
<td>0.15</td>
</tr>
<tr>
<td>Red bone marrow</td>
<td>0.12</td>
</tr>
<tr>
<td>Lung</td>
<td>0.12</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.03</td>
</tr>
<tr>
<td>Bone surface</td>
<td>0.03</td>
</tr>
<tr>
<td>Remainder</td>
<td>0.30 -</td>
</tr>
</tbody>
</table>

This should consist of 5 other unspecified tissues or organs having a weighting factor of 0.06 each.

(b) The dose limit for any specific tissue is 0.5 Sv (50 rem) in a year except the lens of the eye which is 0.3 Sv (30 rem).
<table>
<thead>
<tr>
<th>Tube voltage</th>
<th>Required barrier in millimetres of lead</th>
<th>1 m</th>
<th>2 m</th>
<th>3 m</th>
<th>4 m</th>
<th>5 m</th>
<th>6 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>constant potential</td>
<td>mA min. per week</td>
<td>85 kV</td>
<td>100 kV</td>
<td>125 kV</td>
<td>150 kV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td>0.15</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td>1.1</td>
<td>0.8</td>
<td>0.5</td>
<td>0.2</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td>0.05</td>
<td>0.02</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>0.01</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>0.01</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>0.01</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>0.01</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>0.01</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

The tabled values give the shielding required to reduce the exposure to \( 2.88 \times 10^{-5} \text{ C/kg} \). To compute the total shielding required outside controlled areas it is necessary to add one tenth of the layer to reduce the exposure to \( 2.88 \times 10^{-5} \text{ C/kg} \).
### Schedule 2b

Primary protective barriers in lead and concrete

The tabulated values give the shielding required to reduce the exposure to $2.58 \times 10^{-4}$ CKg\(^{-1}\) in controlled areas.

To compute the shielding required outside controlled areas it is necessary to add a tenth-value layer to reduce the weekly exposure to $2.58 \times 10^{-4}$ CKg\(^{-1}\).

<table>
<thead>
<tr>
<th>Tube voltage constant potential</th>
<th>WUT in mA min. per week</th>
<th>Required barrier in millimetres of lead</th>
<th>Required barrier in centimetres of concrete (2358 kg m(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>At a source distance of 1m 2m 3m 5m 10m</td>
<td>At a source distance of 1m 2m 3m 5m 10m</td>
</tr>
<tr>
<td>50 kV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,000</td>
<td>0.6 0.5 0.4 0.3 0.2</td>
<td>6.4 5.1 5.1 3.8 2.5</td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td>0.5 0.4 0.3 0.2 0.1</td>
<td>5.1 5.1 3.8 2.5 1.3</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>0.4 0.3 0.2 0.1 0.1</td>
<td>5.1 3.8 2.5 1.3 1.3</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>0.3 0.2 0.2 0.1 0.1</td>
<td>3.8 2.5 1.3 1.3 1.3</td>
<td></td>
</tr>
<tr>
<td>70 kV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,000</td>
<td>1.4 1.1 0.9 0.7 0.5</td>
<td>12.7 10.2 7.6 6.4 5.1</td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td>1.1 0.9 0.7 0.5 0.4</td>
<td>10.2 7.6 6.4 5.1 3.8</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>0.9 0.7 0.5 0.4 0.2</td>
<td>7.6 6.4 5.1 3.8 2.5</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>0.7 0.5 0.4 0.3 0.1</td>
<td>6.4 5.1 3.8 2.5 1.3</td>
<td></td>
</tr>
<tr>
<td>85 kV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,000</td>
<td>2.3 1.8 1.5 1.2 0.8</td>
<td>20.3 15.2 12.7 11.3 7.6</td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td>1.8 1.4 1.1 0.9 0.6</td>
<td>15.2 12.7 10.2 7.6 5.1</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>1.4 1.1 0.8 0.6 0.4</td>
<td>12.7 10.2 7.6 5.1 3.8</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>1.1 0.8 0.6 0.4 0.2</td>
<td>10.2 7.6 5.1 3.8 2.5</td>
<td></td>
</tr>
<tr>
<td>100 kV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,000</td>
<td>2.9 2.4 2.0 1.7 1.2</td>
<td>22.9 19.1 16.5 14.0 10.2</td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td>2.5 2.0 1.6 1.3 0.8</td>
<td>20.3 16.5 14.0 10.2 6.4</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>2.0 1.5 1.2 0.9 0.5</td>
<td>16.5 12.7 10.2 7.6 3.8</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>1.6 1.1 0.8 0.6 0.3</td>
<td>14.0 10.2 6.4 5.1 2.5</td>
<td></td>
</tr>
<tr>
<td>125 kV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,000</td>
<td>3.3 2.7 2.4 2.0 1.5</td>
<td>27.9 22.9 20.3 17.8 14.0</td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td>2.8 2.3 1.9 1.6 1.0</td>
<td>24.1 20.3 16.5 14.0 10.2</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>2.4 1.8 1.5 1.1 0.7</td>
<td>20.3 16.5 14.0 10.2 6.4</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>1.9 1.4 1.1 0.8 0.4</td>
<td>16.5 12.7 10.2 7.6 3.8</td>
<td></td>
</tr>
<tr>
<td>150 kV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,000</td>
<td>3.5 2.9 2.6 2.2 1.6</td>
<td>30.5 25.4 22.9 19.1 14.0</td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td>3.0 2.5 2.2 1.7 1.2</td>
<td>25.4 21.6 19.1 15.2 11.3</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>2.6 2.1 1.7 1.3 0.8</td>
<td>22.9 17.8 15.2 11.3 7.6</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>2.2 1.6 1.3 0.9 0.5</td>
<td>19.1 14.0 12.7 7.6 3.8</td>
<td></td>
</tr>
</tbody>
</table>

W = Workload in mA min / week
T = Occupancy factor
U = Use factor
BASIS

In the preparation of this code, references were made to the following publications:

(a) Code of Safe Practice for the Use of X-Rays in Diagnosis (Medical), August 1981 National Radiation Laboratory New Zealand.


(c) Technical Requirements for the supply and Installation of Radiological Apparatus (1980) Department of Health and Social Security United Kingdom.

(d) Approval and Test specification for Electromedical Equipment Part 5 - Dental and Mobile Medical X-Ray Machine, 32015-1977 Standards Association of Australia.


(g) Protection Against Ionising Radiation from External Sources ICRP Publication 15 (1969).

(h) Protection of the Patient in X-Ray Diagnosis.


(m) Structural shielding Design and Evaluation for Medical Use of X-Rays and Gamma-Rays of Energies up to 10 Mev United States Council an Radiation Protection and Measurements No. 49 (1976).

(n) Reports of the United Kingdom Hospital Physicists Association (HPA). HPA Report 32
Measurement of the Performance characteristics of Diagnostic X-Ray Systems Used in Medicine

i) Part I - X-Ray Tubes and Generators

ii) Part III - Computed Tomography X-Rays Scanners.

(p) Manual of Radiation Protection in Hospital and General Practice:
Volume 1. Basic Protection Requirements
Volume 3. X-Ray Diagnosis

(g) Quality Assurance in Diagnostic Radiology

(r) Radioactive Substances Act - 1968

Radiation Health Advisory Services, Malaysia.
W.A. Langmead.