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RADIATION PROTECTION

ICRP PUBLICATION 33

Protection Against Ionizing Radiation from External Sources Used in Medicine

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Protection Against Ionizing Radiation from External Sources Used in Medicine

A report of Committee 3 of the
International Commission on Radiological Protection

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PREFACE

At its meeting in Stockholm in 1978 the International Commission on Radiological Protection established a task group to revise *ICRP Publication 15/21* in conformity with the 1977 Recommendation of the Commission, and to provide recommendations covering all fields in which external sources of ionizing radiation are used in medicine.

The membership of the task group was as follows:

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J. H. E. Carmichael
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The Commission and Committee 3 are particularly grateful to L.-E. Larsson and J. H. E. Carmichael for undertaking the preparation and revision of the draft versions of the report.

Membership of Committee 3 1977–1981

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INTRODUCTION

(1) In 1977 the Commission issued new recommendations on radiation protection (*ICRP Publication 26*). The report now being introduced has been prepared in the light of those recommendations and replaces *ICRP Publications 15* and *21*.

(2) To fulfil the Commission's responsibilities in medical radiology, for the protection of staff, patients and the public, this publication gives recommendations and guidance for competent authorities regarding the safe use of ionizing radiation from external sources used in medicine. Guidance for individual practitioners will be given in the forthcoming ICRP publication Protection of the Patient in X-ray Diagnosis. The use of unsealed radionuclides is covered in *ICRP Publication 25*.

(3) *ICRP Publication 26* introduced new quantities and units in the field of radiation protection and the rationale of those that are applicable to this publication is discussed in a separate section

(4) The recommendations in this report are based on the system of dose limitation laid down by the Commission. It should be the responsibility of international and national regulatory bodies to encourage the setting of standards and specifications to implement these recommendations. In particular, the design of apparatus should be governed by the principle of optimization.

(5) For details of the Commission's system of dose limitation, the reader is referred to *ICRP Publication 26*, and to the subsequent statements issued by the Commission.

(6) This report emphasizes protection relative to the technical aspects of the sources themselves. In addition, appropriate training of staff, optimization of working practices and administrative requirements are discussed as essential factors in radiation protection.

(7) In the recommendations given in this report, the words *shall* and *should* have the following meaning:

Shall—Necessary or essential for protection against radiation;

Should—to apply, whenever reasonable, in the interests of improving radiation protection.

(8) The Commission is aware that compliance with some of the new recommendations may entail structural changes in existing installations, and/or changes in operative procedures. It is desirable that such changes be made as soon as practicable, but not in such a way as to deprive patients of necessary medical attention.

A. QUANTITIES AND UNITS

(9) This section gives a brief review of the basic quantities used in radiation protection and the units in which these quantities are expressed. The purpose is to provide sufficient information for an adequate understanding of this report without reference to other material. Emphasis is given to quantities that are of prime importance in radiation protection. Readers who wish to pursue the subject in greater depth are referred to more detailed ICRP and ICRU reports.

(10) In radiation protection, the quantities and concepts of primary interest are the *absorbed dose*, D, and quantities and concepts related to various expressions of *dose equivalent*, H. The dosimetric quantities of prime importance may be derived from the absorbed dose as the following sequence indicates:

Absorbed dose (D)
Dose equivalent at a point in tissue (H)
Mean organ dose equivalent (H_T)
Effective dose equivalent (H_E)

In the ICRP system of dose limitation, it is the mean dose equivalent in the various body organs and tissues and the effective dose equivalent that are subject to assessments and limitation. The emphasis in this introductory material is therefore on these two quantities.

(11) The *absorbed dose*, D, is the energy imparted by ionizing radiation per unit mass of the irradiated material. The SI unit for absorbed dose is *joule per kilogram* J (J kg^{-1}) and its special name is *gray* (Gy). The previous special unit of absorbed dose was 1 rad = 0.01 J kg^{-1}. If the energy imparted is determined in a small mass, random fluctuations of energy deposition can play a role. The rigorous definition of absorbed dose (*ICRU Report 33*) is therefore given in terms of a statistical expectation value. The important role of the statistical fluctuations of energy deposition in cellular or subcellular structures has led to the introduction of microdosimetric quantities; these are not considered in the present report.

(12) Equal absorbed doses of radiations of different qualities may produce effects which differ in severity or differ in the probability of the occurrence of effect. The Commission has attempted to account for this inequality by introducing the *dose equivalent*, H, which is the absorbed dose modified by weighting factors. The dose equivalent at a point in tissue is given by the equation:

$$H = DQN$$

where D is the dose absorbed dose at the point and Q is the *quality factor* (see para. 13). N is a modifying factor that is presently assigned the value unity by the Commission, but is inserted in order to permit the possible future introduction of other modifying factors which might be needed to account for the influence of, for example, absorbed dose rate or dose fractionation. Since the weighting factors Q and N are dimensionless, the SI unit of dose equivalent is the same as the unit of absorbed dose, i.e. *joule per kilogram*, but to avoid confusion with absorbed dose it is given the special name *sievert* (Sv). The previous special unit was 1 rem = 0.01 J kg^{-1}.

(13) The *quality factor*, Q, is intended to allow for the difference in effectiveness of different types of ionizing radiation in producing deleterious effects. This effectiveness is linked to the differing microscopic or submicroscopic distribution of absorbed energy and Q is therefore defined as a function of the *collision stopping power* (L_∞) in water at the point of interest. Table A

Table A. $L_\infty - Q$ relationship

L_∞ in water (keV μ^{-1})	Q
3.5 (and less)	1
7	2
23	5
53	10
175 (and above)	20

lists the values of Q specified by the Commission for various values of L_∞. Interpolated values of Q as a function of L can be obtained from Fig. A.

(14) In the usual case where D is delivered by particles having a range of values of L_∞, an effective value $\bar{Q}$ of Q at the point of interest can be calculated (see *ICRU Report 33*). When the

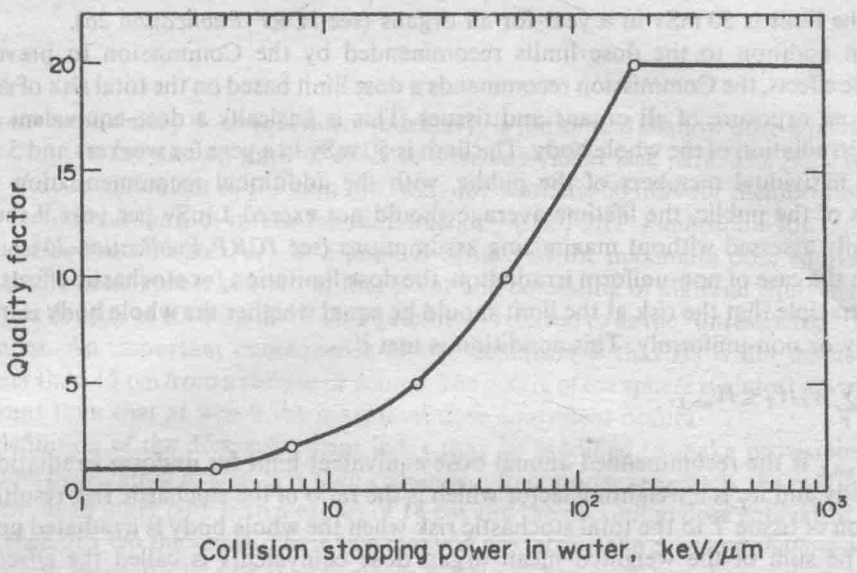

Fig. A. Quality factor as a function of collision stopping power in water.

distribution of L_∞ is not known at the point of interest, it is permissible to use approximate values for $\bar{Q}$, related to the type of radiation. Approximate values of $\bar{Q}$ recommended by the Commission for this purpose, both for external and internal exposures, are listed in Table B.

(15) The quality factors are chosen to represent the effectiveness of different types of ionizing radiation in producing harmful effects at low doses. It is therefore important that dose equivalent should not be used to assess the likely consequence of severe accidental exposures in man. For that purpose, absorbed dose is the appropriate quantity after weighting for the *relative biological effectiveness* (RBE) of each type of radiation for the effects at the high doses, if information is available.

(16) The next quantity of interest in radiation protection is the mean dose equivalent, H_T, in each organ or tissue (T). This is the quantity to which the Commission's dose limits for non-stochastic effects basically apply. For workers, these limits are 500 mSv in a year for all organs

Table B. Recommended permissible approximations of $\bar{Q}$ for various types of radiation

Type of radiation	Approximate value of $\bar{Q}$
X rays, γ rays and electrons	1
Thermal neutrons	2.3
Neutrons, protons and singly-charged particles of rest mass greater than one atomic mass unit of unknown energy	10
α particles and multiply-charged particles (and particles of unknown charge) of unknown energy	20

except the lens of the eye, and 150 mSv in a year for the lens. For individual members of the public, the limit is 50 mSv in a year for all organs (see *ICRP Publication 26*).

(17) In addition to the dose limits recommended by the Commission to prevent non-stochastic effects, the Commission recommends a dose limit based on the total risk of stochastic effects from exposure of all organs and tissues. This is basically a dose-equivalent limit for uniform irradiation of the whole body. The limit is 50 mSv in a year for workers and 5 mSv in a year for individual members of the public, with the additional recommendation that, for members of the public, the lifetime average should not exceed 1 mSv per year if the dose is realistically assessed without maximizing assumptions (see *ICRP Publication 26*).

(18) In the case of non-uniform irradiation, the dose limitation for stochastic effects is based on the principle that the risk at the limit should be equal whether the whole body is irradiated uniformly or non-uniformly. This condition is met if:

$$\sum_T w_T H_T \leq H_{wb,L},$$

where $H_{wb,L}$ is the recommended annual dose-equivalent limit for uniform irradiation of the whole body and w_T is a weighting factor which is the ratio of the stochastic risk resulting from irradiation of tissue T to the total stochastic risk when the whole body is irradiated uniformly.

(19) The sum of the weighted mean organ dose equivalents is called the *effective dose equivalent*, H_E, when the weighting factors, w_T, are those recommended by the Commission (Table C). The Commission's dose limit for stochastic effects, $H_{wb,L}$, therefore applies to the

Table C. Recommended values of the weighting factors w_T for deriving effective dose equivalent

Organ or tissue (T)	w_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder[a]	0.30

[a] $w_T = 0.06$ for each of the five organs or tissues receiving the highest dose equivalent of the remainder.

effective dose equivalent, irrespective of whether the irradiation is uniform or not. The effective dose equivalent is measured in the same units as the dose equivalent, i.e. in sievert.

(20) In practice it is permissible to use secondary standards instead of actually assessing the effective dose equivalent in all circumstances. For internal exposure (not treated in this document) the secondary standard is the annual limit of intake, ALI (see *ICRP Publication 30*). For external exposure, the secondary standard is the dose-equivalent index, H_I (see para. 21). In the case of both internal and external exposure, the Commission's recommended dose limitation for stochastic effects will not be exceeded if both the following conditions are met:

$$\frac{H_{I,d}}{H_{E,L}} + \sum_j \frac{I_j}{\mathrm{ALI}_j} \leq 1$$

and

$$\frac{H_{I,s}}{H_{sk,L}} \leq 1$$

where $H_{I,d}$ is the annual deep dose-equivalent index, $H_{I,s}$ is the annual shallow dose-equivalent index, $H_{E,L}=H_{wb,L}$ is the annual limit of effective dose equivalent (see para. 17), $H_{sk,L}$ is the annual limit of dose equivalent in the skin (500 mSv for workers, 50 mSv for members of the public), I_j is the annual limit of intake for radionuclide j (see *ICRP Publication* 30).

(21) The *dose-equivalent index*, H_I, at a point is defined as the maximum dose equivalent within a 30 cm diameter sphere centred at that point and consisting of material equivalent to soft tissue with a density of 1000 kg m^{-3}. This quantity is referred to as the "unrestricted" dose-equivalent index. An important consequence of this definition is that H_I is not defined at distances closer than 15 cm from a surface or source. The centre of the sphere is almost always at a different point than that at which the maximum dose equivalent occurs.

(22) The definition of the dose-equivalent index may be modified to make provisions for radiation of low penetrating power. It is then convenient to consider separately the maximum dose equivalent in an inner core with a radius of 14 cm and the maximum dose equivalent in a surrounding shell of 1 cm thickness. These two maxima are termed the *deep* and *shallow* dose-equivalent indices, respectively, and their symbols are $H_{I,s}$. They are referred to as "restricted dose-equivalent indices". The larger of the two is the same as the unrestricted dose-equivalent index. It is recommended that the shallow dose-equivalent index shall not include the dose equivalent in the outer 0.07 mm of the 1 cm shell, since this is representative of the depth of the basal layer of the epidermis in areas where the skin is thin; any radiation effects in the outer 0.07 mm are assumed to be negligible.

(23) For a number of purposes, e.g. in optimization assessments of radiation protection measures, the *collective effective dose equivalent*, S_E, may be used. This is the product of the number of exposed individuals and their average effective dose equivalent (see paras. 22–24 of *ICRP Publication 26*). The unit of collective dose equivalent is *mansievert* (or *manrem* with the previous special unit of dose equivalent).

(24) *Kerma*, K (kinetic energy released per unit mass) is the kinetic energy of charged ionizing particles liberated per unit mass of the specified material by uncharged ionizing particles. Kerma is measured in the same units as absorbed dose. The SI unit of kerma is *joule per kilogram* (J kg^{-1}) and its special name is *gray* (Gy). Kerma can be quoted for any specified material at a point in free space or in an absorbing medium. Expressions such as "tissue kerma in air" and "tissue kerma in bone" are acceptable. Over a wide range of photon energies, air kerma and tissue kerma differ by less than 10% and may be considered equal in magnitude for radiation protection purposes. In this respect, air kerma means air kerma in air. Kerma is independent of the complexities of the geometry of the irradiated mass element and permits specification for photons or neutrons in free space or in an absorbing medium. For these reasons, kerma has a wider applicability than exposure (see para. 26).

(25) When kerma is determined with a radiation-measuring instrument designed to approximate charged particle equilibrium conditions, the value of the kerma is the same as that of the absorbed dose when both are expressed in the same units. However, significant differences between kerma and absorbed dose occur close to interfaces between two media, for example in the skin or in cells lying close to the bone surface. For very high energy radiations, the dose build-up due to charged particle energy transport can be substantial, and the kerma at a point may then exceed, or be less than, the absorbed dose in a small mass element at the point. Under such conditions, tissue or air kerma multiplied by the appropriate quality factor will be a

suitable approximation of the dose-equivalent index; absorbed dose in a small tissue element, multiplied by the appropriate quality factor, may underestimate the maximum dose equivalent that would occur in the human body.

(26) *Exposure*, X, is a dosimetric quantity for ionizing electromagnetic radiation, based on the ability of the radiation to produce ionization in air. The exposure is the absolute value of the total charge of the ions of one sign produced in air when all the electrons liberated by photons per unit mass of air are completely stopped in air. The SI unit of exposure is *coulomb per kilogram* ($C\,kg^{-1}$). The former special unit of exposure was *roentgen* (R), with $1\ R = 2.58 \times 10^{-4}\ C\,kg^{-1}$ (exactly).

(27) Exposure can be specified in free space or in an absorbing medium. By suitable conversion factors, exposure can be linked to air kerma and to the dose-equivalent index. For example, 100 kV x rays that produce an exposure of 1 roentgen at a point will also give an air kerma of about 8.7 mGy (0.87 rad) and a tissue kerma of about 9.5 mGy (0.95 rad) at that point. The magnitude of the kerma in any medium other than air depends upon the energy of the x rays and the atomic composition of the medium.

(28) *Fluence*, Φ, provides a characterization of a radiation field without regard to its interaction with the irradiated material. By means of suitable interaction factors one can, for any material of interest, derive various dosimetric quantities, e.g. dose equivalent. The fluence, Φ, of particles is the number of particles traversing a sphere of unit cross section. The SI unit of fluence is m^{-2}. For a unidirectional field, the fluence is equal to the number of particles incident per unit area of a surface perpendicular to the field. The *energy fluence*, Ψ, of a radiation is the kinetic energy of ionizing particles traversing a sphere of unit cross section. The SI unit of energy fluence is $J\,m^{-2}$.

(29) More precise information and precise definitions are found in *ICRU Report 33* (Radiation Quantities and Units). The concept of dose equivalent is discussed in *ICRU Report 25* (Conceptual Basis for the Determination of Dose Equivalent). Quantities and units are also discussed in Chapter C (Basic Concepts) of *ICRP Publication 26*, in the Statement from the 1978 Stockholm meeting of the ICRP (*Annals of the ICRP*, 23 (1), 1978), and in the Statement and Recommendations of the 1980 Brighton meeting of the ICRP (*Annals of the ICRP*, 4 (3/4), 1980).

B. THE SYSTEM OF DOSE LIMITATION

Introduction

(30) The ICRP recommends a system of dose limitation, the main purposes of which are to ensure that every exposure to ionizing radiation is justified in relation to its benefits or those of any available alternative, that any necessary exposures are kept as low as reasonably achievable, and that the dose equivalents received do not exceed certain specified limits. The system of dose limitation has the following main features:

(a) No practice shall be adopted unless its introduction produces positive net benefit—*justification.*

(b) All exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account—*Optimization of Protection.*

(c) The dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission—*Dose Limits.*

The principles of justification and optimization are essentially source-related, i.e. they are concerned with the adequacy of protection as applied to each radiation source. Dose limits are concerned with the individual worker, member of the public and patient participating in research studies.

Justification

(31) Ideally, the acceptability of a proposed operation or practice involving exposure to radiation should be determined by cost-benefit analysis, the purpose of which is to ensure that the total detriment should be appropriately small in relation to the benefit resulting from the introduction of the proposed activity. The choice between practices will depend on many factors, only some of which will be associated with radiation protection.

(32) The professional judgment of the referring physician and radiologist, singly or jointly, that a proposed medical radiological procedure may be of net benefit to the recipient patient will normally constitute "justification" *vis-à-vis* the individual patient's exposure. Retrospective analysis of the correctness of these decisions (efficacy) will refine the indications and non-indications for future patients for whom a given procedure may be considered as useful. This is discussed in detail in the forthcoming ICRP publication Protection of the Patient in X-Ray Diagnosis.

(33) Radiological examination shall be carried out only if it is likely that the information obtained will be useful for the management of the patient or for improving the health status of the population (but see also para. 209).

(34) The choice, and in some cases the order, of radiological examinations and the alternative choices of non-radiological examinations or of foregoing any examinations other than simple clinical examinations should be based on a judgment of the relative benefits, risks and costs of the available choices. In this context, the benefits are influenced by the diagnostic efficacy of the various procedures and on the desirability of employing invasive rather than non-invasive procedures, and it should be remembered that both positive and negative findings may be of benefit to the patient.

(35) When the physician or dentist performs his own radiological procedures, the balance between the radiologist and referring physician or dentist is absent; this could result in unnecessary examinations being performed.

(36) The possibility of inappropriate or too frequent self-referral by individual members of the public (e.g. in mass-miniature chest radiography) must also be considered.

(37) Even when the decision has been made that a radiological procedure is justified, the decision to perform a particular examination is a balance of cost, relative influence on patient-management, information yield, availability of specific equipment and radiation detriment.

(38) The justification of the use of radiation for treatment of malignant neoplasms will take into account the relative merits of treatment by radiation as compared with other methods, e.g. surgery, chemotherapy (see *ICRP Publication 26*, paras. 198, 199).

(39) It is particularly important to establish the justification for treatment of non-malignant conditions in view of the risks of the induction of malignant disease and the risks of alternative procedures. The severity of the condition being treated and its possible life-shortening effect must be balanced against the expectation of stochastic and non-stochastic effects resulting from the treatment.

(40) The justification of the use of ionizing radiation in medical research is more difficult as the person irradiated may receive no direct benefit from the examination. The benefit may be only to future patients whose clinical management may be improved as a result of that research (see para. 207).

Optimization of Radiation Protection

(41) One of the basic components of the system of dose limitation recommended by the Commission is the requirement that all exposures should be kept "as low as reasonably achievable", taking into account the relevant social and economical considerations. This requirement consists of increasing the level of protection to a point such that further improvements achieve exposure reductions which are less significant than the additional efforts required. This requirement is usually called *optimization of radiation protection.*

(42) The efforts involved in protection are taken to be quantifiable in terms of cost. If the radiation detriment (representing all exposures from the source, given the protection under consideration) can also be expressed as a cost, optimization can be expressed as

$$X(w)+Y(w)=\text{minimum}$$

where X is the cost of protection, and Y is the cost of the radiation detriment, both at a level of protection represented by w (e.g. shielding thickness, alternative options of protective equipment, etc.). It should be noted that w, and $X(w)$ and $Y(w)$, can in some cases be continuous, while in other cases they take only discrete values.

(43) When the level of protection, quantified by w, can be varied to any desired level, the minimum for the above expression can be obtained by differentiation

$$\frac{dX}{dw}=-\frac{dY}{dw}$$

As X, Y and w are related to the collective dose S, the optimized situation can also be expressed (see *ICRP Publication 26*) as

$$\frac{dX}{dS}=-\frac{dY}{ds}$$

In many practical assessments of optimization, the changes in protection levels are achieved in finite increments, corresponding to successively more ambitious options. In these cases, the decision of going from a level of protection A to a more expensive level B would be taken if

$$\frac{X_B}{W_B-W_A}-\frac{X_A}{W_B-W_A}\leq\frac{Y_B-Y_A}{W_B-W_A}$$

For example, rare-earth screens of medium speed may be substituted for standard tungstate screens in some fraction of examinations. If the cost of detriment is taken to be $Y=\alpha S$, where α is the monetary value assigned to the unit of collective dose, an optimization assessment can be carried out as follows. Assuming a certain life of the screen, and knowing the collective dose reduction (number of examinations × dose-reduction per examination), then the cost of saving 1 mansievert can be determined. If this figure is below the assigned value α, then the step of using rare-earth screens is acceptable.

(44) Optimization should be exercised in planning new installations both with regard to the protective barriers and the design of protective devices in equipment. However, the case-by-case optimization of widely-used equipment is not appropriate because it would nullify the advantages of standardization and would cause a net social loss. Optimization should, however, play a part in the setting of such standards and specifications on their subsequent application.

For the practical application of this, the reader is referred to the forthcoming ICRP publication Optimization of Radiation Protection.

(45) Quality assurance programmes are, in part, means by which a level of radiation protection can be maintained or even improved (e.g. reduction of the number of rejected films). However, the cost incurred by such a programme has to be balanced against the gain of collective dose reduction and of the longer life of the equipment. Analysis of the reasons for rejection of films may show faults both in radiographic technique and in apparatus. Identifying the most prevalent faults should improve radiographic technique. Apparatus deficiencies will require the services of engineers but, if regularly adjusted, the number of rejected films due to faulty apparatus should fall and often the life of the equipment is increased. On cost-effectiveness analysis, it can be shown that dose-reduction of these means is worthwhile.

(46) The radiation dose delivered during a radiological examination is influenced by the knowledge and skill of both the radiologist and radiographer. In principle, money spent on training the staff can be related to a concomitant reduction in collective dose to the patients. At the present time, improved performance cannot be accurately cost-related nor is reduction in dose the only objective. (The collective dose for a given procedure might increase as a result of training and still be entirely justified on the basis of greater information content.) In spite of these difficulties, the general concept of optimization does have application in assessing the need to improve the performance of the staff.

(47) A simple example of this in fluoroscopy is to introduce a meter giving a reading of the product of radiation dose and area of tissue irradiated. If used to compare individual performance, particularly in a training department, it will encourage good protection practice. Recommendations in the following chapters indicate in more detail means by which the performance of the staff can be improved.

Dose Limits

(48) Although the application of the concepts described in the preceding paragraphs provides sufficient protection for the patient in medical radiology, it does not always provide such protection for staff, visitors, and individual members of the public. Regardless of the result of cost-effectiveness analysis and other measures, individual dose-equivalent limits must be respected (see *ICRP Publication 26*, paras. 92, 93, 103–108).

(49) In practice, risks and benefits are not equally distributed. Those who benefit from a given practice may not be the only ones who are exposed to the risks. Boundary limits are needed in order to ensure that justified and optimized practices do not result in unacceptably high risks to some individuals for the benefits received by others.

(50) The dose-equivalent limits for workers are to be considered as boundary conditions and not as permissible levels in the absence of optimization and other procedures, such as the setting of authorized limits.

(51) Since they form only part of the system of dose limitation, the dose-equivalent limits can no longer be used as the primary basis for planning and design. Operational or design limits should be established by appropriate international or local national authorities on the basis of optimization. For a discussion of authorized limits see *ICRP Publication 26*, paras. 147 and 148. These limits are often the result of optimization and other procedures. The limits that appear in the following paragraphs are based on experience and represent the practical application of the optimization of protection (see also Appendix, paras. 253–256).

C. RECOMMENDATIONS ON DESIGN AND OPERATION

(52) The following recommendations on general principles for operational radiation protection are quoted from *ICRP Publication 26* and are relevant to this section of this report.

"(139) Responsibilities for achieving appropriate radiation protection fall on the employers, the statutory competent authorities, the manufacturers, and the users of products giving rise to radiation exposure and, in some cases, the exposed persons. The management of an institution must provide all the necessary facilities for the safe conduct of the operations under its control. In particular, it should designate persons with special duties for protection, such as members of radiation protection teams."

"(140) All proposed installations and new operations, all changes in existing installations and operations, and all new or modified products containing radioactive materials or emitting ionizing radiation, should be examined at the design stage from the point of view of restricting the resulting occupational and general exposure. Such examinations can often be carried out by comparison with detailed technical standards prepared, taking into account the recommendations of the Commission."

"(141) Before commissioning an installation, starting an operation or distributing a product, it should be established that the installation, operation or product conforms with the approved proposals and that the appropriate radiation protection requirements have been met. In the case of installations and operations, there should be continuing checks on the effectiveness of the organizational arrangements made to achieve protection, and on the availability and application of appropriate working instructions."

"(160) The main responsibility for the protection of workers rests with the normal chain of management in an institution possessing any radiation source that causes exposure of workers. It is necessary to identify technically competent persons to provide advice on all relevant aspects of radiation protection, both inside and outside the institution, and to provide such technical services as are needed in the application of the appropriate recommendations for radiation protection."

"(161) For the purposes of this report, occupational exposure comprises all the dose equivalents and intakes incurred by a worker during periods of work (excluding those due to medical and natural radiation). The scale and form of the problems of radiation protection of workers vary over very wide ranges, and there are practical advantages in introducing a system of classification of conditions of work. Conditions of work can be divided into two classes:

Working Condition A: this describes conditions where the annual exposures might exceed three-tenths of the dose-equivalent limits;

Working Condition B: this describes conditions where it is most unlikely that the annual exposures will exceed three-tenths of the dose-equivalent limits.

The value of three-tenths of the basic limits for occupational exposure is thus a reference level used in the organization of protection. It is not a limit. Where the exposure is unconnected with the work, and where the work is in premises not containing the radiation sources giving rise to the exposure, the working condition should be such that the limits applicable to members of the public are observed.

"(163) The practical application of this system of classification of working conditions is greatly simplified by the introduction of a corresponding system of classification of workplaces. The minimum requirement is to define controlled areas where continued operation would give rise to Working Condition A and to which access is limited. The demarcation of controlled areas will depend on the operational situation and it will often be convenient to use existing structural boundaries. The controlled area should in any case be large enough to make it most unlikely that the annual dose equivalents to workers outside the controlled area will exceed three-tenths of the limits."

"(164) It is sometimes convenient to specify a further class of work place. It is called a "supervised area", and has a boundary chosen so as to make it most unlikely that the annual dose equivalents outside the supervised area will exceed one-tenth of the limits."

"(168) Access to controlled areas should be restricted, at least by the use of warning signs. Inside controlled areas, it may sometimes be necessary to define regions where compliance with the relevant limits can be achieved only by limiting the time spent in the region or by using special protective equipment. The access of workers to controlled areas should be limited to those who are assigned to the area and to others who have been authorized to have access. The access of workers to supervised areas should be the subject of local operating instructions. Visitors, either workers or members of the public, should be admitted to workplaces only with the approval of an appropriate level of the management responsible for the workplace."

(53) The final plans for new installations or for modifications of existing installations involving structural shielding should be reviewed by a qualified expert and should, if required, be approved by the competent authority before building is commenced. Copies of the plans of the installation as built, including the shielding specifications, should be retained and be readily available at the site. Later modifications should be similarly recorded.