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RECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

PREFACE

THE International Commission on Radiological Protection (ICRP) has been functioning since 1928 when it was established, under the name of International X-ray and Radium Protection Commission, by the Second International Congress of Radiology held in Stockholm, Sweden. It assumed the present name and organizational form in 1950 in order to cover more effectively the rapidly expanding field of radiation protection.

The recommendations published in the present volume represent concepts and practices evolved from discussions at formal and informal meetings of the Commission and its Committees, held in recent years. Prior to World War II the Commission published recommendations at intervals of about three years. The first meeting in the post-war period was held in London in 1950. An informal meeting was held in Stockholm in 1952 in connection with the conference organized by the International Joint Committee on Radiobiology primarily to discuss the genetic effects of radiation. The next meeting was held in Copenhagen in 1953, at which time four of the Committees held formal meetings for the first time. The results of the deliberations were published in 1955 as Supplement No. 6 of the *British Journal of Radiology*. The Commission and its Committees met again in the spring of 1956 in Geneva, at which time most of the recommendations in the present volume were adopted in principle. At this meeting the Commission became formally affiliated with the World Health Organization (WHO) as a "non-governmental participating organization".

The Commission (ICRP) and the International Commission on Radiological Units (ICRU) held a special joint meeting in New York in the fall of 1956 to consider an invitation from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) for cooperation in the phase of its work involving exposure from medical procedures. The two

Commissions accepted the assigned task and submitted a report to UNSCEAR, published in the October 1957 issue of *Physics in Medicine and Biology*. Funds for expenses incurred in the preparation of the report were provided by the UNSCEAR. At the time of this joint meeting the Commission held an informal meeting to discuss further the recommendations to be made following the deliberations in Geneva earlier in the year. Additional discussions were carried out at another special meeting of the Commission held in New York in the spring of 1958. At this time an ad hoc Publication Committee was appointed to expedite the preparation of the manuscripts. This Committee held a two-week meeting in New York in May and prepared a first draft of the recommendations, which was sent out to all members of the Commission. The Committee met again during the second half of July and revised the first draft in accordance with suggestions made by members of the Commission. At this time, the Committee reviewed also the available drafts of the reports of the Commission's Committees.

In the preparation of the Commission's recommendations, the Publication Committee found it necessary to fill certain gaps involving items that had not been formally discussed and approved by the Commission. For this reason advantage was taken of the presence of seven members of the Commission in Geneva in September 1958 to review the second draft and make appropriate changes. The amendments were sent to the members who could not attend this meeting. The final draft embodies further comments made by members of the Commission.

Many individuals, who are not members of the Commission, were consulted in the preparation of the recommendations and their cooperation is gratefully acknowledged. In particular the recommendations on genetic dose were discussed by the Chairman of the Publication Committee with several prominent geneticists

at the Xth International Congress of Genetics in Montreal, August 1958. It should be noted, also, that Committee I at its 1956 meeting in Geneva, prepared the first draft of the new recommendations adopted by the Commission at that time, which provided the basis for the recommendations published in the present volume.

In recent years the Commission has received financial assistance from the International Society of Radiology, the National Association of Swedish Insurance Companies and private Swedish sources for incidental secretarial expenses. Practically all the work of the Commission has been done on a voluntary basis by its members and members of its Committees. The Commission is heavily indebted to them for their efforts and to their parent organizations for technical and secretarial help. The World Health Organization contributed funds for travel expenses of some members of the Publication Committee, for secretarial help and for incidental expenses in the preparation and circulation of the manuscripts. The Commission takes this opportunity to express its deep appreciation of these

contributions, without which the preparation of the present recommendations would have been greatly hampered.

The chairman of the Publication Committee and the Temporary Secretary wish to thank the members of the Commission for their cooperative and prompt replies to the numerous questionnaires and ballots that had to be circulated in the course of preparing the final manuscript. Thanks are due also to the members of the Publication Committee who prepared the first two drafts.

The Commission is happy to announce that the Pergamon Press has generously assumed financial responsibility for the publication and distribution (at modest prices and without copyright restrictions) of the present volume and others in preparation embodying the reports of the Commission's Committees.

ROLF M. SIEVERT

Chairman of ICRP

GIOACCHINO FAILLA

Vice-Chairman ICRP

Chairman of Publication

Committee

ORGANIZATION

Rules Governing the Selection and Work of the International Commission on Radiological Protection

(1) The International Commission on Radiological Protection (ICRP) functions under the auspices of the International Congress of Radiology. The following rules, amended in 1953 by the International Executive Committee (IEC) of the Congress, govern the selection and work of the ICRP.

I. (a) The International Commission on Radiological Protection (ICRP) shall be composed of a Chairman and not more than 12 members. The selection of members shall be made by the International Executive Committee (IEC) from a list of nominations submitted by the national delegations and by the International Commission on Radiological Protection itself. Members of the ICRP shall be chosen on the basis of their recognized activity in the fields of radiology, radiation protection, physics, biology, genetics, biochemistry, and biophysics, without regard to nationality.

(b) The members of the ICRP shall be selected during one International Congress to serve through the succeeding Congress. Not less than two, but not more than four, members of the ICRP shall be changed at each Congress. In the intervening period a vacancy caused by conditions beyond the control of the IEC shall be filled on the recommendation of the ICRP.

(c) In the event of a member of the ICRP being unable to attend the ICRP meetings, a substitute may be selected by the ICRP as a temporary replacement. Such a substitute member shall not have voting privileges at the meetings unless specifically authorized by the IEC.

(d) The ICRP shall be permitted to invite individuals to attend its meetings to give special technical advice. Such persons shall not have voting privileges, but may ask permission to have their opinion recorded in the minutes.

II. The continuance of the records of the ICRP shall be in the hands of a Secretary of the ICRP elected by the ICRP from among its regular members and subject to the approval of the IEC.

III. The ICRP shall familiarize itself with progress in the whole field of radiation protection. The Secretary shall be responsible for the preparation of a programme to be submitted to the Commission for discussion at its meetings. Preliminary reports shall be prepared and circularized to all members of the ICRP and other specially qualified individuals at least six months before the meeting of the Congress.

IV. The Chairman shall be elected by the ICRP during one Congress to serve through the succeeding Congress. The choice shall not be limited to the country in which it is proposed to hold the succeeding Congress.

V. Decisions of the ICRP shall be decided by a majority vote, with the Chairman casting the deciding vote in case of a tie. A minority opinion may be appended to the minutes of a meeting if so desired by any member and upon his submission of same in writing to the Secretary.

Policy of the Commission

(2) The policy adopted by the ICRP in preparing its recommendations is to deal with the basic principles of radiation protection, and to leave to the various national protection committees the right and the responsibility of introducing the detailed technical regulations, recommendations, or codes of practice best suited to the needs of their individual countries.

(3) The Commission's recommendations have been kept continually under review in order to cover the increasing number and scope of potential radiation hazards, and to amend safety factors in the light of new knowledge concerning the effects of ionizing radiations.

Official Relations with the World Health Organization

(4) In accordance with rules laid down by the World Health Assembly for the admission of non-governmental organizations into official relations with the World Health Organization, such relations were established between the ICRP and WHO in 1956 and were reaffirmed in 1958. This arrangement has been eminently satisfactory to the Commission and it is hoped that it will continue.

Composition of the ICRP and Its Committees

(5) During the preparation of these recommendations the ICRP has had the following composition:

Main Commission

1953-1956

Sir ERNEST ROCK CARLING, Chairman (Great Britain)
 W. BINKS, Secretary (Great Britain)
 A. J. CIPRIANI (Canada)
 G. FAILLA (U.S.A.)
 H. HOLTHUSEN (Germany)
 J. C. JACOBSEN (Denmark)
 R. G. JAEGER (Germany)
 W. V. MAYNEORD (Great Britain)
 K. Z. MORGAN (U.S.A.)
 R. M. SIEVERT (Sweden)
 R. S. STONE (U.S.A.)
 L. S. TAYLOR (U.S.A.)
 M. TUBIANA (France)

1956-

R. M. SIEVERT, Chairman (Sweden)
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 W. BINKS, Secretary* (Great Britain)
 L. BUGNARD (France)
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 R. S. STONE (U.S.A.)
 L. S. TAYLOR (U.S.A.)
 E. A. WATKINSON (Canada)
 Sir ERNEST ROCK CARLING, Chairman emeritus (Great Britain)

* Mr. BINKS resigned as Secretary in 1957, for health reasons. After his resignation E. E. SMITH (Great Britain) served as Acting Secretary, and since August 1, 1957, B. LINDELL (Sweden) has served as Temporary Secretary.

Committee I (Permissible dose for external radiation)

1953-1956

G. FAILLA, Chairman (U.S.A.)
 L. BUGNARD (France)
 D. G. CATCHESIDE (Australia)
 J. C. JACOBSEN (Denmark)
 J. F. LOUTIT (Great Britain)
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1956-

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 G. BONNIER (Sweden)
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 SHIELDS WARREN (U.S.A.)

Committee II (Permissible dose for internal radiation)

1953-1956

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 E. E. POCHIN (Great Britain)

1956-

K. Z. MORGAN, Chairman (U.S.A.)
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 W. H. LANGHAM (U.S.A.)
 L. D. MARINELLI (U.S.A.)
 W. G. MARLEY (Great Britain)
 M. K. NAKAIZUMI (Japan)
 G. J. NEARY (Great Britain)
 M. N. POBEDINSKI (U.S.S.R.)
 E. E. POCHIN (Great Britain)
 C. G. STEWART (Canada)

Committee III (Protection against X-rays up to energies of 3 MeV and β - and γ -rays from sealed sources)

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 C. E. EDDY (Australia)
 C. GARRETT (Canada)
 H. HOLTHUSEN (Germany)
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 W. J. OOSTERKAMP (Netherlands)
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 H. O. WYCKOFF (U.S.A.)
 J. ZAKOVSKY (Austria)

1956-

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 P. RØNNE (Denmark)
 D. J. STEVENS (Australia)*
 H. O. WYCKOFF (U.S.A.)
 J. ZAKOVSKY (Austria)
 A. ZÜPPINGER (Switzerland)
 Technical Secretary: W. HÜBNER (Germany)

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1953-1956

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 M. TUBIANA (France)
 F. WACHSMANN (Germany)

Committee V (Handling of radioactive isotopes and disposal of radioactive waste)

1953-1956

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 A. PERUSSIA (Italy)
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 F. D. SOWBY (Canada)
 F. W. WESTERN (U.S.A.)
 Technical Secretary: G. G. ROBECK (U.S.A.)

1958 *Publication Committee* (ad hoc)

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 F. D. SOWBY (Canada)

RECOMMENDATIONS OF THE COMMISSION**A. PREFATORY REVIEW**

(1) Prior to the Geneva meeting of the Commission in April 1956, permissible levels of exposure to ionizing radiation had been expressed in terms of a dose in a rather short

interval of time (1 day or 1 week), that is, essentially, in terms of an average dose rate—the average referring to the temporal distribution of the dose in the specified interval of time. Implicitly, if not explicitly, it was assumed that

* From March, 1958

if this average dose rate was low enough, no appreciable bodily injury would become apparent in the lifetime of the individual. The assumption was based largely on radiological experience which indicated that substantial skin recovery occurred within a few months following a moderate therapeutic dose and that the latent period for some long-term effects of radiation (e.g. cancer of the skin) resulting from residual tissue damage, was longer the lower the dose (or dose rate in the case of chronic exposure). Thus, in an occupationally exposed individual a long-term effect might not become apparent in his lifetime, even if a certain amount of permanent injury had occurred.

(2) The basic permissible weekly dose at that time was 0.3 rem/week. Assuming that a person was occupationally exposed at this rate (50 weeks a year) for 50 years, the permissible accumulated dose would be 750 rems in the most critical organs or essentially throughout the body. It was realized then that this constituted a "large" lifetime dose and an appropriate warning was included in the Commission's report of 1955.

(3) The general awareness of radiation hazards, induced caution on the part of those responsible for the protection of workers. Administratively, liberal factors of safety were often used especially in large atomic energy installations. As a result it was found that in general the actual exposure of personnel was kept at levels much below the then existing permissible limits.

(4) At the 1956 meeting of the Commission it became evident that stricter recommendations were needed. The 1955 Conference on the Peaceful Uses of Atomic Energy had aroused great interest in the development of atomic power plants throughout the world. In time this would greatly increase the number of persons occupationally exposed and would also bring about actual or potential exposure of other persons and the population as a whole. More importantly, the pressure for producing power economically might well do away with the "safety factors" mentioned above. Also, the average duration of occupational exposure per individual worker might increase. On the biological side it was considered that perhaps

"recovery" plays a less important part in the long-term effects of radiation to be expected from continued exposure at low levels, than was earlier supposed. Because of the larger number of persons who would be exposed, occupationally or otherwise, genetic damage assumed greater importance. This was accentuated in no small degree by the realization that in some countries the per capita genetic dose contributed by medical procedures was about the same as that contributed by background radiation.

(5) Statistical studies had shown that the incidence of leukemia in radiologists was significantly greater than in other physicians who presumably were not professionally exposed to radiation. Of necessity these radiologists included those who had practiced their specialty at the time when radiation protection was not very effectively carried out. Therefore, the accumulated doses received by those who developed leukemia may have been much higher than the 750 rems mentioned above. On the other hand, since most of the exposure of these radiologists resulted from diagnostic procedures carried out with low voltage X-rays, the lifetime dose in the blood-forming organs may have been lower than 750 rems even if the skin dose, especially in some parts of the body was much higher. The mechanism of leukemia induction by radiation is not known. It may be postulated that if the dose is lower than a certain threshold value no leukemia is produced. In this case it would be necessary to estimate the threshold dose and to make allowances for recovery, if any. There is not sufficient information to do this, but caution would suggest that an accumulated dose of 750 rems might exceed the threshold. The most conservative approach would be to assume that there is no threshold and no recovery, in which case even low accumulated doses would induce leukemia in some susceptible individuals, and the incidence might be proportional to the accumulated dose. The same situation exists with respect to the induction of bone tumors by bone-seeking radioactive substances.

(6) Presently available longevity studies differ as to whether there is a statistically significant life shortening in radiologists as compared to other specialists presumably not occupationally

exposed to radiation. However, in mammals chronically exposed at different daily doses a definite effect on longevity becomes clearly apparent at the higher daily doses. If extrapolation to lower daily doses, and then to man, is justified, it may be concluded that occupational exposure at presently accepted permissible limits may entail some life shortening. This effect may be interpreted as a slight acceleration of the natural aging process.

(7) The effects just discussed illustrate the two different types of possible long-term somatic effect that must be considered in setting up permissible limits of exposure. The first type (leukemia) is a serious effect occurring in some individuals and, therefore, the aim of protection would be to reduce the incidence to the lowest practical limit. The second type (life shortening) is presumably an effect on every individual and, therefore, the aim of protection would be to reduce the degree of effect to the lowest practical value. The definition of permissible dose has been changed to include explicitly these two types of possible effect.

(8) Genetic effects manifest themselves in the descendants of exposed individuals. The injury, when it appears, may be of any degree of severity from inconspicuous to lethal. A slight injury will tend to occur in the descendants for many generations, whereas a severe injury will be eliminated rapidly through the early death of the individual carrying the defective gene. Thus the sum total of the effect caused by a defective gene until it is eliminated may be considered to be roughly the same. The main consideration in the control of genetic damage (apart from aspects of individual misfortune) is the burden to society in future generations imposed by an increase in the proportion of individuals with deleterious mutations. From this point of view it is immaterial in the long run whether the defective genes are introduced into the general pool by a few individuals who have received large doses of radiation, or by many individuals in whom smaller doses have produced correspondingly fewer mutations. However, even in this case it is desirable to limit the dose received by an individual.

(9) In view of the foregoing, recommendations are made in this report in terms of

maximum permissible doses for individuals and for population groups. In either case limits are set on the basis of dose accumulated over a period of years rather than in terms of a weekly dose that could be received for an indefinite period of time. The concept of limiting the accumulated dose was introduced by the Commission at its 1956 meeting in Geneva. The limitation of accumulated dose suggested at the time corresponds roughly to a three-fold reduction in weekly dose, for example, in the case of whole body occupational exposure when the exposure takes place approximately at a constant rate.

(10) In practice the problem of chief concern is chronic exposure either at low dose rates or by intermittent small doses. Under these conditions it is reasonable to assume that the dose accumulated over a period of years is the controlling factor, *provided* the intermittent doses are sufficiently small. Thus, in addition to limiting the accumulated dose it is necessary to limit the magnitude of a single dose (that is, a dose received in a short interval of time). Previously a single exposure equal to the maximum permissible weekly dose ("seven consecutive days") was permitted. Following the same pattern, the single dose limit for occupational exposure recommended in the present report is expressed in terms of the maximum permissible dose accumulated in a period of "13 consecutive weeks". The recommended value for the relevant organ (e.g. 3 rems for the blood-forming organs) has been made as high as it appears prudent, in the light of present knowledge. The stipulation of any 13 *consecutive* weeks has been made to make sure that operations are carried out in such a way that intermittent doses approximating the full 13 week quota do not occur at short intervals.

(11) In the recommendations published in 1955 maximum permissible limits were set on the basis of doses received by certain organs and certain serious late effects known to occur in them with sufficiently large doses. Provisions were made by means of an arbitrary "dose distribution curve" (in the report of Committee I) to limit the dose in other organs and tissues. This was made necessary by the adoption of a

maximum permissible dose for the skin twice as large as that for the blood-forming organs (with an assumed effective depth of 5 cm). In the present report separate recommendations are made for three groups of organs or tissues:

- (a) Blood-forming organs, gonads and lenses of the eyes.
- (b) Skin and thyroid gland.
- (c) All other organs or tissues, specifically as regards exposure essentially limited to the organ or tissue in question.

(12) For the blood-forming organs, gonads and the lenses of the eyes the limits for occupational exposure are set in terms of the dose accumulated at various ages, according to the formula $D = 5(N - 18)$, where D is the dose in rems and N is the age in years, with the additional stipulation that the dose accumulated during any 13 consecutive weeks shall not exceed 3 rems.

(13) For the skin and the thyroid gland the limit for occupational exposure is set in terms of the dose accumulated during any 13 consecutive weeks, and the recommended value is 8 rems. This is derived from an average of 0.6 rem/week (the maximum permissible weekly dose formerly recommended for the skin of the whole body) which in 13 weeks amounts to 7.8 rems, and the nearest whole number is used to avoid the implication of greater accuracy than is warranted by present knowledge. The limit for the dose in these tissues accumulated in 1 year is $(0.6 \times 50) = 30$ rems. It should be noted that the new recommendation refers to the dose in the skin itself, irrespective of the dose distribution in the subcutaneous tissues. Therefore, the comparison should be made with the previous recommendation for exposure to radiation of very low penetrating power, for which the recommended limit was 1.5 rem/week. Accordingly, in this case also a reduction has been made in the accumulated dose, but the single exposure limit has been increased from 1.5 to 8 rems. This should provide more flexibility in practice than was possible formerly.

(14) For all organs and tissues of the body except the blood-forming organs, the gonads and the lenses of the eyes, the limit for occupational exposure is set in terms of the dose accumulated during any 13 consecutive weeks.

With the exception of the skin, the pertinent practical cases in this category relate to exposure from internal sources essentially limited to individual organs or tissues. The following points require consideration. Whereas in the case of the blood-forming organs, the gonads, the lenses of the eyes and the skin, the objective of protection is to prevent or minimize definitely known types of injury, in the case of other organs the type of injury is not known. (Bone constitutes the only exception, in which case the relevant injury is cancer and permissible limits may be set on the basis of data furnished by human subjects who accumulated radium in their skeletons.) Possibly, radiation in sufficient dosage may increase the incidence of cancer in one of these organs (e.g. the thyroid gland) or it may accelerate aging of the organ. In the absence of factual data, it was deemed prudent in earlier recommendations of the commission to set the maximum permissible limit for these organs, when irradiated by internal sources, as low as that for the more sensitive organs such as the gonads, that is, 0.3 rem/week. When the exposure is essentially limited to *one organ* because of the more or less selective accumulation of a certain radioactive isotope therein, it is obvious that this limit embodies a factor of safety not present when the *whole body* is exposed at the same permissible limit. For this reason and the fact that none of these organs is known to be as sensitive as the blood-forming organs, the gonads and the lenses of the eyes, the Commission has decided to retain the previously recommended maximum permissible dose of 0.3 rem/week for each organ singly (with some exceptions noted in the report of Committee II). However, the limit is now expressed in terms of 13 consecutive weeks, which makes it 4 rems, in round figures, with an annual accumulated dose of 15 rems. Committee II has made the necessary adjustments to conform with the lower permissible limits now recommended for some organs and for what may be regarded as constituting "whole body" exposure (e.g. isotopes distributed throughout the body, or several isotopes present simultaneously, each concentrating significantly in a different organ).

(15) The Commission has given particular

attention to the difficult problem of setting permissible limits for exposure of persons in the neighborhood of radiation installations. The chief obstacle is the almost complete lack of knowledge of the deleterious effects that may result from low level exposure starting at conception and continuing throughout life. It is reasonable to expect a more marked effect than in the case of exposure starting after the individual has reached maturity (for one thing, because the period of exposure is longer), but it is very difficult to decide what allowance to make. Guidance could be obtained from suitable experiments carried out with mammals and it is hoped that such studies will be undertaken soon in some laboratories. In the meantime caution is in order. The Commission recommends that provisions be made in a controlled area or areas to make sure that under normal operating conditions no child residing outside such controlled areas, receive more than 0.5 rem/year (in the appropriate organs) from radiation or radioactive material originating in the controlled area or areas. In practice it may be expected that while fluctuations in exposure rate would occur, they would not be such as to require special limitations. It will be noted that this is one tenth of the *lowest* annual dose in any organ permitted for occupational exposure. It includes contributions made by external and internal sources but does not include doses contributed by natural background radiation or medical procedures.

(16) Special groups of *adults* in the vicinity of a controlled area are permitted to receive larger annual doses in the gonads, the blood-forming organs and the lenses of the eyes, by a factor of three (i.e. 1.5 rems). No biological significance should be attached to the magnitude of this factor, since present radiobiological information is grossly inadequate in this respect. The value recommended (1.5 rems/year) is one tenth of the former maximum permissible annual dose for occupational exposure, on the basis of 0.3 rem/week in the most sensitive organs. (See also paragraphs 54, 56 and 57.)

(17) Planning for the future expansion of nuclear energy programs and the more extensive uses of radiation, requires measures intended to protect whole populations. Genetic damage is

of greatest concern in this regard. The problem has been discussed by various national and international groups and tentative suggestions have been made. The Commission considered the problem at its 1956 meeting and later issued a statement in general terms. However, recommendations in quantitative terms are needed in the design of power plants and other radiation installations and particularly in making plans for disposal of radioactive waste products. It is of the utmost importance in this connection to make sure that nothing is done now that may prove to be a serious hazard later, which cannot be corrected at all or will be very expensive to correct. The Commission is aware of the fact that a proper balance between risks and benefits cannot yet be made, since it requires a more quantitative appraisal of both the probable biological damage and the probable benefits than is presently possible. Furthermore, it must be realized that the factors influencing the balancing of risks and benefits will vary from country to country and that the final decision rests with each country (insofar as operations within one country do not affect other countries).

(18) The Commission wishes to point out that it is important to assign quotas of a maximum permissible genetic dose to the different modes of exposure, in order to make sure that those responsible for the control of exposure in one category do not take up a disproportionate share of the permissible total in their planning. However, at this time it is deemed best not to assign rigid quotas. As a tentative guide an illustrative apportionment is appended to paragraph 65.

(19) Briefly, the suggested limit for the genetic dose was arrived at in the following manner: Estimates made by different national and international scientific bodies indicate that a per capita gonad dose of 6–10 rems accumulated from conception to age 30 from all man-made sources, would impose a considerable burden on society due to genetic damage, but that this additional burden may be regarded as tolerable and justifiable in view of the benefits that may be expected to accrue from the expansion of the practical applications of "atomic energy". There is at present considerable uncertainty as to the magnitude of

the burden (see for example the report of the United Nations Scientific Committee on the Effects of Atomic Radiation) and, therefore, it is highly desirable to keep the exposure of large populations at as low a level as practicable, with due regard to the necessity of providing additional sources of energy to meet the demands of modern society. A genetic dose of 10 rems from all man-made sources is regarded by most geneticists as the absolute maximum and all would prefer a lower dose. In some countries the genetic dose from medical procedures has been estimated to be about 4.5 rems (see *Report of Joint Study Made by ICRP-ICRU for the U.N. Scientific Committee*). Therefore, if the limit for the genetic dose from all man-made sources were set at 6 rems, the contribution from all sources other than medical procedures, would be limited to 1.5 rems in these countries. This would impose unacceptable restrictions on these countries. Accordingly, as a matter of practical necessity the Commission recommends that medical exposure be considered separately and that it be kept as low as is consistent with the necessary requirements of modern medical practice. The joint study of ICRP-ICRU indicates that careful attention to the protection of the gonads would result in a considerable reduction of the genetic dose due to medical procedures without impairment of their value. In view of these considerations the Commission suggests a limit of 5 rems for the genetic dose from all man-made sources of radiation and activities, except medical procedures.

(20) At the present time the contribution to the genetic dose from all man-made sources (other than medical procedures) is small. With careful planning the rate of increase can be kept under control and the ultimate value of this

contribution may never reach the suggested limit of 5 rems. Since the genetic dose from medical exposure in most countries is much lower than 4.5 rems and since in those countries in which it is high efforts are being made to reduce it, the total genetic dose from all man-made sources actually received by the world population may be expected to be considerably less than 10 rems, perhaps even less than 6 rems in the foreseeable future. Furthermore, if a thermonuclear reaction can be utilized as a source of power, the problem of radiation protection may be greatly simplified.

(21) The Commission is aware that compliance with the new recommendations may entail structural changes in some existing installations and/or changes in operative procedures. Since in fact the new recommendations are more restrictive because of the greater emphasis put on the dose accumulated over a long period of time, it is not essential that such changes be made immediately, although it is obviously desirable. As a practical guide it is suggested that the transition period during which the necessary changes would be made, should not exceed five years.

(22) The Commission wishes to point out again that the setting up of maximum permissible limits of occupational and non-occupational exposure (especially the latter) requires quantitative information not yet available about the risks and benefits of an expanded use of "atomic energy". For this reason the Commission will be glad to receive factual data and suggestions from those concerned with the production or utilization of ionizing radiation, so that as much pertinent information as possible may be available to it in its future deliberations.

B. BASIC CONCEPTS

OBJECTIVES OF RADIATION PROTECTION

(23) Exposure to ionizing radiation can result in injuries that manifest themselves in the exposed individual and in his descendants: these are called somatic and genetic injuries respectively.

(24) Late somatic injuries include leukemia

and other malignant diseases, impaired fertility, cataracts and shortening of life. Genetic injuries manifest themselves in the offspring of irradiated individuals, and may not be apparent for many generations. Their detrimental effect can spread throughout a population by mating of exposed individuals with other members of the population.

(25) The objectives of radiation protection are to prevent or minimize somatic injuries and to minimize the deterioration of the genetic constitution of the population.

CRITICAL ORGANS AND TISSUES

(26) The organs and tissues of the body exhibit varying degrees of radiosensitivity, and it is therefore necessary, for purposes of protection, to consider their radiosensitivity with respect to specific functions as well as the doses they receive. When this is done, some organs and tissues assume a greater importance, according to the circumstances under which they are irradiated. They are then said to be critical.

(27) In the case of more or less uniform irradiation of the *whole body*, the critical tissues are those tissues of the body that are most radiosensitive with respect to the ability of carrying out functions essential to the body as a whole. In this report these are taken to be the blood-forming organs, the gonads, and the lenses of the eyes. In previous reports the skin was listed as a critical organ in the case of whole body exposure. The presentation of the recommendations in the present report is simplified by not designating the skin as a critical organ.

(28) In the case of irradiation more or less limited to *portions of the body*, the critical tissue is that tissue most likely to be permanently damaged either because of its inherent radiosensitivity, or because of a combination of radiosensitivity and localized high dose.

PERMISSIBLE DOSE

(29) Any departure from the environmental conditions in which man has evolved may entail a risk of deleterious effects. It is therefore assumed that long continued exposure to ionizing radiation additional to that due to natural radiation involves some risk. However, man cannot entirely dispense with the use of ionizing radiations, and therefore the problem in practice is to limit the radiation dose to that which involves a risk that is not unacceptable to the individual and to the population at large. This is called a "permissible dose"

(30) The permissible dose for an *individual* is that dose, accumulated over a long period of

time or resulting from a single exposure, which, in the light of present knowledge, carries a negligible probability of severe somatic or genetic injuries; furthermore, it is such a dose that any effects that ensue more frequently are limited to those of a minor nature that would not be considered unacceptable by the exposed individual and by competent medical authorities.

(31) Any severe somatic injuries (e.g. leukemia) that might result from exposure of individuals to the permissible dose would be limited to an exceedingly small fraction of the exposed group; effects such as shortening of life span, which might be expected to occur more frequently, would be very slight and would likely be hidden by normal biological variations. The permissible doses can therefore be expected to produce effects that could be detectable only by statistical methods applied to large groups.

(32) The permissible dose to the gonads for the *whole population* is limited primarily by considerations with respect to genetic effects (see paragraphs 58-65).

CATEGORIES OF EXPOSURE

(33) These recommendations are designed to limit not only somatic but also genetic effects; it is therefore necessary to reduce as much as possible the dose to the population as a whole, as well as to the individual. In general, doses resulting from all sources of ionizing radiation should be considered in the appraisal of possible biological damage. However practical considerations make it necessary to consider separately the doses resulting from two categories of exposure, namely:

- (a) Exposure to natural background radiation.
- (b) Exposure resulting from medical procedures.

(34) Natural background radiation varies considerably from locality to locality and the doses it contributes to the various organs are not well known. If maximum permissible limits recommended by the Commission included background radiation, the allowable contribution from man-made sources—which are the only ones that can be controlled—would be uncertain and would have to be different for different localities. Accordingly, doses resulting

from natural background radiation are excluded from all maximum permissible doses recommended in this report.

(35) In medical procedures, exposure of the patient to primary radiation is generally limited to parts of the body, but the whole body is exposed to some extent to stray radiation. The contributions to the doses in various organs and the part played in the over-all effects on the individual are practically impossible to evaluate at the present time. The Commission recognizes especially the importance of the *gonad* doses resulting from medical exposure and the attendant genetic hazard to the population. Accordingly, it recommends that the medical profession exercise great care in the use of ionizing radiation in order that the gonad dose received by individuals before the end of their reproductive periods be kept at the minimum value consistent with medical requirements. However, individual doses resulting from medical exposure are excluded from all maximum permissible doses recommended in this report.

(36) The recommendations cover the following categories of exposure. In principle both the exposure of *individuals* and averages over the whole *population* have to be considered, but recommendations with regard to individual exposure are given only for the groups A and B.

A. *Occupational exposure.*

B. *Exposure of special groups:*

- (a) Adults who work in the vicinity of controlled areas (see paragraphs 71 and 72), but who are not themselves employed on work causing exposure to radiation.
- (b) Adults who enter controlled areas occasionally in the course of their duties, but are not regarded as radiation workers.
- (c) Members of the public living in the neighborhood of controlled areas.

C. *Exposure of the population at large.*

D. *Medical exposure.*

Occupational exposure

(37) Exposure of an *individual* who normally works in a controlled area constitutes occupational exposure. Maximum permissible doses

are set for the individuals in the small portion of the population that can be occupationally exposed (paragraphs 46–52). The contribution from this group to the genetic dose to the *population* as a whole is discussed in paragraph 65.

Exposure of special groups

(38) Persons who only occasionally enter a controlled area and persons who work or reside in the vicinity of a controlled area may be exposed to radiation originating in the controlled area. They constitute groups that may include children and pregnant women as well as individuals subject to other hazards, and may in total constitute a large fraction of the whole population. For these reasons the maximum permissible dose to these persons as *individuals* is set lower than for persons occupationally exposed (paragraphs 53–57). The contribution from these groups to the genetic dose to the whole *population* is discussed in paragraph 65.

Exposure of the population at large

(39) Members of the population at large may be exposed to radiation that cannot be related to any specific controlled area; e.g. exposure from environmental contamination and widely distributed radiation sources such as wrist-watches, TV-sets and various applications of radioactive materials to be expected as a result of future expansion in the atomic energy field. As such exposure is not easily controlled, it will be impossible to ensure that a recommended maximum permissible individual dose is not exceeded in any single case. Where large numbers are involved, it will not be possible to examine the habits of every individual. A reasonable procedure would be to study a sample of the group involved and to set the environmental level so that no individual in the sample receives any excessive exposure. There will always remain the possibility that someone of grossly different habits from those in the observed sample may receive a higher dose than the maximum in the sample.

(40) In order to facilitate planning for the anticipated increased uses of nuclear energy and other sources of radiation, it is desirable at this time to recommend a maximum for the genetic dose to the *population* (paragraph 64); this

maximum will determine what average gonad exposure could be allowed. Part of the recommended maximum genetic dose will have to be used for exposure of groups such as A and B and for medical exposure. The proper apportionment for exposure of the population at large must allow for both internal and external exposure (paragraph 65).

Medical exposure

(41) No recommendations are given with regard to the dose to the individual from medical exposure. (The contribution of medical exposure to the genetic dose is discussed in paragraphs 69–70.)

REDUCTION IN MAXIMUM PERMISSIBLE DOSE

(42) The new recommendations were introduced partly with the intention of limiting the genetically significant radiation exposure (see paragraph 63) of the population, and partly to limit the probability of somatic injury by reducing the lifetime dose. This reduction does not result from positive evidence of damage due to the use of the earlier permissible dose levels,

but rather is based on the concept that biological recovery may be minimal at such low dose levels.

TIME INTERVAL OVER WHICH DOSE IS TO BE ASSESSED

(43) The maximum permissible weekly doses recommended by the Commission in 1950 have been replaced by limits for the doses received over longer periods of time (paragraphs 47–49). In the case of occupational exposure the maximum permissible dose that may be accumulated at a certain time depends on the age of the worker. The dose to individuals in the population at large, or in special groups other than occupational, may be accumulated at a rate that is determined by a maximum permissible annual dose. The genetic dose to the whole population is assessed over the period between conception of the individual and conception of each child of the individual. (See paragraph 63 for method of evaluation.)

(44) These extended periods of time allow for some flexibility in the way in which radiation exposure may be received, and at the same time provide what is considered to be adequate protection for each group of the population.

C. MAXIMUM PERMISSIBLE DOSES

GENERAL

(45) It is emphasized that the maximum permissible doses recommended in this section are *maximum* values; the Commission recom-

mends that all doses be kept as low as practicable, and that any unnecessary exposure be avoided.

EXPOSURE OF INDIVIDUALS

OCCUPATIONAL EXPOSURE

(46) In any organ or tissue, the *total* dose due to occupational exposure shall comprise the dose contributed by external sources during working hours and the dose contributed by internal sources taken into the body during working hours. It shall not include any medical exposure or exposure to natural radiation.

Exposure of the gonads, the blood-forming organs and the lenses of the eyes

(47) The maximum permissible total dose

accumulated in the gonads, the blood-forming organs and lenses of the eyes at any age over 18 years shall be governed by the relation

$$D = 5(N - 18)$$

where D is tissue dose in rems and N is age in years.

(48) For a person who is occupationally exposed at a constant rate from age 18 years, the formula implies a maximum weekly dose of 0.1 rem. It is recommended that this value be used for purposes of planning and design.

Rate of dose accumulation

(49) To the extent the formula permits, an occupationally exposed person may accumulate the maximum permissible dose at a rate not in excess of 3 rems during any period of 13 consecutive weeks (i.e. in no 13 consecutive weeks shall the dose exceed 3 rems). If necessary, the 3 rems may be received as a single dose, but as the scientific knowledge of the biological effects of differing dose rates is scant, single doses of the order of 3 rems should be avoided as far as practicable.

Application to special cases

(50) Setting permissible limits of exposure in terms of the dose accumulated up to a given age introduces certain practical complications. Thus, some workers (previously exposed at levels within the then permissible limits) may have already accumulated a dose in excess of the maximum permitted by the formula. There are also special cases in which exceptions in the application of the formula may be desirable for practical reasons and are justifiable within the context of paragraph 42. The following recommendations are intended to provide guidance on administrative policy, which may well vary according to circumstances at the local level. (It should be noted that this situation will obtain only during a relatively short transition period.)

(51a) *Previous exposure history unknown.* When the previous occupational exposure history of an individual is not definitely known, it shall be assumed that he has already received the full quota permitted by the formula.

(51b) *Persons exposed in accordance with the former maximum permissible weekly dose.* Persons who were exposed in accordance with the former maximum permissible weekly dose of 0.3 rem and who have accumulated a dose higher than that permitted by the formula, should not be exposed at a rate higher than 5 rems in any one year, until the accumulated dose at a subsequent time is lower than that permitted by the formula.

(51c) *Persons starting work at an age of less than 18 years.* When a person begins to be occupationally exposed at an age of less than 18 years, the dose shall not exceed 5 rems in any one year

under age 18, and the dose accumulated to age 30 shall not exceed 60 rems. (The minimum age at which occupational exposure is legally permitted is lower than 18 years in some countries.)

(51d) *Accidental high exposure.* An accidental high exposure that occurs *only once in a lifetime* and contributes no more than 25 rems shall be added to the occupational dose accumulated up to the time of the accident. If the sum then exceeds the maximum value permitted by the formula, the excess need not be included in future calculations of the person's accumulated dose. Accidental exposure to doses higher than 25 rems must be regarded as being potentially serious, and shall be referred to competent medical authorities for appropriate remedial action and recommendations on subsequent occupational exposure. This is intended as an administrative guide to permit the continuation of work with radiation, following a bona fide accident ("once in a lifetime"), in cases in which interruption of such work, or curtailment of exposure, would handicap the individual in the pursuit of his career.

(51e) *Emergency exposure.* Emergency work involving exposure above permissible limits shall be planned on the basis that the individual will not receive a dose in excess of 12 rems. This shall be added to the occupational dose accumulated up to the time of the emergency exposure. If the sum then exceeds the maximum value permitted by the formula, the excess shall be made up by lowering the subsequent exposure rate so that within a period not exceeding 5 years, the accumulated dose will conform with the limit set by the formula. Women of reproductive age shall not be subjected to such emergency exposure.

Exposure of single organs other than the gonads, the blood-forming organs and the lenses of the eyes

(52) For exposure that is essentially restricted to portions or single organs of the body, with the exception of the gonads, the blood-forming organs and the lenses of the eyes, a higher dose than the one derived from the formula $D = 5(N - 18)$ is permitted. The following recommendations are made.

(52a) *A maximum dose of 8 rems/13 weeks for*

*the skin.** The earlier recommended weekly maximum doses for exposure of the skin, namely 0.6 rem in connection with a whole body exposure and 1.5 rems for exposure with radiation of very low penetrating power, have been replaced by the recommendation that the dose in the skin, accumulated over any 13 consecutive weeks, shall not exceed 8 rems. This recommendation now applies to all exposure of the skin, except the skin of the hands and forearms, feet and ankles. As the 8 rems are derived from an average of 0.6 rem/week, the annual dose for a 50 week year is limited to 30 rems.

(52b) *A maximum dose of 20 rems/13 weeks for the hands and forearms, feet and ankles.* The earlier recommended weekly maximum of 1.5 rems for exposure of hands and forearms, feet and ankles has been replaced by the recommendation that the dose accumulated over any 13 consecutive weeks shall not exceed 20 rems. This recommendation applies to all tissues of the above-mentioned extremities. As the 20 rems are derived from an average of 1.5 rems/week, the annual dose for a 50 week year is limited to 75 rems.

(52c) *A maximum dose of 4 rems/13 weeks for limited exposure of internal organs other than the thyroid, the gonads and the blood-forming organs.* In the case of internal organs, limited exposure originates almost exclusively from radioisotopes within the body. As most planning of release of radioactive isotopes to the air and water supplies in controlled areas is made under conditions where occupational groups rather than single individuals are exposed, a formula corresponding to the one given in paragraph 47 cannot in general be applied to internal exposure. An average of 0.3 rem/week in the organ of interest (with some exceptions noted in the report of Committee II) is expected to be maintained under equilibrium conditions if the concentration in air or water of the relevant isotope is kept at levels given in the tables in the report of Committee II. Variations of the dose rate will occur in practice, and are permissible, provided that the dose accumulated over any 13 consecutive weeks does not exceed

4 rems. As this maximum is derived from a weekly average of 0.3 rem, the annual dose for a 50 week year is limited to 15 rems.

(52d) *Whole body exposure from uptake of several radioisotopes.* When the radioactive isotopes in a mixture are taken up by several organs and the resultant tissue doses in such organs are of comparable magnitude, the combined exposure is considered to constitute essentially whole body exposure. Accordingly, the permissible levels of exposure will be those applicable to the gonads, the blood-forming organs and the lenses of the eyes.

EXPOSURE OF SPECIAL GROUPS

(53) The total maximum permissible individual dose shall consist of the sum of the doses contributed by both external and internal sources. It shall not include any medical exposure or exposure to natural radiation.

Total annual dose to the gonads, the blood-forming organs and the lenses of the eyes

(54) For any individual in the groups B(a) and B(b) (see paragraph 36), the total annual dose, including contributions from external and internal sources, to the gonads, the blood-forming organs and the lenses of the eyes, due to operations within the controlled area shall not exceed 1.5 rems, nor shall the contribution from a mixture of isotopes whose combined exposure constitutes essentially whole body exposure, make the total annual dose exceed 1.5 rems. There is an exception in the case of the skin and the thyroid where an annual maximum of 3 rems is allowed.

(55) The group B(c) differs from the groups B(a) and B(b) in that it contains children for whom it is considered that a lower figure, namely 0.5 rem/year (in the gonads, the blood-forming organs and the lenses of the eyes), should apply. Accordingly the presence of children in the group B(c) will require the use of a value of 0.5 rem/year for this group for purposes of planning and design.

Internal exposure of single organs

(56) The *individual* maximum permissible annual dose will not be exceeded *from internal exposure* of any single organ, if the release of radioactive material is planned on the basis

* This also applies to the thyroid, see report of Committee II.

of $\frac{1}{10}$ of the maximum permissible concentration (MPC) in air or water as given for continuous occupational exposure ("168-hour week") in the tables in the report of Committee II.

Whole body exposure from uptake of several radioisotopes applicable to group B(c)

(57) When the radioactive isotopes in a mixture are taken up by several organs in such a way that the combined exposure constitutes essentially whole body exposure, a reduction of the maximum permissible concentrations based on the exposure of single organs (see report of Committee II) becomes necessary. The reduction should take into account the

number and importance of the organs in question and the contribution to whole body exposure made by radioactive material in the circulating blood and in organs other than those in which it is assumed to concentrate. In this case the total body is considered to be the critical organ and the MPC values for the individual radioisotopes are reduced so that the MPC for the mixture corresponds to an average annual dose of 0.5 rem to the total body. For such mixtures of radioisotopes this is equivalent to a reduction in the MPC values of the individual radioisotopes in the mixture by a factor of $\frac{1}{3}$ or less in addition to the factor of $\frac{1}{10}$ recommended in paragraph 56.

EXPOSURE OF POPULATION

GENERAL

(58) Proper planning for nuclear power programs and other peaceful uses of atomic energy on a large scale requires a limitation of the exposure of whole populations, partly by limiting the individual doses and partly by limiting the number of persons exposed.

(59) This limitation necessarily involves a compromise between deleterious effects and social benefits. Consideration of genetic effects plays a major role in its evaluation. The problem has been discussed extensively in recent years and suggestions have been made by different national bodies. The Commission is aware of the fact that a proper balance between risks and benefits cannot yet be made, since it requires a more quantitative appraisal of the probable biological damage and the probable benefits than is presently possible. Furthermore, it must be realized that the factors influencing the balancing of risks and benefits will vary from country to country and that the final decision rests with each country.

(60) Because of the urgent need for guidance in this regard, the Commission in the following sections suggests an interim ceiling for the exposure of the whole population. The proposed level is essentially in accordance with suggestions by other scientific groups that have studied the problem and tried to evaluate the possible biological effects. It is felt that this level

provides reasonable latitude for the expansion of atomic energy programs in the foreseeable future. It should be emphasized that the limit may not in fact represent the proper balance between possible harm and probable benefit, for reasons already mentioned.

(61) On the assumption that the genetic effects are linearly related to the gonad dose and provided that no threshold dose exists, it is possible to define a population dose average that is relevant to the assessment of genetic injury to the whole population (paragraphs 62-63). In the case of somatic effects no such dose can easily be defined although the annual per capita dose to certain tissues or to the whole body may be relevant on the assumption of a non-threshold, linear dose-effect relation.

GENETIC DOSE

Assessment of genetic dose

(62) The genetic dose to a population is the dose which, if it were received by each person from conception to the mean age of childbearing, would result in the same genetic burden to the whole population as do the actual doses received by the individuals. A permissible genetic dose is that dose, which if it were received by each person from conception to the mean age of childbearing, would result in an acceptable burden to the whole population.

(63) The genetic dose to a population can be assessed as the annual genetically significant dose multiplied by the mean age of child-bearing, which for the purpose of these recommendations is taken to be 30 years. The annual genetically significant dose to a population is the average of the individual gonad doses, each weighted for the expected number of children conceived subsequent to the exposure.

Maximum permissible genetic dose

(64) It is suggested that the genetic dose (see paragraph 63) to the whole population from all sources additional to the natural background should not exceed 5 rems plus the lowest practicable contribution from medical exposure. The background is excluded from the suggested value because it varies considerably from country to country. The contribution from medical exposure is considered separately for the same reason and also because the subject is being studied for the purpose of limiting such exposure to the minimum value consistent with medical requirements.

Apportionment of genetic dose

(65) The suggested maximum genetic dose of 5 rems in addition to the dose from medical procedures and natural background must not be used up by one single type of exposure. The proper apportionment of the total will depend upon circumstances which may vary from country to country, and the decision should therefore be made by national authorities.

Addendum to paragraph 65

(a) *Illustrative apportionment.* The Commission does not wish to make any firm recommendations as to the apportionment of the genetic dose of 5 rems but, for guidance, gives the following apportionment as an illustration.

(A) Occupational exposure	1.0 rem
(B) Exposure of special groups	0.5 rem
(C) Exposure of the population at large	2.0 rems
Reserve	1.5 rems

(b) *Fractions of population.* Assuming that the ratio of the total population to the reproductive population is the same in all groups, the largest fraction (ϵ) of the whole population that can be exposed to an

average annual dose \bar{D}_1^i is given by the equation:

$$\epsilon \cdot 30 \cdot \bar{D}_1^i = D_{30}^i$$

where D_{30}^i is the apportionment of the genetic dose to the i th exposure group, and the average annual dose within the group can be expressed as a fraction of the maximum permissible individual annual dose; i.e. $\bar{D}_1^i = F_1 D_1^i$.

(c) *Occupational exposure.* Assigning 1.0 rem to occupational exposure would mean that 1.7 per cent of the whole population could accumulate the maximum permissible occupational gonad dose of 60 rems by age 30. It is very unlikely that such a figure will be approached in the foreseeable future. At the present time, the number of persons occupationally exposed in technologically developed countries is about 0.1–0.2 per cent of the population, and most of these persons receive doses which are considerably less than the maximum permissible doses.

(d) *Exposure of special groups.* Since the contribution from the special groups is largely due to group B(c) an apportionment of 0.5 rem for the special groups would imply that about 3 per cent could be exposed to the maximum permissible individual annual gonad doses for these groups. The allowable size of these groups varies inversely with the average dose within the groups. Thus, if this dose were only 10 per cent of the maximum individual doses, the groups could amount to 30 per cent of the whole population, which is very much larger than is likely to occur.

(e) *Exposure of the population at large.* The apportionment of 2.0 rems (with a long-term reserve of 1.5 rems for possible eventualities) for the genetic exposure of the population at large is intended for planning purposes in the development of nuclear energy programs (with the associated waste disposal problems) and more extensive uses of radiation sources. In the case of internal exposure, the radioisotopes of interest are those that contribute to the gonad dose directly (by local concentration) or indirectly (by radiation produced elsewhere in the body). In either case the maximum permissible concentrations in air and water of these isotopes recommended by Committee II for continuous occupational exposure ("168-hour week") are based on an average yearly dose of 5 rems in the gonads or the whole body. If for these isotopes the average concentrations in public air and water supplies are lower than the values recommended for continuous occupational exposure by a factor of 1/100, the genetic dose to the population would amount to 1.5 rems ($5 \times 1/100$ rems/year in the gonads \times

30 years = 1.5 rems). In this case the contribution from external sources should be limited to 0.5 rem in order not to exceed the total of 2 rems.

SOMATIC DOSE

(66) No specific recommendations are made at this time as to the maximum permissible "somatically" relevant dose to the population. However, it is expected that the maximum permissible limits of the *individual* total doses recommended in paragraphs 46-57 will keep the average dose in any tissue at such a level that the injuries that could possibly occur in a population would be well within acceptable limits. (See paragraph 31.)

(67) In the case of external exposure of the whole body to penetrating radiation the restriction imposed by the genetic dose to the population automatically reduces the doses to internal organs below the *individual* maximum permissible annual doses recommended in paragraphs 46-57. Thus the probability of somatic injury in these organs is considerably lower than indicated in paragraph 66. The same thing applies to internal exposure resulting from radioisotopes that directly or indirectly contribute to the gonad dose of a population. (See addendum to paragraph 65.)

(68) There remain for further consideration those isotopes that concentrate in specific organs (other than the gonads). In view of the existing uncertainty as to the dose-effect relationships for somatic effects, it is suggested that for planning purposes the average concentrations of such isotopes, or mixtures thereof, in air or water, applicable to the population at large, should not exceed one-thirtieth of the MPC values for continuous occupational exposure given in the report of Committee II.

MEDICAL EXPOSURE

(69) Estimates of the current annual genetically significant dose from medical procedures in various countries were surveyed in a report of a joint study group of the ICRP and ICRU to the United Nations Scientific Committee on the Effects of Atomic Radiation. The United

Nations Scientific Committee gives the following summary statement in its 1958 report to the General Assembly:

"The contribution made by medical procedures to the radiation exposure of populations has only lately been estimated and has increased very rapidly in some countries in recent years, so that it is difficult to evaluate such genetic and somatic effects as are associated with an increasing employment of radiological procedures in medicine. No information is yet available for prediction of the future trend of medical exposures. It is expected that improvements in equipment and techniques may considerably reduce individual exposures, but the ever-expanding use of X-rays may well increase the world population dose. Precautions of the type described by the International Commissions on Radiological Protection and on Radiological Units and Measurements should make possible such reduction of exposure to radiation as is without detriment to the medical value of these procedures."

(70) Reported values of the annual genetically significant dose in various countries range up to about 150 mrems, corresponding to a genetic dose of 4.5 rems (from conception to age 30 years, averaged over the whole population). Even with the highest values reported (corresponding to the genetic dose of 4.5 rems), the total genetic dose from all types of exposure would not exceed 10 rems if the apportionment for the contributions from other exposure sources than medical is not exceeded. There are indications that the highest levels of medical exposure reported could be reduced significantly by careful attention to techniques. On the other hand, the use of X-rays may increase, although probably to a lesser degree in the countries which now report the most extensive use. A certain allowance for medical exposure of populations must be made and may be made in the near future as the subject is being studied for the purpose of limiting such exposure to the minimum value consistent with medical requirements.

D. GENERAL PRINCIPLES REGARDING WORKING CONDITIONS**RESPONSIBILITY**

The owner or the person in charge of a controlled area shall be responsible for the working conditions and for the instruction of all persons working in the area regarding radiation hazards and methods of control. He shall be responsible for maintaining radiation levels outside the controlled area resulting from operations within the area so that exposures do not exceed the maximum permissible doses recommended in paragraphs 53-57.

(71) A controlled area shall be established where persons occupationally exposed could receive doses in excess of 1.5 rems/year.

(72) A controlled area is an area in which the exposure of personnel to radiation or radioactive material is under the supervision of a radiation protection officer.

(73) A radiation protection officer is one who has the knowledge and responsibility to apply appropriate radiation protection regulations. He may be the owner or the person in charge of the controlled area or he may be a technically competent person appointed by the above.

(74) A qualified expert (or health physicist) is a person having the knowledge and training needed to measure ionizing radiations and to advise regarding radiation protection. The qualification should be of the type specified by a National Committee.

RADIATION SURVEYS AND MONITORING*Surveys prior to use of controlled areas*

(76) In those instances where the operations in a controlled area may disturb or alter significantly the environment with respect to radiation hazards, adequate surveys should be made of the radioactivity of the air, soil, and water prior to the start of operations. This will provide a base line from which to judge the adequacy of radiation controls within the area.

(77) During and after installation, appropriate radiation surveys shall be made to ensure that the pertinent recommendations will be complied with when routine operations commence. Routine operations shall be deferred until such compliance is assured.

(78) When additional operations are planned in the area, a thorough survey should be made of the background radiation prior to the start of the new operations. This will aid in the identification of the operation responsible for any increase of the background radiation or the contamination in the area.

Routine surveys and monitoring

(79) Radiation surveys shall be made regularly, at a frequency dictated by the operations within the area, to determine the adequacy of safety procedures. This should include checks of the facilities, equipment (radiation warning devices, radiation shields, hoods, respirators, ventilating system etc.), and working techniques. When there is any reasonable probability of a radiation hazard existing, the vicinity of the controlled area should also be surveyed.

Special surveys

(80) Specific and detailed recommendations regarding radiation surveys applicable to some special cases will be given in the Reports of the Committees of ICRP.

HEALTH SURVEILLANCE*Pre-employment examination*

(81) All new personnel in radiation work shall have a pre-employment medical examination. Notes should be made of the family history, of the previous occupational history, and of previous X-ray diagnostic examination or radiation therapy. The examination shall include a complete blood count, with determination of erythrocyte and leukocyte levels and a differential white cell count. It should be recognized that the examination is directed toward determining the "normal" condition of the worker at the time of employment, and toward noting any abnormalities that might later be confused with radiation damage.

(82) In cases where there has been previous occupational exposure, the total accumulated dose shall be recorded (see paragraphs 47-51) and any appropriate additional medical examinations performed. These should include

ophthalmological examinations, with particular reference to changes in the lens in cases of exposure to neutrons and to heavy particles, and examinations of skin and nails in the case of partial external irradiation and external contamination.

Routine medical examinations

(83) Medical examinations should be performed at a frequency depending upon the conditions of the occupational exposure. Blood counts, although they are a part of a medical examination, are not to be considered as a method of radiation monitoring.

(84) Persons occupationally exposed to neutrons and to heavy particles of significant penetration should have ophthalmological examinations, with particular reference to changes in the lens. The frequency of the examination will depend upon the conditions of exposure.

PERSONNEL MONITORING

External radiation

(85) Doses received as a result of occupational exposures shall be systematically checked with appropriate instruments to ensure that the maximum permissible doses are not exceeded

and to make it possible to keep individual cumulative dose records.

Internal radiation

(86) Tests should be performed to estimate the total body burden for workers who deal with unsealed radioactive isotopes that may give rise to levels of ingestion or inhalation in excess of the maximum permissible concentrations. Such tests should also be performed where radioisotopes may enter the body through the skin or through skin punctures and open wounds. These tests may require the monitoring of breath and excreta, and the direct determination of the body burden by means of a total body monitor, according to circumstances. The radiation doses delivered to the appropriate organs or tissues should be calculated and noted on the personal record, and the permitted doses of external radiation should be adjusted to allow for the "internal" doses.

RADIATION WARNING DEVICES

(87) An appropriate form of warning shall be provided to indicate the existence of a radiation hazard, even if the hazard is of a temporary nature only. In the latter case the warning device should be removed when the hazard no longer exists.