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MEDICAL SUPERVISION IN RADIATION WORK

Second Report of the Expert Committee on Radiation

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EXPERT COMMITTEE ON RADIATION

Geneva, 28 September - 3 October 1959

Members :

Dr M. N. Fateeva, Head, Radiological Clinic, Institute of Work Hygiene and Occupational Diseases of the USSR Academy of Medical Sciences, Moscow, USSR

Dr Asher J. Finkel, Director, Health Division, Argonne National Laboratory, Lemont, Ill., USA (*Rapporteur*)

Dr Bo Lindell, Institute of Radiophysics, Karolinska Hospital, Stockholm, Sweden

Dr A. S. McLean, Director, Authority Health and Safety Branch, United Kingdom Atomic Energy Authority, London, England

Dr Carlo Polvani, Principal Medical Officer, Centre for Nuclear Studies, National Committee for Nuclear Research, Ispra (Varèse), Italy

Dr J. Reboul, Professeur de Clinique d'Electro-Radiologie, Hôpital Saint-André, Bordeaux, France

Dr Ernest M. Renton, Plant Physician, Atomic Energy of Canada Limited, Chalk River, Ontario, Canada

Dr James H. Sterner, Associate Professor of Medicine, University of Rochester, Rochester, N.Y.; Consultant to the United States Atomic Energy Commission, USA (*Chairman*)

Dr Katharine Williams, Principal Medical Officer, Atomic Energy Research Establishment, United Kingdom Atomic Energy Authority, Harwell, Berks., England (*Vice-Chairman*)

Representatives of other agencies :

Dr H. T. Daw, Division of Health, Safety and Waste Disposal, International Atomic Energy Agency, Kaerntnerring, Vienna

Dr R. Murray, Occupational Safety and Health Division, International Labour Office, Geneva

Mr E. Hellen, Occupational Safety and Health Division, International Labour Office, Geneva

Secretariat :

Dr R. Lowry Dobson, Chief Medical Officer, Radiation and Isotopes, WHO (*Secretary*)

Dr Hermann Lisco, Division of Biological and Medical Research, Argonne National Laboratory, Lemont, Ill.; Department of Pathology, University of Chicago, Ill., USA (*Consultant*)

Dr P. Taillard, Medical Officer, Radiation and Isotopes, WHO

Dr B. M. Wheatley, Health Physicist, European Organization for Nuclear Research, Meyrin, Switzerland (*Consultant*)

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MEDICAL SUPERVISION IN RADIATION WORK

Second Report of the Expert Committee on Radiation *

The WHO Expert Committee on Radiation met in Geneva from 28 September to 3 October 1959. The meeting was opened by Dr P. Dorolle, Deputy Director-General. On behalf of the World Health Organization, he welcomed the participants and the representatives from the International Atomic Energy Agency and the International Labour Office. He referred to the importance of the subject under discussion because of the increasing use of ionizing radiation and radioactive materials and the development of atomic energy activities in many countries. Dr Dorolle pointed out that medical supervision in radiation work is an essential aspect of health protection against radiation hazards. With the rapidly increasing amount and variety of radiation work there was a growing need for sound consideration of the basic questions involved in medical supervision in this field. The hope was expressed that the results of this meeting would be of considerable help and provide valuable guidance to medical and health personnel engaged in establishing health protection programmes; the conclusions of the Committee should also be of interest to persons with experience in the field who are engaged in reviewing existing programmes or advising on related questions.

Dr James H. Sterner was elected Chairman, Dr Katharine Williams, Vice-Chairman and Dr Asher J. Finkel, Rapporteur.

1. General Considerations

A dramatic demonstration of the value of carefully developed health protection measures and medical supervision in radiation work is provided by the occupational health record, unrivalled by any other industry, which has accompanied the birth and evolution of atomic energy. This excellent record resulted in large measure from the appreciation and understanding

* The Executive Board, at its twenty-fifth session, adopted the following resolution:
The Executive Board
1. NOTES the second report of the Expert Committee on Radiation (Medical Supervision in Radiation Work);
2. THANKS the members of the Committee for their work; and
3. AUTHORIZES publication of the report.
(Resolution EB25.R1, *Off. Rec. Wld Hlth Org.*, 1960, **99**, 5)

of the great potential hazards that would be involved in this new and complicated undertaking. An important feature, often overlooked, of the whole question of radiation protection is that a great deal is known about the health problems associated with ionizing radiation. In fact, the effects of radiation have been studied in much greater detail than have those of most other injurious physical and chemical agents that are commonly met with in industry and in modern life.

The injurious effects of radiation on human tissues were recognized very shortly after the discovery of X-rays and radioactivity more than sixty years ago, and have been the subject of study ever since. As a consequence, a substantial body of knowledge concerning these effects had already been accumulated before the atomic energy developments of the 1940's. In addition, considerable clinical experience with the use of X-rays and naturally-occurring radioisotopes had been acquired. Furthermore, experimental and clinical studies with artificially-produced radioisotopes had made important contributions to the basic medical sciences and to an understanding of metabolism.

It was this body of knowledge and experience that guided the growth of the health protection programmes which have contributed so substantially to the successful development of nuclear energy. This development in turn gave great impetus to the rapid further growth of radiobiology, radiation medicine and health protection in radiation work.

The principles involved in radiation health protection are now well understood, and they are basically the same whether one is dealing with a single individual or with a large industrial population. These principles are universally applicable to the problems of health protection in all types of radiation work in such diverse situations as the medical use of X-rays or radioisotopes, industrial processes, or large atomic installations.

Standards of protection relating to exposure to various types and amounts of radiation have been the concern of local, national, and international bodies. The International Commission on Radiological Protection (ICRP) has for many years made basic contributions to the health of radiation workers by recommending maximum permissible levels of radiation exposure.[1] These have served to guide the formulation of various national standards, and the acceptance of such standards by industry and by research laboratories in various countries has led to the development of occupational health programmes designed to protect persons engaged in work with these hazards. Medical supervision in radiation work has come to be, especially in the past 15 years, an important aspect of these health protection measures. It appears timely to review some of the prin-

[1] International Commission on Radiological Protection (1958) *Recommendations of ...*, London & New York, Pergamon Press; International Commission on Radiological Protection (1959) *Recommendations of ...; Report of Committee II on permissible dose for internal radiation* (ICRP Publication 2), London & New York, Pergamon Press

ciples and practices, especially those of a medical character, that are involved in this activity.

2. The Role of Medical Supervision in a Health Programme for Radiation Workers

The promotion and maintenance of health and safety in radiation work is based upon principles that have been applied to many other problems in occupational hygiene. A fundamental aspect is the appreciation of the nature and magnitude of the radiological safety problem. The effective control of radiation hazards must begin with the initial engineering design of a process and equipment if acceptably low limits of exposure are to be achieved in later operation. Continuing success in the control of these hazards depends upon the persistent application of good operating practices in working with radiation equipment and radioactive substances.

In the protection of persons exposed to radiation, the health physicist exercises an important function by monitoring both the environment and the individual. The methods of monitoring include the use of film badges and of ionization chambers for the evaluation of external radiation exposure. The absorption of radioactive material into the body by inhalation or ingestion is usually assessed by measuring the radioactivity content of urine and faeces.

The physician is responsible for the medical aspects of the health programme, including such elements as the selection of radiation workers, the continuing evaluation of work assignments, and the diagnosis and treatment of radiation injury. In carrying out these responsibilities the physician requires the co-operation of physicists and chemists who are concerned with measurements of radiation levels as well as of biologists who are familiar with the effects of radiation. For an effective programme these various disciplines must be co-ordinated and integrated, preferably by an active and continuing " team " approach. The value of the synthesis, based on the contributions from these diverse sources, is related to the mutual understanding and extended knowledge of the team members.

Knowledge of the kinds and quantity of radiation in the working environment is essential. With this information, it is possible to determine the extent of specific measures required for the protection of personnel. The radiation levels in the environment can be ascertained from an initial survey and from such subsequent monitoring as appears necessary.

Although the exposure of individuals can sometimes be estimated approximately on the basis of environmental monitoring data, accurate knowledge of individual exposures cannot be obtained in this way. Frequently, the degree of exposure in a particular area is so small as not to require special medical supervision. At the present time, because of differences in operating practices, it is not advisable to assign a definite numerical limit to the level of radiation exposure *below* which specific medical supervision is unnecessary. When the level of exposure is uncertain, it is necessary to assess the exposure of each individual to external radiation or to determine his intake of radioactive material.

When the actual or potential exposure is appreciable, a decision can be made as to whether or not any particular individual belongs to the category of radiation worker for which special medical supervision is necessary. The ICRP has recommended, for example, that medical supervision should be provided for all workers liable to receive doses in excess of 1.5 rem per year.[1]

It is evident that the extent of medical supervision needed for workers who receive doses approaching the maximum permissible levels may be greater than that provided for workers whose exposures are considerably lower. More frequent and elaborate methods of medical supervision may become necessary for persons working under conditions of potentially higher exposure.

There is great diversity in the size and kind of establishment in which ionizing radiation is used. They range from large atomic energy establishments having a great variety and a large number of radiation sources to small organizations where often there is only one person using an X-ray apparatus or a radioactive isotope. The extent to which normal medical supervision should include special health protection procedures depends upon the nature of the radiation hazards rather than on the number of individuals engaged. Only the relatively large establishments are likely to be self-sufficient in providing all the necessary medical facilities. For others, it may be necessary to make special arrangements with regional or national organizations that are able to provide the needed health facilities and services.

The scope of the medical survey itself depends largely on the type of work performed by the radiation worker. For example, the examinations arranged by the physician in charge of the survey for a worker in industrial radiography may be different from those for a worker in a plant where unsealed sources of radioisotopes are used.

3. Medical Supervision and Categories of Radiation Work

The scope of a programme of medical supervision in radiation work should be related to the specific character of the operation. A large proportion of the jobs involving exposure to radiation will have such a degree of technical control as to require only minimal to moderate effort and understanding by the worker to maintain working conditions within

[1] International Commission on Radiological Protection (1958) *Recommendations of ...*, London & New York, Pergamon Press, p. 10 (para. 37) & p. 17 (para. 71)

acceptable limits. For these situations, the selection of personnel and of the medical control required will be similar to that for many other industrial operations.

A smaller number of work situations, involving a greater risk of radiation exposure, will require a programme of closer medical supervision. In some instances, as in research laboratories, the changing pattern of the operations may involve variation in the quantity and nature of unsealed radionuclide sources. These circumstances may require considerable flexibility in the application of health protection measures. Similarly, such procedures as *in situ* radiography for pipeline welds may preclude the fixed controls that can be applied in a factory. The transient character of certain other operations may not warrant, on economic and technical grounds, the use of the more permanent safeguards that may provide a high degree of safety in the completed installation. In addition to the concern for possible excessive radiation exposure to the individual worker, a programme of medical supervision should consider the possible consequences to other workers and to the surrounding community in the event of an accident.

In general it is impossible to associate specific exposure risks with particular industries or group activities, and it is necessary for the physician to determine the hazards to which people under his supervision are potentially exposed. Several major categories of radiation work are discussed in the following sections.

3.1 Medical radiology

The sources of radiation in medical radiology are chiefly equipment for generating X-rays and sealed sources of radium and cobalt. Their wide distribution throughout many countries makes difficult a close and effective medical supervision. The very nature of their function in diagnosis and therapy, with the generation of relatively high levels of radiation, imposes technical difficulties, particularly in the handling of radium or cobalt sources to be applied directly to the patient. In the latter cases, people in several departments of a hospital may be exposed in any one application. The risk is not confined to those who check and dispense the material nor to those who introduce the material into the patient, but may extend to many other persons associated with the patient. Some of these exposures constitute the highest occupational levels at present known. In the larger hospitals and clinics, the exposure from X-ray equipment is usually so well controlled that the operating personnel receives only a small fraction of the permissible dose. It is often much more difficult to limit the exposure of personnel in the offices of physicians and dentists because of the lack of general appreciation of the hazard and the difficulties in providing effective inspection.

3.2 Medical applications of radioisotopes

In addition to the radioactive sources considered in the preceding paragraph, radioisotopes are increasingly employed for the investigation and treatment of disease. The materials are usually liquids or solids in quantities ranging from fractions of a microcurie to many millicuries. In most cases the work is primarily related to the diagnostic use of radioisotopes with limited risk to personnel. At a number of clinics, however, the therapeutic use of gamma-emitting isotopes, such as ^{131}I and ^{198}Au, may create risks of the same order as those associated with radium application. In the event of death of the patient, the risk may be extended to the pathologist and his team and to the undertaker. In addition to the environmental gamma-radiation, the use of hard beta-emitters, such as ^{32}P and ^{90}Y, will give an irradiation of skin and eye that is difficult to monitor. The general risk of contamination and body intake, especially in the case of volatile isotopes such as ^{131}I, adds a potential internal exposure. Hospitals in which radioactive materials are used should be suitably equipped with efficient protection against both internal and external radiation, and should be prepared for any decontamination procedures that may be necessary in the dispensing laboratory, the wards, or the pathology department. There should also be adequate facilities for handling bedding and excreta contaminated with radioactive materials. The problems confronting the health medical supervisory team in hospital situations are similar to those encountered in other establishments in which radiochemicals are used.

3.3 Radiography and radioisotopes in industrial operations

Industrial radiography employs, primarily, sources of gamma- or X-radiation, usually from sealed sources or X-ray generating equipment. Here the hazard is chiefly external radiation, except where there is a leak or rupture of a radionuclide source. In a considerable number of instances, it is possible to exert a high degree of fixed control, with enclosure, shielding, and interlocking devices to prevent operation of equipment when personnel could be exposed. When sources are more mobile, as in the radiography of large castings, the operation requires a greater degree of operator knowledge and supervision to ensure safety.

Sources of radiation are finding an ever-widening application in industry. Some examples are: thickness gauges, luminizing processes, static eliminators, liquid-level indicators, tracer indicators for product control, X-ray diffraction equipment, and high-energy rectifying devices. The diversity of these hazards requires the selection of an appropriate medical supervision programme.

3.4 Research uses of radiation and radioisotopes

The medical programme for the control of radiation hazards in the research uses of radiation and radioisotopes must be sufficiently versatile to meet the wide range of conditions inherent in this type of work. Effective protection is much more dependent upon the co-operation and understanding of the research personnel. An education programme, to be effective, must have a quite different motivation and appeal than that developed for routine industrial operations. The research worker, in his zeal for the experiment, is apt to take risks which the factory worker might avoid. This is particularly true in the academic setting, where safety and health programmes are not as well developed and accepted as in the research laboratory in industry. In many academic institutions it may be necessary to clarify the responsibility for the health supervision of students and staff. A proper appreciation of the risks should stimulate the evaluation and control of the working environment, and the provision of adequate personnel monitoring services.

A high proportion of research operations involve unsealed radioisotope sources. The changing pattern of experiments requires a versatility with respect to the nature of the hazard, and the medical techniques for evaluating and controlling exposures. Effective rapport between the research and medical personnel will be dependent upon the demonstrated scientific competence of the medical supervisory team.

3.5 Atomic energy activities

Practically the full range of activities and operations involving all types of ionizing radiation will be encountered in the highly diversified atomic energy industry. The requirements for medical control procedures will vary considerably in such operations as mining, processing of nuclear fuel materials, construction and operation of nuclear reactors, and the production of radionuclides. In some instances, as in the processing of fuel materials, the operations permit the development of relatively fixed protective measures requiring only a moderate degree of compliance on the part of the worker. On the other hand, the special processing of a batch of spent nuclear reactor fuel elements may demand the closest scrutiny and most rigorous and constant supervision to ensure safety. When the hazard is limited to external radiation, greater reliance will be placed on environmental measurements and controls. When radionuclides are involved, procedures for determining the absorption and retention in body tissues and the elimination in excreta become increasingly important.

The magnitude and multiplicity of types of radiation exposure encountered in atomic energy installations usually justify a diversified and adequate health protection programme. In the past, many of the important contributions in the field of radiation health supervision have come from the organizations developed to meet the needs of these complex activities.

4. Objectives of Medical Supervision

Medical supervision of personnel engaged in radiation work of any kind forms an essential part of a comprehensive programme of occupational health and hygiene, just as it does in other potentially hazardous occupations. The following items may be considered as the major general objectives of medical supervision in radiation work.

4.1 Protection of the worker

The protection of the individual worker against the health hazards of the work environment is accomplished by a number of procedures. Medical and other examinations should be designed to detect any possible physiological and pathological effects associated with exposure to radiation and with the absorption, distribution, retention and excretion of radioactive materials. The findings from environmental and experimental studies should be correlated with medical investigations of radiation-exposed workers for the purpose of developing standards or criteria for safe and healthful working conditions. The effective development, application, and acceptance of safety and control measures should be promoted by the influence and authority of the physician.

4.2 Selection and placement of personnel

Proper selection of personnel for work involving actual or potential exposure to ionizing radiation can be achieved through medical examinations prior to placement and at periodic intervals afterwards. These examinations aid in the selection of individuals according to their physical capacity and emotional make up and in their placement in work which they can perform with an acceptable degree of efficiency and without endangering their own health and safety or that of their fellow employees. For effective medical supervision it is essential that the job requirements be known and matched with the physical and mental capacities of the worker.

4.3 Medical care

Prompt and effective medical care must be provided for occupational injury and disease. This includes the diagnosis and treatment of radiation injury in case of accident or over-exposure. Specialized evaluation of the environmental factors, knowledge and availability of measures for minimizing and counteracting the injurious effects of radiation, and the availability of special facilities for diagnosis and treatment are essential elements of a medical control programme.

4.4 Personal health maintenance

Every good occupational health programme should encourage and promote personal health maintenance. A special feature of the health education programme where workers are occupationally exposed to radiation will include wise counsel and advice in individual instances where medical radiation is recommended, and aid in the education of the medical profession and the community with respect to radiation hazards.

5. The Role of the Physician and his Staff

Although the ultimate responsibility for radiation protection lies with the employer, the physician has specific responsibilities in the field of preventive medicine. His skill and experience is also indispensable in cases of accident where treatment of radiation injury may be required. To be able to fulfil these obligations, he must have at his disposal facilities and supporting staff to an extent consistent with the character and magnitude of the problems that he may encounter. In many cases, he may be a part-time industrial physician or private practitioner who is consulted by the employer and for whom radiation hazards constitute only a minor portion of his professional activity. He may then need little more than normal industrial hygiene facilities and examination techniques. In other cases, however, he may be in charge of the medical programme in a large establishment where many workers are engaged in radiation work and where exposure to radiations is the major occupational hazard. In these circumstances, radiation protection, including medical supervision, should be organized as an integrated function. Such a programme, and the services and facilities that are required, differ only in magnitude from the work of the individual physician who is concerned with one specific problem. In the following discussion, the emphasis is placed on the role of the physician in this larger and more complex situation, chiefly because a more complete consideration of the pertinent elements is then possible. Since the underlying principles are the same, this discussion should be equally helpful to the physician concerned with more limited problems.

The supporting staff in a medical department may include medical and surgical consultants in various specialties, nurses and nurses' assistants, and medical technologists (clinical laboratory technicians). Furthermore, physicians responsible for medical supervision may have to depend on a variety of associated specialists and technicians. These may include radiation safety personnel, physicists, health physicists, radiation chemists, and radiobiologists, among others. Additional assistance, under special conditions, may be needed from diverse groups such as meteorologists, ecologists, sanitarians, and fire protection and safety engineers. No physician with responsibilities for radiation protection can command authoritative knowledge in all these various disciplines, and he should be ready and willing to seek appropriate assistance in any specific situation. Such assistance may also be available from his national and international colleagues charged with similar responsibilities.

Medical personnel may or may not have direct supervision over health physics personnel. In any case, very close working relations should be established and should exist at all times between the strictly medical (clinical) personnel and other groups. The latter may include personnel and facilities for area and personnel monitoring, film badge and dosimeter evaluation, instrument development and maintenance, bioassay, industrial hygiene, occupational safety, and fire protection. Whole-body counting by gamma-ray spectrometry is becoming an increasingly valuable tool for the measurement of internally deposited gamma-ray emitting nuclides. Special services may be needed for the evaluation of specific hazards associated with reactor operations, radiochemical processing plants, high-energy apparatus, and high-level waste disposal.

Physicians charged with responsibilities for medical supervision should have an understanding of the principles underlying the biological effects of ionizing radiation. In addition, they should be familiar with the general nature of the radiation activities in their establishments. By this is meant knowledge of the general research, production, or applied processes actively pursued in a particular installation as well as the associated specific radiation problems. They should be acquainted with the nature of the potential external radiation hazards and the specific hazards of radioactive materials that might be absorbed by the body. Physicians should have access to and should spend time in various work and research areas where these special situations exist. They should be encouraged to visit similar installations in their own and other countries.

An employee is entitled to be informed of the risks of his occupation. When such information regarding exposure levels is imparted it should be done in a manner that will not provoke unnecessary anxiety. Such considerations would imply that after accidental overexposure a patient should not be given information that might be further detrimental to his health or morale, or that might impede his recovery. In less urgent medical situations, data regarding exposures *in excess* of permissible amounts should be transmitted with full consideration of the employee's ability to understand the information. When exposures are well below the permissible limits, the physician should exercise his discretion in informing employees, in the same way that he would with regard to the transmission of medical data that are difficult to understand.

The question of teaching radiation medicine has been considered by the WHO Expert Committee on Professional and Technical Education of Medical and Auxiliary Personnel.[1] The important role of the education programme in the dissemination of knowledge regarding the protection of workers against the harmful effects of ionizing radiations should be emphasized. The teaching programme must be directed both toward the physician and his supporting staff, and toward the worker.

Different approaches are necessary in different situations, e.g., in hospitals, laboratories, or industrial plants. The medical staff should have knowledge of the biological and medical aspects of radiation exposure and of radiation protection techniques. In many countries, special training courses in these fields are available to physicians.

The workers should be instructed in good occupational hygiene practice so that accidents and unnecessary high exposures can be prevented. The medical staff should assume a responsible role in this instruction.

6. Selection of Personnel for Radiation Work

The selection of personnel for work involving exposure to ionizing radiations requires, in addition to the basic elements of sound occupational placement practice, a consideration of special problems peculiar to radiation exposure, especially in so far as these may relate to the individual. It may be said in general, however, that there are few such special considerations that need enter into the decisions regarding placement in radiation work.

As noted earlier, the majority of tasks involving radiation exposure, particularly in the expanding peace-time application of nuclear energy, will be subject to such a degree of technical control with respect to radiation hazards that only minimal to moderate training of the worker and reasonable compliance with protective regulations will be needed to assure adequate control. For work of this type, the selection of employees will differ little from that for industry in general.

For the limited number of jobs that inherently involve a greater risk of radiation exposure, a higher degree of selectivity will be required. In some instances the hazard may be limited to the individual only, or to a small group of associates. In other situations, as in the case of operators of nuclear reactors, a serious mistake may involve many people and expensive equipment within the installation and in the surrounding community. An adequate evaluation of the mental and emotional qualifications of

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[1] *Wld Hlth Org. techn. Rep. Ser.*, 1958, **154**, **155**

these workers is of paramount importance. Particular attention should be paid to the emotional stability of persons in positions where calm and decisive action is needed in crises.

Job placement, in so far as it constitutes a medical problem, should be effected according to standards consistent with enlightened principles of occupational medicine. Such standards include the physical and emotional fitness of an applicant for the specific responsibilities of a particular job. Persons with various handicaps may be accepted for employment in positions commensurate with their abilities but they should not be placed in jobs where they might constitute a hazard to themselves or to other persons. The action of medical personnel in job placement should be permissive or restrictive, as may be appropriate in any individual case, but the physician must assume neither the role of the employment officer nor that of the prospective supervisor in placing the employee in specific work positions.

7. Medical Criteria for Radiation Work

In general, the physical requirements for employees liable to exposure to radiation will be determined by the specific demands of the job rather than by the factor of radiation. The examining physician must be familiar with the requirements of the job, either from personal knowledge or from written descriptions of the job characteristics. This is particularly true in the case of persons required to work alone or in a small firm or group in relative isolation. The emphasis that is placed on specific elements of the physical examination will depend upon the job requirements.

Certain significant and possibly restrictive factors that may be considered in the selection of personnel for work carrying a high risk of exposure to penetrating radiations are: age, sex and pregnancy, history of hereditary defects, pre-existing disease, previous radiation history, and certain special medical findings.

7.1 Age

A consideration of the age at which occupational radiation exposure may first be permitted is influenced by many factors. While, in general, no restrictions are suggested for any age-group because of *specific hazards of ionizing radiation*, current recommendations for persons engaged in radiation work refer in a seemingly arbitrary way to the age of 18 years as the starting point for accumulating the work-related radiation dose. These recommendations are in general agreement with those that have been made for other types of hazardous work and are usually made on the basis of biological and social considerations. Similarly, in the case of the radiation worker, they are based not so much on any knowledge that ionizing radiations may have a greater effect on the growing than on the adult organism but rather on the realization that a certain degree of physical and emotional maturity, such as has generally been attained by the age of 18 years, is desirable in a worker involved in any potentially hazardous operation, including radiation work. In the latter case, however, it should be pointed out that any limitation of radiation work during the reproductive period would tend to decrease the total time of exposure and hence the total accumulated dose. This is of particular significance from a genetic point of view.

7.2 Sex and pregnancy

Generally speaking, there is no medical reason for differentiating between men and women in radiation work in so far as exposures below the recommended maximum permissible levels are concerned. While the same might also be said in the case of women who are pregnant, it should be borne in mind that the unborn child may be irradiated if the mother is exposed to penetrating radiation and owing to its small size will be subject to essentially whole-body exposure. The foetus may also be irradiated in the event of internal radioactive contamination of the mother, in which case there is the added possibility of the transfer of radioactive material across the placenta to the foetal tissues.

There is general agreement that the embryo is especially vulnerable to radiation damage in the early stages of development. However, this increased liability to injury is particularly significant during those phases of embryonic development occurring at a time when the mother is apt to be unaware of her pregnancy. Hence, the only effective way of ensuring that women are not exposed to radiation during the early period of pregnancy would be to prevent all women of childbearing age from working with radiation. In general, wisdom would suggest that women in this age-group should not be exposed to *high* radiation risks.

7.3 Medical history

In taking the medical history, the examining physician should explore the family history, especially as it pertains to hereditary defects, in more detail than is the usual routine practice. In the medical history, attention should be given to any pre-existing disease that could have been due to or confused with radiation exposure from any source. It should be pointed out that, in most instances, pre-existing disease does not disqualify a person from engaging in work with ionizing radiations. Such persons should, in fact, be given employment opportunities in accordance with good principles and practices of employment.

7.4 Previous radiation

The previous radiation history should be carefully explored, although the amount of exposure may be difficult to establish. The occupational history, if it includes previous significant exposure to radiation, must be developed so as to obtain at least a quantitative guess of the accumulated dose and the best possible estimate should be made. It must be borne in mind that even if the applicant has received several times the maximum permissible accumulated dose, it is unlikely that the physical examination will reveal specific findings indicative of this. If, however, the history reveals that there have been repeated diagnostic X-ray exposures, or radiation therapy for any cause, the medical conditions associated with or resulting from such exposures should be carefully weighed in relation to the work of the individual.

7.5 Special medical findings

Factors in the examination that may require special consideration because of radiation exposure include the condition of the skin and blood, and the mental and emotional status.

In examining the skin, atrophy, multiple telangiectases, hyperkeratoses, brittleness and ridging of the nails, diminution or loss of ridge markings of fingers, and any of the chronic dermatoses should be noted.

Careful examination of the blood should be made and haematologic values outside the normal range should be noted. The finding of abnormal or excessive numbers of immature cells in the blood smear, instability of or wide fluctuations in haematologic elements on repeated examinations, or an apparent decrease or abnormal characteristics of platelets should be given careful attention. Each laboratory should develop standardized techniques and submit their results to critical analysis. A normal or acceptable range should be established for the employment group, since variations in some elements of the blood have been demonstrated in various geographic areas and among different ethnic groups. The adoption of a level leading to an unjustifiable rejection of applicants would result in exclusion of normal people. Exclusion from radiation work should not be based on a single blood evaluation since variations frequently occur due to purely physiological causes or to minor transitory diseases.

The evaluation of the mental and emotional capacities should begin with the initial employment interview. In addition to data relating to the specific education and training experience, much valuable information can be obtained from a careful history of school and work performance, including reasons for change, record of absenteeism, and behaviour patterns.

8. Limited Radiation Work

Reference has already been made to considerations of age and sex and to the importance of exploring the previous exposure history as fully as possible. It is essential that the medical examiner evaluate critically each individual case before making a recommendation on medical grounds for any limitation of or exclusion from radiation work. If there is doubt whether limitation is desirable, the physician may require further discussion, not only with the individual concerned but also with those to whom the individual will be responsible or with whom he will be working. A much more detailed and accurate investigation of the working conditions will be needed in cases where doubt exists, since previous exposure at higher levels, or an unknown occupational history, may require certain limitations with regard to the future *degree* and *type* of exposure, according to accepted national or international standards.

In some countries radiation workers are granted special privileges, such as shorter working hours and additional holidays. These privileges are given for several reasons — historical, social, and economic as well as medical. The recommendations of the ICRP are independent of working hours and are based on levels considered to be so conservative as to allow continuous exposure regardless of working hours or length of vacation, provided that the dose received in an appropriate period does not exceed the maximum permissible limits. It should be remembered that practical experience has shown that for most radiation workers permissible dose limits are not reached and that in most installations exposure of personnel is well below these limits.

There is no convincing medical evidence to show that limitation of working hours or the granting of additional holidays is necessary as such for the radiation worker, useful measures as they may be in themselves from the point of view of general health and welfare in all industries. These measures may sometimes be introduced, however to serve as a means of limiting the dose in the case of certain special categories of workers or for individual workers subject to higher exposure levels. In such cases, however, if the limitation of working hours is based on dose considerations, suitable alternative work without radiation exposure is usually available.

9. Medical Examinations

9.1 Objectives of medical examinations

As has been stated above, the objectives of medical supervision for workers exposed to ionizing radiation are identical with those for people occupationally exposed to other hazardous physical and chemical agents.

The following may be considered the main objectives of medical examinations :

(*a*) Assessment of the medical fitness of individuals to perform their duties without danger to themselves and others.

(*b*) Establishment of a record of the condition of the individual at the time of each examination to serve as a base-line against which any subsequent change can be evaluated.

(*c*) Assessment of continuing fitness and the detection of effects due to harmful working conditions.

(*d*) Development of data to form a basis for suitable preventive and corrective measures.

The medical examinations and the knowledge that his health is under constant medical surveillance serve to give psychological support to the worker, and the records serve to provide evidence for the legal protection of the employee and employer.

There are no specific medical procedures that will indicate any harmful effects from radiation exposure of the order of, or moderately exceeding, the maximum permissible dose from external sources of ionizing radiation recommended by the ICRP. It is only when the amount of radiation has greatly exceeded the permissible dose levels that physical changes can be detected by the medical tests at present available. Thus, while the value of the periodic examination is limited as a control procedure, it is an indispensable and final factor in evaluating the effect of such exposure.

9.2 Frequency and general content

The programme of medical examinations for initial selection must be supplemented with sufficiently frequent periodic examinations to assure a healthy work force. Medical evaluations, which may be either complete or partial check-ups, are useful on transfer or after prolonged sickness absence, or for special work, and are essential after accidents involving confirmed or suspected high exposure. Medical evaluation of the status of the individual may also be desirable on termination of employment.

The time-interval between periodic medical examinations is also related to the degree of exposure and the circumstances in which the work is performed. Factors that may affect the frequency include the efficiency and thoroughness of the radiation monitoring and environmental control, and the possibility or likelihood of occasional over-exposures. In general, a complete medical examination would not be more frequent than once a year, but in many cases the examining physician might deem a longer or shorter interval appropriate to meet the needs of the case. Specific types of examination and the time-interval between examinations are determined in part by the nature of the exposure—whether to external radiation or to internally deposited radio-elements.

Thus, periodic examinations can include such standard elements as physical examinations, chest X-rays, and clinical laboratory examinations of urine and of blood. Specific laboratory procedures might include analyses of excreta for radioactive substances and special radioactivity tests. In certain special types of exposure, such as to fast neutrons or high-energy particles, appropriate tests may be desirable, for example, slit-lamp examinations of the lens of the eye.

At subsequent examinations, the occupational history should be brought up to date, with the addition of any information on diagnostic or therapeutic radiation exposure to which the worker has been subjected in the interval. The periodic medical examination should be similar to the initial examination, except that additional special examinations related to the nature of the work may be needed. Since the hands are frequently exposed to external radiations and radioactive materials, special attention should be paid to the fingertips and the skin.

On transfer or termination of employment, the medical examination may not need to be so comprehensive. However, a blood count and other special tests may be considered desirable by the physician, according to the circumstances of each individual case. The physician should be satisfied that the medical record presents a reasonably up-to-date evaluation of the medical status of the worker and that no major change in this status has gone unrecorded.

After sickness absence and for special work, a partial check-up may be required, first to establish whether or not the sickness was related to the work and second to determine how or whether this may affect the employee's work assignment. The scrutiny of causes of sickness absence helps the physician to pick out cases which might be attributable to the occupation ; the physician may wish to interview the individual on his return to work and, if necessary, carry out further relevant tests. Considerable help may be obtained through a careful history and through communication with the patient's personal physician.

As in other occupations, an important function of the medical examination is to evaluate possible effects of illness on the occupational status of the worker. Blood disorders or anaemia, dermatitis of the hands, or cancer of any organ are of obvious importance in this connexion, but minor disease of a temporary nature, such as infectious mononucleosis, for example, should not be disregarded.

9.3 Laboratory examinations

9.3.1 *Haematological*

In pre-employment and routine follow-up medical examinations, haematological procedures are valuable in the detection of blood dyscrasias from any cause. It is also important to establish and maintain a base-line for an individual for use in clinical evaluation in the event of an over-exposure.

It should be noted that there are considerable physiological variations in the number of circulating white cells in the peripheral blood, and that there is a time-based random variation. The day-to-day variation in an individual has been estimated at about 15% and the technical error in an average case is about 10%, even with carefully standardized techniques.

Numerical changes in the white cell count that might be considered indicative of radiation effects can be ascertained only by repeated blood examinations; a single examination must be considered insufficient for this purpose. A persistent trend in either direction in the white cell count, or a deviation from normal in the blood picture, merits further consideration in relation to the possibility of radiation effect. In general, it should be remembered that the sensitivity of ordinary haematological methods of examination is grossly insufficient for the detection of effects from radiation at levels at or moderately above permissible dose levels. In spite of this, haematological investigations are indicated where the working conditions involve exposure to several types of radiation or to external and internal radiation. Where a radiation worker is exposed to irradiation both from external sources and from internally deposited radioactive materials, or where there is mixed neutron-beta-gamma exposure, dosimetry is difficult.

The blood examination should include haemoglobin in grams per cent.; packed cell volume; total and differential white cell count; evaluation of blood film with note of any abnormal cells; and estimate of platelets. It may include an Arneth count, mean red cell diameter, blood type and other indices, at the discretion of the physician.

9.3.2 *Evaluation of body-burden*

When workers are engaged in the preparation and manipulation of open radioactive sources the chief hazard may be the absorption and deposition of radio-elements. Maximum permissible body-burdens related to critical organs have been recommended for a number of isotopes by the ICRP. Where practicable and appropriate, medical supervision of workers should be extended to include tests designed to indicate the degree and trend of the retention.

While direct physical measurements of the retained body-burden cannot usually be made, it is possible to make direct *in vivo* measurements on the gamma radiation from the retained isotopes in some instances. In other cases it is possible to use the amounts determined in the urine or faeces as indicators of retention. Radium and thorium, in addition, can be estimated from the measurements of the exhaled air.

The practice of measuring urinary and faecal excretion of radioactive substances is merely an extension of the customary industrial hygiene procedure of determining the presence in the excreta of chemically toxic substances ; such procedures have been in use for many years. However, the sensitivity of radiation measurements allows the detection of micro-microcurie amounts and permits the measurement of extremely small body-burdens, including those of isotopes that have a low rate of excretion.

For the *in vivo* measurement of gamma radiation, instruments have been developed of sufficient sensitivity to measure even the natural radio-activity of the body ; this represents the development of a technique that is not applicable to non-radioactive toxic substances. However, such installations are expensive and available in only a few places. More simple devices designed for measurements on the thyroid gland in radio-diagnostic applications might be used to detect undue uptake of radio-iodine in personnel working with this isotope.

In using analysis of urine as an indicator of absorption it should be remembered that excretion is greatest during the first few days after absorption. In many cases, the method may be used as an occasional special test, a practice similar to that adopted in other industries for measuring toxic materials when it is desirable to check on the absorption and retention in the body for diagnostic purposes.

Where practicable and appropriate, an excretion test can be applied to workers engaged in the preparation and manipulation of open sources of radioactive isotopes. Periodic excretion tests can provide a very useful check of laboratory and environmental conditions and in some circumstances may give an indication that these should be investigated further. This use of these tests is similar to the health control procedures employed in the chemical industry. In all these cases, whether chemically toxic or radioactive materials are being considered, one of the objectives is to detect any excessive or progressive body retention and to make use of this information for guidance in subsequent preventive action. In the case of radioactive substances, consistently low excretion and the absence of an upward trend give some assurance that body retention is not becoming progressively greater, and support the results of environmental surveys where these have indicated that the maximum permissible limits have not been exceeded. In places where work with open sources of radioactive materials is on a routine basis and covers long periods of time, it may be desirable for the analysis of excreta to be conducted on a routine basis. Use should be made of any facilities for analysis and counting which are available locally for the estimation of these substances.[1]

In cases where insoluble dusts have been inhaled, some of the material is carried upward by the ciliary action of the tracheobronchial tree and

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[1] *Wld Hlth Org. techn. Rep. Ser.*, 1959, **173**

then enters the gastro-intestinal tract, following the same route as ingested material. Thus for both inhalation and ingestion of insoluble substances, faecal excretion may be higher than urinary excretion. Although it is difficult to carry out the analysis of faecal specimens on a routine basis in all cases, this method should be used as a supplement in special cases where it is important to establish the magnitude of the body-burden with as much exactitude as possible. The method is of particular value after accidental high contamination with the possibility of high intake of radioactive material, and in such a case the collection of samples should begin as soon as possible. After an accident involving high exposure, if the results of determinations in urine and faeces indicate a high degree of absorption and retention, a determination of the concentration of the isotope in the blood plasma is indicated as further confirmation.

10. Medical Records

Accurate, complete, well-organized medical records are essential to the effective, continuing medical care and health maintenance of the individual employee. They also serve to protect both the employee and employer if any medico-legal problems should arise. The medical records of groups of people in an occupational population, a specific exposure group, a department, or a plant, furnish data for the periodic assessment of the health of the group. The value of complete records, even though the medical findings are normal or negative, has been demonstrated repeatedly in occupational health situations.

10.1 Content

It is important that sufficient data be kept in one place to provide a complete record of the occupational medical history of the individual. Correspondence, or abstracts of correspondence, concerning the individual should be kept in the same place. The documents filed may be in their original form, or in shortened form with reference to more complete files on specialized items such as radiographs or personnel monitoring results. If shortened forms are used, great care should be exercised that all essential results, opinions, and references are recorded.

10.2 Confidential nature of medical records

The confidential nature of medical records should be closely guarded. Suitable filing equipment and training of personnel should be provided for the safekeeping and confidential maintenance of all medical records in the exclusive custody and control of medical staff. Information, other than that legally required by governmental health authorities and courts, should be released only with the consent of the employee. Generalizations regarding a person's health, in terms of his capabilities, can be given ethically to the employer for the purpose of job placement or adjustment of working conditions without violating medical confidence. Data which do not identify a specific individual may be collected from medical records for research purposes.

10.3 Retention

The length of time for which records of occupational health should be kept is determined by law in some countries ; otherwise, it may be left to the discretion of individual medical departments. The minimum time for the retention of records is the period of employment of the worker in the establishment coming under the supervision of the particular medical department. However, the records or portions of them, such as the accumulated radiation dose, may be asked for at a later date, either in connexion with new employment elsewhere or for the assessment of an insurance claim, and these considerations should be weighed against those of cost when determining the length of time for which the records should be kept. It is suggested that records be kept throughout the lifetime of the individual, or retained for a few decades after the end of his employment. Although records may provide data of value to research workers, it seems likely that with the low levels of exposure at present encountered occupationally they will be of only limited use for statistical studies of radiation effect by epidemiological techniques.

11. Physical Facilities

Medical departments engaged in medical supervision of radiation workers should have facilities appropriate to the type of work conducted by the parent organization. Such facilities may be simple or elaborate, depending on the nature and scope of the radiation work in each case, and may consist of any combination of items specified in the subsequent paragraphs. While it is recognized that large atomic installations will have complete medical and health physics facilities on their sites, smaller establishments will require limited facilities appropriate to their own operation. From an economic standpoint, small establishments could help control the safety of the working conditions and the health of the worker by having specialized tests performed for them by outside agencies, such as government or university laboratories, or by private organizations.

Basic requirements include the features of a properly operated occupational medicine programme and specifically designed facilities for handling health hazards associated with radiation work. These special facilities are usually required on the site, since proper equipment and trained personnel for these problems are not ordinarily available at community medical centres.

Proper planning of locations and of arrangements for a medical service depends on a number of factors that include: (*a*) the scope of the occupational medical programme; (b) the number and turnover rate of employees and prospective employees; (*c*) the numbers of available physicians, nurses, and other auxiliary medical personnel; (*d*) ease of access to the medical unit or units; (*e*) availability of outside medical support and facilities; (*f*) safety considerations to ensure freedom from hazard in the event of an accident; and (*g*) the specific conditions of radiation exposure and radioactive contamination that might be encountered. With medical departments, large or small, attention should be given to certain essential architectural features: simplicity of construction, ease of revision, and accessibility of essential services such as electricity, heat and water. Functional requirements should include the proper flow of traffic (patients and staff), waiting space, freedom from excessive noise and vibration, ease of cleaning, and adequate storage space. Other aspects that merit consideration are the provision of ambulance and emergency entrances, central stations for the control of traffic, sanitary facilities, and examining rooms. The type of examining rooms will depend on the nature of the medical programme and its operating philosophy. Examining rooms may be used for routine physical examinations as well as for consultations for illness and injury. These features, and many others, enter into the organization of conventional occupational medical facilities, and are equally applicable to problems that are specific to work with ionizing radiation.

The number and type of treatment rooms will depend upon the size of the medical establishment and on various medical and surgical requirements. A small examining room, reserved for treatment of minor injuries, removal of sutures and change of dressings, will frequently be sufficient. In large installations, more elaborate arrangements may be made and rooms reserved for special treatments. Separate space may be provided for the care of eye conditions, or for other treatments such as physiotherapy. Equipment for major surgery is not ordinarily required, except in isolated installations, since such procedures are best performed in hospitals.

A complete medical centre would include facilities for routine examinations and treatment, clinical laboratory investigations, radiochemical analyses, and where necessary a decontamination suite. Decontamination facilities are described below.

X-ray equipment ordinarily required in connexion with examinations may be limited to that needed for radiography of chest and bones. Laboratory facilities should include such clinical and radiochemical equipment as is deemed necessary for the operation of a particular occupational medical programme. Clinical laboratory facilities need not be elaborate but should provide for routine studies such as urinalysis and haematological procedures, and such other tests (biochemical, serological, mycological, and microbiological) as are part of the programme of the medical department. Rooms for radiochemical analyses, normally sited to be free from wide variations of ambient radiation level, need equipment for the detection and possible identification of radioactive materials at levels of medical interest. Where open sources of radioactive materials are used, equipment should be available for detection and measurement of skin and wound contamination, and for external counting of organs (such as thyroid), and for assay of excreta, nasal swabs, and body fluids. In many establishments, some of these measurements may be made outside the medical department. Under some special circumstances a whole-body counter may be desirable for the identification and measurement of internally deposited radio-elements. Since such equipment needs special shielding, complicated electronics and skilled maintenance, it may be sufficient for most establishments to have access to such a counter elsewhere by means of prior arrangements.

Decontamination facilities are essential where exposures to radioactive materials may occur and where these substances become potential hazards as internally deposited radio-elements. Where the nature of the work is such that occasional contamination occurs, it is convenient to provide simple washing facilities very close to the place of work. The decontamination facilities of the medical department are then required only in those cases where the contaminant is difficult to remove, or where medical supervision of the decontamination process is indicated for other reasons, such as a break in the skin. Contamination of personnel may occur not only in large installations but in smaller organizations as well. Thus, smaller establishments using radioactive materials should also have a planned procedure designed to cope with situations that may arise. In the simplest case, this would consist of a survey of what room or rooms might lend themselves most efficiently to the purpose. It is hoped that the description of the larger facility given below may also provide some guidance to smaller installations.

In the larger installation, personnel decontamination facilities should provide for: (*a*) separate entrance, preferably via an ambulance port; (*b*) vestibule or disrobing room, preheated in winter, for discarding contaminated clothing; (*c*) monitoring devices for checking the location and degree of skin contamination; (*d*) scrub-up fixtures near the entrance for the decontamination of persons who have assisted in the transport of non-ambulatory contaminated patients; (*e*) sinks with shampoo attachment to scrub up local areas of the body such as hands, face and hair; (*f*) showers for general decontamination of the ambulatory patient; (*g*) a shallow tub for the decontamination of the non-ambulatory patient; (*h*) medical equipment and supplies stored accessibly but in such a manner that contamination by radioactive materials is minimized.

A decontamination unit need not be elaborate, but attention should be given to certain construction features. Floors and walls should be such that they can be easily cleaned and economically replaced if not readily decontaminated. Barriers such as simple lift-up gates will impede the carry-over of contamination from one area to another. In order to make the unit as self-contained as possible, a small toilet, containing a bed-pan sterilizer in addition to the standard fixtures, might be included. In the design and construction of some decontamination units, the advisability of including tanks for the retention of contaminated waste-water should also be considered. A decontamination unit may be built quite inexpensively with suitable attention to the form of construction and the choice of materials. Furthermore, if the design is sufficiently flexible it may be used for other medical purposes. The chief purpose of the unit is to function as a casualty clearing station where initial decontamination and emergency treatment can be carried out. Where it is necessary to transfer the patient to a general hospital this decontamination unit will eliminate, or at least minimize, contamination of the hospital concerned.

Hospitalization facilities should be available for treatment of seriously ill or injured patients. Isolated installations far from ordinary community medical services may have to provide for hospitalization at the place of work. More often, patients will be transported to nearby hospitals, or even to distant hospitals where highly competent specialists are located. Such patients must be free of readily removable radioactive contaminants before they are sent to outside hospitals. Ambulances transporting patients should also be designed with surfaces that are easily decontaminated so that they can be cleaned if necessary. Medical services should be organized to provide for early hospitalization, where indicated, but promptness must be consistent with proper and sufficient decontamination.

12. Preliminary Management of Radiation Accidents

Accidents involving exposure to radiation or contamination with radioactive materials may pose complex problems for physicians who are charged with medical responsibilities in radiation work. Exposure to radiation may be complicated by concomitant surgical problems as a result of trauma and by psychological problems as a result of excitement. These and other emergency situations have to be met quickly and decisively by medical personnel.

The definitive care of patients severely injured by radiation is not the subject of this report and has been discussed in detail elsewhere. It is appropriate, however, to conclude a statement on medical supervision in radiation work with a brief consideration of the preliminary management of radiation accidents. A summary guide of suitable procedures up to the time when the patient is safety transferred to a hospital is given here.

Immediately after the accident the patient should be removed from the radiation area and given first aid. The services of health physicists should be sought promptly in order to appraise the level of radiation and to detect any contamination. The danger area should be closed off and the patient, if contaminated, should be isolated to prevent contamination of other persons. The degree and type of radiation exposure of the patient needs to be determined as promptly and as reliably as possible as a basis for further action; detailed dosimetry studies can be worked out subsequently. The contaminated patient should be cleaned up to remove all readily removable radioactivity; this may be accomplished along with initial medical and surgical procedures. The patient should be put to bed as quickly as possible and kept in bed until the diagnosis of actual or impending acute radiation syndrome can be confirmed or excluded. Routine blood counts should be performed and all samples of blood, urine, faeces, vomitus, and sputum, as well as clothing, should be saved. The patient should be protected from the inevitable parade of curious non-medical visitors, and he should be transferred to a hospital for study and treatment if an exposure in excess of 100r is suspected.

13. Summary

The principles for the control of the health hazards associated with the constantly increasing applications of radiation and radioactive materials are similar to those applied for the safe use of other hazardous physical and chemical agents found in industry. Medical supervision is an essential element in the control programme for radiation work.

Preventive measures for the effective protection of workers exposed to radiation have been developed. A major problem is to inculcate an appreciation of the hazard and to disseminate the knowledge and skill for applying control procedures to keep pace with the expanding use of radiation.

The scope of medical supervision, as with the other elements of the radiological health protection programme, should be related to the specific character of the operation. Even though the medical procedures at present available cannot detect physical changes due to radiation until the amount of exposure has greatly exceeded the permissible dose levels, the preplacement and periodic medical examination programme is an indispensable and final factor in evaluating the effect of such exposure on the health of the worker.

The need for medical supervision in radiation work is related to the nature of the radiation hazard rather than to the number of individuals engaged. Thus, a single isolated individual using an X-ray apparatus or a radioactive isotope may have a greater level of exposure than the majority of the operators of a nuclear reactor unit, and may have as great or greater need for medical supervision.

There are few special considerations in the selection of individuals for work with radiation. The majority of tasks involving radiation exposure will have such a degree of technical control of the hazard as to require only minimal to moderate effort and compliance by the worker to assure reasonable safety. For this work, the selection and placement of employees will differ little from that for industry in general. For the limited number of jobs inherently involving a greater risk of radiation exposure, a higher degree of selectivity will be required, with particular consideration for those conditions which could have been caused by radiation, or which might be aggravated by it.

Restrictive factors to be considered in the selection of personnel for work carrying a *high* risk of exposure to radiation are: age, sex and pregnancy, history of hereditary defects, some types of pre-existing disease, previous radiation history, and certain special medical findings.

The limitation of work with radiation for individuals under age 18 is based chiefly on general biological and social considerations such as also apply to other potentially hazardous occupations, and not on a special and differential effect of radiation *per se*.

In general, there is no valid reason for excluding women from work with radiation at or below maximum permissible dose levels. Since it is during the earlier period of pregnancy and at a time when the mother is probably unaware of her pregnancy that the embryo is unusually sensitive to radiation, the only effective way of excluding the pregnant woman from radiation exposure would be to prevent all women of child-bearing age from working with radiation. Wisdom would suggest that women in this age-group should not be exposed to *high* radiation risks.

Certain elements of the history and physical findings should be considered in the selection of individuals for radiation work, having regard to the protection of the employee and employer, and it may be considered necessary to limit the future degree and type of exposure, according to accepted national or international standards.

The content and frequency of the medical examination programme should be directly related to the type and degree of radiation hazard. Accurate, complete, confidential, and well-organized medical records are essential to the effective continuing medical care and health maintenance of the individual employee and for the evaluation of work-related effects on groups of exposed workers.

A medical programme for radiation workers should have facilities appropriate to the type of work conducted by the parent organization. A special feature of such a medical installation is the provision of facilities for the decontamination of personnel where exposures to radioactive materials occur. Where there is the possibility of a serious radiation accident, a plan should be developed for the preliminary management and definitive care of injured personnel.