

**AERB SAFETY GUIDE NO. AERB/SG/O-5**

**RADIATION PROTECTION  
DURING  
OPERATION OF NUCLEAR POWER  
PLANTS**

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## FOREWORD

Safety of public, occupational workers and the protection of environment should be assured while activities for economic and social progress are pursued. These activities include the establishment and utilisation of nuclear facilities and use of radioactive sources. They have to be carried out in accordance with relevant provisions in the Atomic Energy Act 1962 (33 of 1962).

Assuring high safety standards has been of prime importance since the inception of nuclear power programme in the country. Recognising this aspect, the Government of India constituted the Atomic Energy Regulatory Board (AERB) in November 1983 vide standing order No. 4772 notified in Gazette of India dated 31.12.1983. The Board has been entrusted with the responsibility of laying down safety standards and to frame rules and regulations in respect of regulatory and safety functions envisaged under the Atomic Energy Act of 1962. Under its programme of developing safety codes and guides, AERB has issued four codes of practice covering the following topics:

- Safety in Nuclear Power Plant Siting
- Safety in Nuclear Power Plant Design
- Safety in Nuclear Power Plant Operation
- Quality Assurance for Safety in Nuclear Power Plants.

Safety guides are issued to describe and make available methods of implementing specific parts of the relevant codes of practice as acceptable to AERB. Methods and solutions other than those set out in the guides may be acceptable if they provide at least comparable assurance that nuclear power plants can be operated without undue risk to the health and safety of general public and plant personnel.

The codes and safety guides may be revised as and when necessary, in the light of experience as well as relevant developments in the field. The appendices included in the document are considered to be an integral part of the document, whereas, foot-notes and bibliography are to provide information that might be helpful to the user.

The emphasis in the codes and guides is on the protection of site personnel and public from undue radiological hazard. However, for aspects not covered in the codes and guides, applicable and acceptable national and international codes and standards shall be followed. Industrial safety shall be assured through good engineering practices and through compliance with the Factories Act 1948 as amended in 1987 and the Atomic Energy (Factories) Rules, 1996.

The Code of Practice on Safety in Nuclear Power Plant Operation states the minimum safety requirements to be met during the operation of thermal neutron reactor based power plants in India. This safety guide provides guidance for radiation protection during the operation of such power plants.

This safety guide has been prepared by the staff of AERB and other professionals. In drafting this guide, they have used extensively the relevant guides of International Atomic Energy Agency (IAEA) developed under Nuclear Safety Standards (NUSS) programme, specially the IAEA Safety Guide on "Radiation Protection during Operation of Nuclear Power Plants" (No.50-SG-05,1980) and recommendations of the International Commission on Radiation Protection (ICRP-60) issued in 1990.

This safety guide has been reviewed by experts and vetted by the AERB Advisory Committees before issue. AERB wishes to thank all individuals and organisations who reviewed the draft and finalised this safety guide. The list of persons who have participated in the committee meetings, alongwith their affiliations, is included for information.

(P. Rama Rao)  
Chairman, AERB

## DEFINITIONS

The following definitions apply to the purposes of this guide.

### **Absorbed Dose\***

The fundamental dosimetric quantity  $D$ , defined as:

$$D = d \epsilon / dm$$

where  $d \epsilon$  is the mean energy imparted by ionising radiation to matter in a volume element and  $dm$  is the mass of matter in the volume element. The energy can be averaged over any defined volume, the average dose being equal to the total energy imparted in the volume divided by the mass in the volume. The SI unit of absorbed dose is the joule per kilogram ( $\text{J.kg}^{-1}$ ), termed the gray (Gy).

### **Accident**

Any unplanned event resulting in (or having the potential to result in) injury or damages to equipment, which could cause release of unacceptable quantities of radioactive material.

### **Accident Conditions**

Substantial deviations from Operational States which could lead to release of unacceptable quantities of radioactive materials. They are more severe than anticipated operational occurrences and include design basis accidents and severe accidents<sup>1</sup>.

### **Activity\***

The quantity  $A$  for an amount of radionuclide in a given energy state at a given time, is defined as:

$$A = dN/dt$$

where  $dN$  is the expectation value of the number of spontaneous nuclear transformations from the given energy state in the time interval  $dt$ . The SI unit of activity is the reciprocal second ( $\text{s}^{-1}$ ), termed the becquerel (Bq).

### **Annual Limit on Intake (ALI)\***

The intake by inhalation, by ingestion or by absorption through the skin of a given radionuclide in a year by Reference Man which would result in a committed dose equal to the relevant dose limit. The ALI is expressed in units of activity.

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<sup>1</sup> A substantial deviations may be a major fuel failure, a Loss of Coolant Accident (LOCA) etc. Examples of engineered safety features are: an Emergency Core Cooling System (ECCS) and containment.

**Atomic Energy Regulatory Board (AERB)**

National authority designated by Government of India having the legal authority for issuing the regulatory consents for various activities related to a facility and to perform safety and regulatory functions including enforcement for the protection of the public and operating personnel against radiation.

**Collective Dose\***

An expression of the total radiation dose incurred by a population, defined as the product of the number of individuals exposed to a source and their average radiation dose. The collective dose is expressed in man-sieverts (man.Sv).

**Collective Effective Dose\***

The total effective dose  $S$  to a population, defined as:

$$S = \sum_i E_i \cdot N_i$$

where  $E_i$  is the average effective dose in the population subgroup  $i$  and  $N_i$  is the number of individuals in the subgroup.

**Committed Effective Dose\***

It is the time integral of the whole body effective dose rate following an intake of a radionuclide. The quantity  $E(\tau)$ , defined as:

$$E(\tau) = \sum_T w_T \cdot H_T(\tau)$$

where  $H_T(\tau)$  is the committed equivalent dose to tissue  $T$  over the integration time  $\tau$ . When  $\tau$  is not specified, it will be taken to be 50 years for adults and to age 70 years for intakes by children.

**Committed Equivalent Dose\***

It is the time integral of the equivalent dose rate in an organ or tissue following an intake of a radionuclide. The quantity  $H_T(\tau)$ , defined as:

$$H_T(\tau) = \int_{t_0}^{t_0+\tau} H_T(t) dt$$

where  $t_0$  is the time of intake,  $H_T(\tau)$  is the equivalent dose rate at time  $t$  in an organ or tissue  $T$  and  $\tau$  is the time elapsed after an intake of radioactive substance. When  $\tau$  is not defined it will be taken to be 50 years for adults and to age 70 years for intakes by children.

**Contamination\***

The presence of radioactive substances in or on a material or in the human body or other place in excess of quantities specified by the Competent Authority.

**Controlled Area\***

A delineated area to which access is controlled and in which specific protection measures and safety provisions are, or could be, required for:

- (a) controlling normal exposures or preventing the spread of contamination during normal working conditions; and
- (b) preventing potential exposures or limiting their extent should they occur.

**Countermeasure\***

An action aimed at alleviating the consequences of an accident.

**Decontamination\***

The removal or reduction of contamination by physical or chemical process.

**Derived Air Concentration (DAC)\***

It is that activity concentration of the radionuclide in air ( $\text{Bq/m}^3$ ) which, if breathed by Reference Man for a working year of 2000 hours under conditions of light physical activity (breathing rate  $1.2 \text{ m}^3/\text{h}$ ), would result in an inhalation of one ALI, or the concentration which for 2000 hours of air immersion would lead to irradiation of any organ or tissue to the appropriate annual dose limit.

**Derived Intervention Level (DIL)\***

Derived Intervention Levels are quantities that can be directly measured, such as exposure rate from ground deposited activity and activity concentration in foodstuff and water, at which intervention in the form of countermeasures should be initiated.

**Design Basis Accident (DBA)**

Design basis accidents are a set of hypothesised accidents which are analysed to arrive at conservative limits on pressure, temperature and other parameters which are then used to set specifications that must be met by plant structures, systems and components, and fission product barriers.

**Dose\***

A measure of the radiation received or 'absorbed' by a target. The quantities termed absorbed dose, organ dose, equivalent dose, effective dose, committed equivalent dose or committed effective dose are used, depending on the context. The modifying terms are used when they are not necessary for defining the quantity of interest.

**Effective Dose\***

The quantity  $E$ , defined as a summation of the tissue equivalent doses, each multiplied by the appropriate tissue weighting factor:

$$E = \sum_T w_T . H_T$$

where  $H_T$  is the equivalent dose in tissue  $T$  and  $w_T$  is the tissue weighting factor for tissue  $T$ . The unit of effective dose is  $\text{J.kg}^{-1}$ , termed the sievert (Sv).

**Emergency Situation**

A situation which endangers or is likely to endanger safety of the Nuclear Power Plant (NPP), the site personnel or the environment and the public.

**Emergency Plan**

A set of procedures to be implemented in the event of an accident.

**Equivalent Dose\***

It is the absorbed dose in an organ or tissue multiplied by the relevant radiation weighting factor.

**Exposure\***

The act or condition of being subject to irradiation. Exposure can be either external (irradiation by the sources outside the body) or internal (irradiation by sources inside the body). Exposures can be classified as normal exposure or potential exposure; either occupational, medical or public exposure; and in intervention situations, either emergency exposure or chronic exposure. The term exposure is also used in radiodosimetry to express the amount of ions produced in air by ionising radiation.

**Intervention\***

Any action intended to reduce exposure or the likelihood of exposure to sources, which are not part of controlled practice or which are out of control as a consequence of an accident.

**Intervention Level (IL)\***

A level of avertable dose at which a specific protective action or remedial action is taken in an emergency exposure situation or chronic exposure situation.

**Medical Exposure\***

Exposure incurred by patients as part of their own medical or dental diagnosis or treatment; by persons, other than occupationally exposed knowingly while voluntarily helping in the support and comfort of patients; and by volunteers in a programme of biomedical research involving their exposure.

**Normal Operation**



Operation of a plant or equipment within specified operational limits and conditions. In the case of nuclear power plants this includes start-up, power operation, shutting down, shutdown state, maintenance, testing and refuelling.

**Nuclear Power Plant (NPP)**

A thermal neutron reactor or reactors together with all structures, systems and components necessary for safety and for the production of power, i.e., electricity.

**Occupational Exposure\***

All exposures of personnel incurred in the course of their work.

**Off-site Emergency**

Accident condition/emergency situation involving excessive release of radioactive materials/hazardous chemicals from the plant into the public domain calling for intervention.

**Operational Limits and Conditions**

Limits on plant parameters, and set of rules on the functional capability and the performance level of equipment and personnel, approved by the Regulatory Body, for safe operation of the facility.

**Plant Management**

The members of site personnel who have been officially delegated responsibility and authority by the Operating Organisation for directing the operations of the plant.

**Potential Exposure\***

Exposure that is not expected to be delivered with certainty, but that may result from an accident at a source or owing to an event or sequence of events of a probabilistic nature, including equipment failures and operating errors.

**Practice\***

Any human activity that introduces additional sources of exposure pathways or extends exposure to additional people or modifies the network of exposure pathways from existing sources, so as to increase the exposure or the likelihood of exposure of people or the number of people exposed.

**Prophylaxis\***

Prophylaxis is the intake of specific stable chemical compounds, which have a reducing or blocking effect on the uptake of certain radionuclides. E.g., the use of stable KI or KIO<sub>3</sub> to reduce the uptake of radioiodines (particularly I-131) in thyroid gland.

**Public Exposure\***

Exposure incurred by members of the public from radiation sources, excluding any occupational or medical exposure and the normal local natural background radiation

but including exposure from authorised sources and practices and from intervention situations.

**Radiation Worker**

Any person who is occupationally exposed to radiation and which in the opinion of the Regulatory Body should be subjected to radiation surveillance.

**Reference Level\***

Action level, intervention level, investigation level or recording level. Such levels may be established for any of the quantities determined in the practice of radiation protection.

**Reference Man\***

An idealised adult Caucasian human defined by the ICRP for the purpose of radiation protection assessment.

**Regulatory Constraints\***

Restrictions on radiation protection parameters specified by the Regulatory Body.

**Responsible Organisation (RO)**

The organisation having overall responsibility for siting, design, construction, commissioning, operation and decommissioning a facility.

**Site Emergency**

Accidental condition/emergency situation in the plant involving radioactivity transgressing the plant boundary but confined to the site, or involving release of hazardous chemicals/explosion, whose effects are confined to the site, with off-site consequences expected to be negligible.

**Site Personnel**

All persons working on the site, either permanently or temporarily.

**Supervised Area\***

An area not designated as controlled area but for which occupational exposure conditions are kept under review even though specific protective measures and safety provisions are not normally needed.

**Technical Specification for Operation**

A document submitted on behalf of or by the Responsible Organisation covering Operational Limits and Conditions, Surveillance and Administrative Control requirements for the safe operation of the facility and approved by Regulatory Body.



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# 1. INTRODUCTION

## 1.1 General

- 1.1.1 This Safety Guide is prepared as a part of Atomic Energy Regulatory Board's (AERB) programme for establishing Codes of Practice and Safety Guides relating to Nuclear Power Plant (NPP) Operation. The purpose of this Guide is to provide practical guidance for establishing and maintaining a Radiation Protection Programme.
- 1.1.2 This Guide deals with the protection of site personnel and the general public from exposure to ionising radiation while still allowing necessary activities from which radiation exposure might result. It outlines how radiation protection at the NPP site can be implemented, in compliance with the guidelines established by the AERB, for all operational states of the plant.
- 1.1.3 In the preparation of this guide, guidelines from IAEA Safety Guide on Radiation Protection During Operation of Nuclear Power Plants [1], International Basic Safety Standards for Protection Against Ionising Radiation and for the Safety of Radiation Sources [2], Recommendations of International Commission on Radiological Protection [3] and AERB Safety Manual on Radiation Protection for Nuclear Facilities [4] have been taken into consideration.

## 1.2 Objectives

- 1.2.1 The objectives of this Safety Guide are as follows:
  - (1) To provide guidelines to the Plant Management for establishing Radiation Protection Programme to be carried out efficiently and effectively to achieve protection of the occupational workers, members of the public and the environment from adverse effects of radiation while at the same time allowing the justified activities.
  - (2) To focus on the need for a high degree of commitment on the part of all levels of management of Operating Organisation and the plant personnel to follow the exposure control measures during all operational states and accident conditions at the plant site.

## 1.3 Scope

- 1.3.1 This Guide deals with the Radiation Protection Programme for NPPs. It outlines the basic principles of radiation protection, organisational aspects, the responsibilities of different groups of personnel and the practical aspects of establishing and implementing a Radiation Protection Programme during the operation of NPPs.

- 1.3.2 This Guide covers the requirements for a Radiation Protection Programme for all operational states of the NPP. It also provides limited guidelines for accident conditions.
- 1.3.3 This Guide outlines the principles of dose limitation to plant personnel and to the public, but it does not give the methodology for the assessment of exposures to members of public. It also covers the principal steps in environmental monitoring programme, but does not include details on environmental surveys.
- 1.3.4 This Guide does not cover detailed information on handling of radiation sources nor does it include guidelines on the transport of irradiated fuel and other radioactive materials. Separate Guides on these topics are available and they are referred to at appropriate places.



## 2. ORGANISATIONAL ASPECTS

### 2.1 General

- 2.1.1 The Operating Organisation<sup>#</sup> shall be responsible for the establishment and implementation of the Radiation Protection Programme.
- 2.1.2 A health physics unit shall be established at the NPP at an appropriate time in order to ensure that the Radiation Protection Programme is implemented by the operating organisation.
- 2.1.3 The position of the Station Health Physicist, who is in-charge of the health physics unit, will be such that he can readily advise plant management on all aspects related to Radiation Protection Programme. He shall have access to the levels of the management which have authority to establish and to enforce radiation protection procedures.
- 2.1.4 The plant management shall provide appropriate training and retraining to all levels of personnel so as to have a continuing degree of competence.
- 2.1.5 All site personnel have an individual responsibility for practising exposure control measures specified in the Radiation Protection Programme.
- 2.1.6 The operating organisation shall make adequate reviews and audits of the implementation and the effectiveness of the Radiation Protection Programme.

### 2.2 Duties and Responsibilities of the Operating Organisation and Plant Management

- 2.2.1 A strong commitment to ensure radiation safety should come from all levels of management, including the Responsible Organisation, Design Group, Plant Management and Operations and Maintenance Groups. Systematic efforts should be made to induce safety awareness and propagate safety culture amongst staff on continual basis.
- 2.2.2 Starting at the design stage, the responsible organisation shall review the design provisions to determine if they are adequate for the successful implementation of the Radiation Protection Programme. The aspects to be reviewed should include:

- (1) Radiation shielding;
- (2) Ventilation and air cleaning;
- (3) Radioactivities in active systems;

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<sup>#</sup> Where Operating Organisation is not instituted, this will be the responsibility of Responsible Organisation (R.O) or Plant Management as delegated by R.O.

- (4) Containment integrity;
- (5) Instrumentation for radiation, contamination and personnel dose monitoring and control under operational states and accident conditions;
- (6) Equipment layout and access;
- (7) Radiation and contamination zoning arrangements;
- (8) Access controls, with particular attention to the number of persons employed in controlled areas;
- (9) Adequacy of access, and of working space for maintenance;
- (10) Elements of design that allow quick and remote handling for dismantling and reassembling of components, shielding, etc.;
- (11) Radioactive waste storage, handling and equipment;
- (12) Availability of protective equipment, protective wear and respirators, and decontamination and monitoring rooms;
- (13) Effluent Control and monitoring;
- (14) Facilities for sampling during accident conditions;
- (15) Availability of up-to-date set of drawings, supplemented by photographs, and those operating and maintenance manuals and instructions that are required for planning procedures to minimise exposure; and
- (16) Radiological data acquisition, processing and retrieval.

Details of the design aspects of radiological protection during design are dealt with in the AERB Safety Guide "Design aspects of Radiological Protection for PHWR based NPPs" (AERB/SG/D-12) [5].

- 2.2.3 The plant management is responsible for all aspects of station operation. They shall ensure compliance with radiation protection procedures by all the station personnel in order to maintain occupational exposures within the specified limits and As Low As Reasonably Achievable (ALARA).
- 2.2.4 The plant management shall prepare, in consultation with the Station Health Physicist, Operating Manual for Radiation Protection Procedures and Radiation Emergency Procedures for the plant giving details of the methods of controlling the radiation exposure to site personnel and members of the public before commencement of operation.
- 2.2.5 Adequate training in plant radiation protection and emergency procedures shall be imparted to personnel at all levels.
- 2.2.6 The plant management shall provide adequate equipment and facilities for personnel protection, for monitoring of external and internal exposure, for monitoring the radiological conditions in the plant, and for monitoring the effluent and the environment.
- 2.2.7 The plant management shall arrange for routine and non-routine medical examinations of all radiation workers in the plant in accordance with the requirements of the AERB.

- 2.2.8 The plant management shall establish procedures for periodic review of the implementation of the Radiation Protection Programme, and shall ensure that its objectives are achieved. Special attention shall be given to radiation incidents, exposures beyond authorised limits and effluent discharge control. Periodic audits shall also be arranged to ensure effective compliance with established procedures.
- 2.2.9 The plant management shall arrange for proper collection, storage, handling and disposal of the wastes that are generated in the plant as per approved procedures.
- 2.2.10 The plant management shall supply all necessary information to assist the health physicist in carrying out investigations in any radiation related unusual occurrence or incident. The plant management should take effective measures to implement the suggestions and recommendations given by the health physicist for improvement of safety and rectify the deficiencies on priority.
- 2.2.11 All the data pertaining to radiological safety shall be maintained and periodic reports shall be sent to the AERB as per the requirement [4].
- 2.2.12 The plant management shall maintain complete and up-to-date records of medical and occupational histories of every radiation worker. The plant management shall preserve the occupational health records along with the dose records for the working life of the individual, and thereafter as specified by AERB [4].
- 2.2.13 The plant management shall arrange for appropriate monitoring of both liquid and gaseous effluents to be discharged from the plant to the environment and also for maintenance of relevant records of the same.
- 2.2.14 Compliance with applicable requirements of the AERB and with the radiation protection aspects of the policies and procedures of the operating organisation shall be demonstrated appropriately.

### 2.3 **Duties and Responsibilities of Health Physics Unit**

The duties and responsibilities assigned to health physics unit include the following:

- (1) To advise plant personnel/management regarding measures to be taken for effective exposure control on the basis of assessment of the radiological status in the plant areas;
- (2) To arrange for and implement personnel monitoring for external and internal exposures, site radiation surveys and other related services;
- (3) To specify procedures and protective equipment for radiation work and to issue radiological work permits prescribing the same;
- (4) To prepare radiation protection procedures and data forms;

- (5) To specify radiation protection procedures for handling and storage of radioactive material on site in accordance with the guidelines stipulated by the regulatory body;
- (6) To maintain adequate stocks of instruments for personnel dosimetry, radiation survey, counting and analyses ;
- (7) To classify and delineate radiation and contamination zones and to survey and monitor them periodically;
- (8) To monitor compliance by site personnel with plant radiation protection procedures;
- (9) To check that the active or contaminated waste or components sent off site conform to the appropriate transport regulations with respect to the radiological aspects;
- (10) To notify plant management of any individual dose in excess of specified limits, which shall be investigated by appropriately constituted committees;
- (11) To participate in investigations of radiation exposures exceeding prescribed levels for personnel and of abnormal radiological conditions and emergency conditions;
- (12) To prepare and maintain all records relevant to the Radiation Protection Programme;
- (13) To collaborate in the preparation of and implementation of emergency plans and procedures;
- (14) To specify, and equip the NPP with, special instrumentation and equipment for radiation protection that is adequate to cope with emergency situations;
- (15) To select and train adequate health physics personnel; and
- (16) To train all site personnel in radiation protection measures as appropriate to their duties as prescribed in station radiation protection procedures and to prepare radiological training materials.

## 2.4 **Duties and Responsibilities of Radiation Workers**

- 2.4.1 The radiation worker shall follow the approved radiation protection and radiation emergency procedures and shall refrain from any wilful act that could be detrimental to self or to his co-workers or to the plant or to the environment.

He shall further:

- (1) provide information about his past radiation work if any;
- (2) make proper use of the protective equipment, radiation monitors and dosimetric devices provided;
- (3) inform forthwith the supervisor/health physicist of any unusual incident or potentially unsafe situation that may come to his notice;
- (4) comply with the requirements of health surveillance and dose assessment programme;
- (5) inform the health physicist regarding loss or damage to his personal dose-monitoring device.

2.4.2 A female worker shall, on becoming aware that she is pregnant, notify the plant management and health physicist in order that appropriate dose limits be applied.

**2.5 Health Surveillance and Medical Examination**

2.5.1 A health surveillance programme for radiation workers shall be established on the general principles of occupational health. Health surveillance has the following objectives:

- (1) To assess the health status of the individual;
- (2) To help in ensuring initial and continuing compatibility between the health of the individual and the conditions of their work; and
- (3) To provide base-line information useful in the case of occupational or accidental radiation exposure.

2.5.2 The surveillance shall be done for all radiation workers. This shall consist of pre-employment medical examination, which shall include family and personal history, previous occupational history, previous radiation therapy and clinical investigations.

2.5.3 All radiation workers shall be medically examined at specified intervals. Appropriate information on individuals, who would require a change or restriction in the job allocation on the basis of their health status, will be included in the medical report submitted to the plant management.

2.5.4 When the life time dose exceeds a level as prescribed by AERB, further exposure of such individuals shall be allowed only after reviewing the health status by medical authorities as per approved procedures.

2.5.5 In case of an individual receiving or suspected to have received exposures exceeding the specified values, medical investigations like chromosome aberration analysis should be carried out and appropriate medical treatment, if required, should be given.

2.5.6 Plant management should utilise the services of a physician who has had special training in industrial and radiation medicine and who is competent to advise on and supervise the medical examinations and treatment of any person involved in a radiation accident.

### **3. SYSTEM OF RADIATION PROTECTION**

#### **3.1 Basic Principles**

For the radiation protection of site personnel and members of the public, a system of radiation protection shall be established based on the following principles and objectives.

- (1) The effective dose or equivalent dose to individuals shall not exceed the applicable dose limits stipulated by AERB.
- (2) All exposures, individual, collective and potential shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account.

#### **3.2 Radiation Protection Programme**

- 3.2.1. The above objectives should be accomplished by means of a Radiation Protection Programme of precautionary measures, radiation and dose monitoring, safety culture, management and surveillance.
- 3.2.2 The common objective of radiation protection measures in the operation of NPPs is to protect the personnel and the environment from the deleterious effects of radiation while at the same time allowing the operation and maintenance activities as envisaged by the design.
- 3.2.3 The Radiation Protection Programme is structured to ensure that the exposures of all site personnel, and the public are maintained consistent with the stipulations issued by the AERB in this regard.

#### **3.3 Dose Limits**

- 3.3.1 The dose limits are given in Appendix-II. These dose limits do not include radiation doses due to natural background radiation and those resulting from medical exposure.
- 3.3.2 The safety directives and other requirements issued by the AERB shall be translated into provisions or procedures that individuals can apply and shall be incorporated in the radiation protection procedures of the plant.
- 3.3.3 The dose limits apply to the sum of the relevant doses from external exposure in the specified period and the committed doses from intakes of radioactive substances in the same period.

- 3.3.4 There is no separate occupational dose limit for women in general. However, once pregnancy is declared or diagnosed the equivalent dose limit to the surface of the abdomen shall be as given in Appendix-II (1.1.4).
- 3.3.5 No person below the age of 18 years shall be employed as radiation worker except with prior permission of AERB in writing.
- 3.3.6 In the event of any site personnel receiving exposures exceeding the prescribed levels it shall be investigated promptly and reported to AERB and remedial actions taken to prevent the recurrence of the same.
- 3.3.7 The plant management should establish a dose reduction and ALARA programme at the station and make all efforts to adhere to the guidelines on the collective dose for a particular NPP prescribed by AERB.
- 3.3.8 In case collective dose exceeds the values specified by AERB, the same should be reviewed and reported to AERB along with measures being taken to control the same.

#### 3.4 **Exposure Control Scheme**

- 3.4.1 The exposure control scheme should consist of a three-tier system, namely, application of primary dose limits, regulatory constraints and operational restrictions.
- 3.4.2 Operational restrictions shall be established on quantities such as dose rate, effluent release rate and other operational parameters so that the exposure of site personnel and members of the public does not exceed any relevant dose limit or authorised limits.
- 3.4.3 The regulatory constraints stipulated by the AERB shall be followed for controlling the exposures so as to keep the total exposure of personnel below the specified dose limits. Individual exposures exceeding the regulatory constraints shall be investigated and reported to the AERB.

#### 3.5 **Measures for Control of Exposures to Site Personnel**

- 3.5.1 Exposures to site personnel should be limited by an appropriate combination of radiation protection measures such as:
- (1) Restriction of external exposure by means of shielding, remote operation, source control and minimising the exposure time;
  - (2) Restriction of internal exposure by means of isolation, ventilation, cleanliness and the use of protective clothing and respiratory equipments;
  - (3) Proper layout of plant areas including zone classification of areas;

- (4) Training of personnel;
  - (5) Review of work procedures, planning and dose budgeting;
  - (6) By appropriate mock up arrangements for rehearsing work plans for special jobs;
  - (7) Monitoring of individuals and work areas.
- 3.5.2 The plant management shall in consultation with health physics unit prepare a Collective Dose Estimate for the year including that for special jobs as per approved procedures. The actual collective dose expenditure should be reviewed by the plant management towards achieving exposures ALARA.
- 3.5.3 Use of techniques such as computerised dose tracking will aid in better management of the overall radiological control process.
- 3.5.4 Proper work culture should be promoted among all levels of personnel for reducing individual and collective doses. Workforce required for a specific job should be carefully deployed keeping in view the special skills required and also the budgeted collective dose for the job.
- 3.5.5 Adequate auxiliary lighting and a comfortable working environment can increase the efficiency of the worker and thus reduce the time spent in the higher radiation zones and thereby minimise the dose received.
- 3.5.6 Inspections and other works in high radiation areas should be carefully scheduled taking advantage of reduction of radiation sources due to decay and other processes during the reactor shut down period and absorption or exhaust of air contaminants so that exposures can be minimised. Survey data and previous experience can be made use of in planning and scheduling of specific tasks.
- 3.5.7 Adequate supervision and radiation protection surveillance should be provided, while personnel work in radiation areas, to ensure that the appropriate procedures are followed, that proper protection is taken and that potential problems that might develop during the operation are addressed to in a timely manner.
- 3.5.8 There should be adequate communication systems such as telephones/ headphone sets, walkie-talkie, CCTV between personnel working in high radiation zones and those who monitor the work from other locations. This can permit exchange of information and avoid unnecessary exposures to personnel.
- 3.5.9 Ventilation balancing, integrity of the ventilation system and proper airflow pattern should be ensured to minimise the external exposure contribution due to radioactive inert gases.
- 3.5.10 Ventilation of work areas and system integrity should be such that airborne radioactive concentration in the work areas are maintained as low as possible and



below the prescribed limits. Airborne radioactivity concentrations in excess of the prescribed limits will require work restrictions, use of respiratory protection and other protective equipment. This may also be required to be followed up by bio-assay/whole body monitoring.

- 3.5.11 Auxiliary ventilation system as appropriate should be employed to augment the permanent system in case there is substantial scope for potential airborne contamination.
- 3.5.12 Uptake of radioactive material should be minimised by ensuring that adequate protective equipment is properly worn, removed, stored, laundered and surveyed. These physical controls in conjunction with training and administrative requirements such as, prohibition of eating, drinking and smoking in controlled areas and decontamination techniques ensure that potential ingestion of radioactive material is minimised.
- 3.5.13 In order to limit internal exposures, procedures should be evolved regarding restrictions on access of individual to radiation areas when his intake crosses a certain level.

### 3.6 **Exposure Control of Temporary Workers**

Besides ensuring compliance with the applicable exposure control measures as in section 3.5.1 above, the temporary workers employed for working in the controlled areas should meet the following requirements.

- (1) They should undergo pre-employment medical check up and training in elementary radiation protection procedures applicable at the plant.
- (2) They should be closely supervised by an appropriately qualified person during their work to ensure that the safety procedures including use of personnel monitoring devices and protective equipments are being followed and they are guided during normal and emergency situations in the plant.
- (3) The plant management should obtain the previous dose data, if any. The dose received by temporary workers shall be within the limits prescribed by the AERB. The dose limit for this category is normally lower than that for the radiation workers.
- (4) Persons below the age of 18 years shall not be employed for radiation work.

### 3.7 **Reference Levels**

In order to facilitate the administrative control of exposures to personnel, plant management should establish values of measurable quantities called reference levels that are lower than the limits prescribed. Whenever these levels are

exceeded, a review or investigation should be carried out by plant management. Reference levels may be applicable for dose for periods of less than one year, dose rates or contamination levels in an area.

### **3.8 Control of Exposure to the Members of the Public**

- 3.8.1 The doses to the members of the public due to operation of NPPs shall not exceed the limits prescribed by the AERB. The control of public exposure in all normal situations shall be exercised by application of controls at source rather than in the environment. The dose limits for members of the public do not include occupational exposures, exposures from the natural environment and medical exposures.
- 3.8.2 The authorised limits for discharge of effluents to the environment should be established based on the dose apportionment assigned to different facilities at the site for different routes of releases and different radionuclides as approved by AERB.
- 3.8.3 The amount and methods by which radioactive materials are released to the environment shall be controlled in accordance with the Safety Directives issued by the AERB.
- 3.8.4 Effluent monitoring shall be performed to demonstrate compliance with the prescribed discharge limits. Environmental surveillance shall be carried out in order to assess the radiological impact on the environment and to estimate the public exposures to confirm compliance with the regulatory requirements.

## **4. IMPORTANT ASPECTS FOR IMPLEMENTATION OF RADIATION PROTECTION PROGRAMME**

### **4.1 Design Aspects**

4.1.1 The design philosophy established for NPPs should strive to maintain occupational radiation exposures ALARA and should be in compliance with applicable regulations.

4.1.2 In order to achieve the above objectives, working procedures and methods should be examined with regard to the possibility of reducing doses resulting from these activities. The main methods of dose reduction are:

- (1) Reducing the radiation levels in work areas achieved by proper design, plant layout, and provision of shielding;
- (2) Reducing surface and airborne contamination by design;
- (3) Reducing the personnel exposure time by component selection, choice of work methods and proper training; and
- (4) Source control by proper selection of materials/components.

Details on the design aspects of radiological protection during design are dealt with in the AERB Safety Guide on "Design Aspects of Radiological Protection" (AERB/SG/D-12) [5].

4.1.3 The spread of airborne contamination within the station should be limited by maintaining air pressure gradients and air flows from areas of low potential airborne contamination to areas of higher potential contamination. Periodic checks would ensure that the design pressure differentials are being maintained.

### **4.2 Operational Aspects**

During the operating stage of NPPs, the following methods should be used for achieving the objectives of radiation protection programme:

- (1) Radiation and contamination control procedures;
- (2) Adherence to approved operating and maintenance procedures;
- (3) Implementing training programme;
- (4) Appropriate use of automatic or remote controlled equipment;
- (5) The use of temporary shielding;
- (6) Provision of local ventilation with adequate filtration and
- (7) Source control by ensuring leak tightness of components and systems.

#### 4.3 Dose Determination

A complete dosimetry programme should be developed, documented and implemented. Dose monitoring shall comply with the requirements established by the AERB. It should include such aspects as:

- (1) Personnel monitoring for external and internal exposures;
- (2) Criteria for determining type and periodicity of monitoring;
- (3) Procedures to be followed by radiation workers to comply with dosimetry or monitoring requirements;
- (4) Methods and procedures for ensuring quality assurance in the dosimetry programme;
- (5) Methodology for assigning dose;
- (6) Establishment of recording levels, investigation levels and other levels which may be appropriate and
- (7) Recording and retention of dosimetry and other related data.

#### 4.4 Classification of Areas

4.4.1 The plant areas should be classified into two types of areas, namely controlled areas and supervised areas.

4.4.2 **Controlled Area:** Any area in which specific protection measures or safety provisions are or could be required for controlling normal exposures or preventing the spread of contamination during normal working conditions and preventing or limiting the extent of potential exposures shall be designated as controlled area.

##### 4.4.3 **Requirements of Controlled Areas:**

- (1) delineate controlled areas by suitable means such as doors, distinctive painting and signboards, etc.;
- (2) restrict access to controlled areas by means of administrative procedures such as the use of work permits, and by physical barriers which could include locks or interlocks; the degree of restriction being commensurate with the magnitude and likelihood of the expected exposure;
- (3) provide individual personnel monitoring;
- (4) provide protective clothing and equipment, monitoring equipment and suitable storage for personal clothing, as appropriate, at entrances to controlled areas;
- (5) provide contamination monitors, washing or shower facilities and suitable storage for contaminated protective clothing and equipment, as appropriate, at the exits from controlled areas.

4.4.4 **Supervised Area:** Any area not already designated as a controlled area but where occupational exposure conditions need to be kept under review even though specific protection measures and safety provisions are not normally needed, shall be designated as supervised areas.

4.4.5 **Requirements of Supervised Areas:**

- (1) delineate the supervised areas by appropriate means;
- (2) display approved signs at appropriate access points to supervised areas.

4.4.6 The radiation status of such supervised areas should be confirmed by regular area monitoring. Routine individual personal monitoring is not needed while confirmatory monitoring may be carried out once in a while.

4.5 **Zone Classification**

4.5.1 **General**

4.5.1.1 In order to restrict contamination in various areas to minimum and also to facilitate control of spread of contamination potential, the entire plant area is divided into various distinct zones.

4.5.1.2 Each zone is clearly demarcated and provided with interzonal barriers with monitors such as hand and foot monitors/body monitor (frisker) for checking personnel and equipment while passing from higher contaminated zone to lower contaminated zone.

4.5.2 **Typical Zoning Classification**

4.5.2.1 Typically Supervised areas and Controlled Areas are assigned the following zoning classification based on contamination potential.

- (1) Supervised Area: Zone-1
- (2) Controlled Areas: Zone-2  
Zone-3  
Zone-4

4.5.2.2 The various zones have the following features:

- (1) **Zone-1**
  - (a) This zone will contain no radioactive equipment and will be kept free of contamination at all times.

- (b) Typically it may comprise Administrative Buildings, Control Room, DG Room, Turbine Building, Switch Yard etc.

(2) **Zone-2**

- (a) This zone contains no radioactive equipment and should not normally become contaminated. However some contamination may, though inadvertently get into this area with movement of personnel and equipment from zone-3. Contamination in zone-2 will be cleared as soon as it is discovered.
- (b) Typically this zone will include inactive shops (mechanical, electrical, control), laboratories, change room, wash room etc.
- (c) For zone 2, Radiological Work Permit (RWP) is not generally called for even though this is controlled area since no radiation related activities are expected to be carried out normally. This zone is a sort of buffer zone, which may get contaminated occasionally.

(3) **Zone-3**

- (a) It generally has only “closed” radioactive sources/ systems. These zones will normally be contamination free unless the equipment/systems are opened. This zone includes the service areas for entire equipment and materials that are potential sources of contamination. Hence this zone is likely to get contaminated at times. Equipment lay out and work procedures will be planned to keep contamination localised and loose contamination will be cleared up whenever it occurs.
- (b) Shops and laboratory areas handling contaminated equipment frequently come under this zone. Reactor Auxiliary Building, some parts of Decontamination Centre, laundry, and waste management facility are also covered by this zone.

(4) **Zone-4**

- (a) This zone normally contains sources of high radiation and hence can be expected to remain contaminated.
- (b) Contamination in this zone is kept localised and under control by routine clean up operations to maximum extent feasible; but some parts will remain contaminated.
- (c) Whole of Reactor Building, some parts of Decontamination Centre, Waste Management Plant, Spent Fuel Storage Bay come under zone-4.

4.5.2.3 Use of TLD in zone-2 and beyond is mandatory. Additional dosimeters as appropriate should be used in higher zones.

#### 4.6 **Work in Controlled Areas**

4.6.1 The controlled areas and the different zones inside these areas shall be delineated by suitable means. Contamination monitors should be located on authorised routes between zones. Warning signs and entry requirements shall be posted at the entrance of each zone. Procedures should be laid down for the movement of personnel and equipments through different zones. Exits from controlled areas shall be clearly marked.

4.6.2 Plant personnel who are required to enter the controlled areas shall be duly authorised. Fulfilment of radiation protection requirement shall be a pre-requisite for entry. The entry authorisation for a particular area of the plant may be for a specified period, or it may be withdrawn if the situation warrants. The access to controlled area should preferably be through a single checkpoint in order to limit the spread of contamination.

4.6.3 Requirements for access to a controlled area may include:

- (1) Possession of an authorisation issued by plant management and radiation work permit;
- (2) Availability of support personnel, equipment and personnel monitoring devices;
- (3) Protective clothing and equipments and
- (4) The required qualification in radiation protection.

4.6.4 Rubber area procedures should be employed to control the spread of contamination, within a particular zone, in locations where floor contamination already exists or where it is anticipated due to the nature of work to be done. The rubber area protective equipment should consist of rubber over-shoes, booties (shoe covers) or gumboots, gloves and cover-alls or lab coats. Personnel and equipment shall be checked for contamination and follow up action ensured at the interzonal cross-point and final exit.

4.6.5 All items shall be monitored for radiation and loose contamination before they are removed from the controlled area. Appropriate radiation protection measures such as decontamination, adequate shielding and labelling etc shall be employed before permitting these items outside controlled and/or supervised areas.

#### 4.7 **Work Planning**

4.7.1 Major radiological work, particularly during plant shut down, should be planned well in advance and the plans will include steps to minimise radiation exposures.

The different sections of personnel including work units and health physics personnel involved in a job should participate in the advance planning.

- 4.7.2 Detailed written plans should be prepared early enough to provide time to identify all potential radiation hazards. Job planning should include use of special tools and techniques, collective dose targets, comparison with similar jobs and simulated mock up operations as appropriate to increase job efficiency and keep radiation exposure ALARA.
- 4.7.3 There should be clear identification of responsibilities and co-ordination among different agencies participating in the job. It should be ensured that personnel, tools and equipment are available at the work place before starting the work, and the personnel are skilled and trained in carrying out the job. Preparation of the area such as cordoning off and posting warning signs, laying down temporary shielding, local ventilation exhaust and contamination monitors, may be required during certain jobs.
- 4.7.4 Radiological work associated with very high dose rates must be subject to rigorous planning in consultation with the health physicist and approved by appropriate levels of plant management.
- 4.7.5 Written reports, including the radiation protection aspects should be prepared and reviewed subsequent to any major radiological work.

#### 4.8 **Radiation Work Permits (RWP)**

- 4.8.1 The practical implementation of work planning includes issuance of a radiation work permit to authorise any work, which requires specific radiological precautions.
- 4.8.2 For each job that requires radiological precautions to be taken a Radiation Work Permit (RWP) should be prepared, issued and terminated in an approved manner. Such job situations generally include:
  - (1) Entry into any area having high radiation levels;
  - (2) Any maintenance work, which involves opening of any system that, contains or could potentially contain any radioactive fluid;
  - (3) Any job that involves removal or closure of shielding from any equipment containing radioactive solid material;
  - (4) Any maintenance of contaminated or potentially contaminated equipment using methods involving abrasion, cutting, machining or welding, and
  - (5) Handling of radioactive materials such as spent resin filters/ strainers, spent fuel, etc..



- 4.8.3 The RWP should contain brief description of the job, location and starting time. The issuer should be of the level of a shift health physicist duly qualified in radiation protection and authorised by the Station Health Physicist. The radiation protection personnel should evaluate the radiological conditions associated with the work to be performed based on radiation surveys and specify appropriate protective clothing/devices, dosimeters, special samples, surveys, procedures and precautions to be taken, time limit and the duration of validity of the permit. On completion of the job, after noting down the work details and recording the doses received, the supervisor gets the RWP terminated. If the work is of longer duration the RWP should be revalidated in each shift and fresh RWP should be obtained every day.
- 4.8.4 The person in whose name the RWP is issued, remains responsible for the radiation protection of the individuals covered by the permit until the surrender of the permit and must advise the personnel of time limitation, correct use of protective equipments and dosimeters, bioassay sample submission and of changes in the radiological conditions.
- 4.8.5 The RWP should be retained as a record. The RWP procedure provides a mechanism for collection and evaluation of data pertaining to radiation exposures.

#### 4.9 **Use of Protective Clothing and Equipment**

- 4.9.1 Appropriate protective clothing and equipment shall be used in areas where the airborne and/or surface contamination will involve exposure to internal contamination.
- 4.9.2 Protective clothing is used as a barrier to prevent contamination from reaching the body surface. The higher the level of contamination, the greater the degree of protection that will be required. This can be achieved by wearing protective clothing like plastic suits over the coveralls, gloves and shoe covers. When the individual leaves the contamination zone after work, the outer set of protective clothing should be removed and placed in bins or bags provided for this purpose.
- 4.9.3 Ventilated plastic suit shall be used in case it requires complete and effective isolation of the individual from the environment due to the nature of airborne contamination prevailing in the work area. This is appropriate for protection against high airborne tritium contamination and work involving high levels of loose surface contamination. In special circumstances, plastic suit together with a self-contained breathing apparatus could also be used as necessary.
- 4.9.4 Respiratory protective equipment shall be used in areas where airborne contamination exceeds or is likely to exceed the prescribed limits. The respirators used should be of approved types only. They should be suitable for the specific radionuclide of concern. The equipment shall be specifically selected to provide

the degree of protection (protection factor) that is needed for the radiological conditions.

- 4.9.5 Reusable protective clothing, shoe covers, gloves etc. used in contaminated areas should be collected separately and surveyed before sending them to laundry. They should be surveyed again before reissue to ensure that the contamination levels are within the prescribed limits. Respirators should be checked for contamination prior to cleaning and disinfection. The protective equipment should be routinely inspected, tested and checked for contamination before issue.
- 4.9.6 Personnel should be trained in the appropriate use of protective clothing and protective equipment. Special training should be given in the handling of Self-Contained Breathing Apparatus (SCBA).
- 4.9.7 The medical compatibility of the individual for the use of specific protective equipment should also be considered.

#### 4.10 **Decontamination**

- 4.10.1 The objective of decontamination is to remove the radioactive materials from surfaces where it is not desired and to reduce radiation exposure. Adequate decontamination facility and equipments shall be provided in the controlled area for personnel as well as equipment decontamination.
- 4.10.2 All the contaminated equipment should be decontaminated to appropriate levels before commencement of any maintenance work.
- 4.10.3 The floor area should be decontaminated periodically on completion of the job so as to minimise the spread of contamination.
- 4.10.4 While decontaminating, following a liquid spillage, attention to airborne contamination should be given and appropriate protective equipment should be used.
- 4.10.5 On detection of contamination on any part of the body of the radiation worker, the decontamination procedures as laid down by the health physicist shall be followed. If contamination still persists above the prescribed levels medical advice should be sought through the health physicist.

#### 4.11 **Area Monitoring and Surveys**

##### 4.11.1 *General*

- 4.11.1.1 The objectives of area monitoring and surveying are to provide information on radiological conditions throughout the plant and to ensure that the zone designation remains valid.
- 4.11.1.2 Surveys related to specific operations and maintenance jobs should be performed before the start of a job as well as through the operation of the job. Non-routine surveys should be conducted as and when necessary.
- 4.11.1.3 All areas designated as controlled areas and supervised areas shall be monitored regularly. Workplace monitoring should be done for (a) external monitoring (b) monitoring for air contamination and (c) monitoring for surface contamination.
- 4.11.1.4 The nature and frequency of monitoring will be determined by the likelihood of changes in the radiological conditions and the potential for exposure.
- 4.11.1.5 There should be a periodic review of the data collected and remedial actions taken. A review on implementation plan for improvement should be conducted.
- 4.11.2 **External Radiation Monitoring**
- 4.11.2.1 External radiation monitoring of the plant areas should be carried out with a frequency determined by consideration of expected changes in radiation environment. Areas subject to variation in radiation levels or increased time of occupancy should be surveyed on a more frequent basis. Radiation monitoring of the areas should be done for beta-gamma and neutrons as appropriate. The radiation field on contact of equipments and at a reference distance also should be carried out. The results of monitoring should be documented and displayed as necessary.
- 4.11.2.2 Work place monitoring for external radiation can be carried out automatically by fixed area gamma and neutron monitors. However this should be supplemented by periodic manual monitoring by Health Physics personnel. The area monitors should have recording facilities and shall be calibrated and checked at appropriate intervals. Audio-visual alarms for these monitors shall be available in control room in addition to the local area. Whenever area monitor gives an alarm, the area should be thoroughly surveyed to ascertain the radiological status.
- 4.11.3 **Air Monitoring**
- 4.11.3.1 An air-monitoring programme should be designed to meet the following objectives:

- (1) To monitor airborne contamination in the workplace and to assess the need for appropriate protective equipments;
- (2) To help to detect unexpected airborne contamination, if any, to enable timely protective action; and
- (3) To assess the potential intake of radioactive materials through inhalation and to plan for individual internal monitoring.

4.11.3.2 Airborne radioactivity within the plant areas should be kept below prescribed level and every effort should be made to minimise it. Air activity measurements should be carried out from different areas of the plant for tritium in air, radioactive particulates and radioiodines. Methods for the collection of air samples, assessment of air activity, frequency of sampling should be available in the Radiation Protection Procedures. Reference levels and the protective measures to be taken in case the air activity exceeds the same should be included. There should be provision for identification of the radionuclides by spectrometry.

4.11.3.3 A centralised system for collection and analysis of air samples from different areas of the plant could be employed. Spot samples also shall be collected for tritium measurements and high volume air samplers for particulates. In addition, the air activity measurements can be carried out through continuous air activity monitors for beta-gamma (particulates) and tritium.

#### 4.11.4 **Monitoring for Surface Contamination**

4.11.4.1 Surface contamination monitoring should have the following objectives:

- (1) Assessment of contamination levels in the plant areas and on equipments and personnel;
- (2) Preventing spread of contamination; and
- (3) Restricting contamination to approved levels.

4.11.4.2 A system of periodic contamination monitoring of the controlled areas and supervised areas of the plant should be established to meet the above objectives. Contamination surveys are normally performed to establish gross beta-gamma contamination level, but if need be the samples may be processed for specific type of radiation or specific radionuclides using spectrometry.

## 5. DOSE ASSESSMENT

### 5.1 External Dose Monitoring

- 5.1.1 Routine individual monitoring shall be done for all personnel entering the controlled areas.
- 5.1.2 Dose to site personnel shall be assessed by monitoring of individuals and working areas by appropriate means. When an individual receives only external radiation, uniformly distributed over his body, the reading of a properly located personal dosimeter may be taken to represent the effective dose. When it is known or suspected that the exposure has been significantly non-uniform, a special assessment of the dose to individual parts of the body should be done with additional dosimeters worn at appropriate body locations.
- 5.1.3 The dosimeters should be used for a specific period and the readings taken to assess the integrated equivalent dose over the specified period. However, in suspected or known case of higher exposures, arrangements shall be made to evaluate the dose from personnel monitoring device such as Thermoluminescent Dosimeter (TLD) as soon as practicable. Direct Reading Dosimeter (DRD) should be issued for all jobs under Radiation Work Permit (RWP). DRD readings help to control day to day exposure of personnel.
- 5.1.4 The issue of TLD badge shall be authorised by appropriate authorities in the plant management. All occupational radiation workers shall be allotted a permanent number for monitoring purposes and the TLD should have the photograph of the individual.
- 5.1.5 The visitors should be accompanied by a person duly qualified in Radiation Protection during their visit in the plant areas. In the case of visitors, group monitoring may be done instead of individual monitoring.
- 5.1.6 Any loss of a personnel monitoring device should be promptly reported. Duplicate shall be issued only after due authorisation and shall be clearly marked. If a dosimeter, which has recorded a person's long-term exposure is lost before the exposure has been recorded or if the information it provides is suspect for some reason, it will be necessary to estimate the external radiation dose by using other available information such as:
  - (1) Summing the DRD records for the same period;
  - (2) Calculating the dose based on the known radiation field in work location and the exposure period;
  - (3) Assessing the dose based on the dose received by co-workers; and
  - (4) Using chromosome aberration analysis wherever applicable.

A record of all these actions should be maintained for future reference.

- 5.1.7 In the case of personnel working in an area where neutron exposure is likely, special neutron badges shall also be used to assess the neutron exposure.

5.2 **Internal Dose Monitoring**

- 5.2.1 Internal dose monitoring, to assess the committed effective dose (CED) or committed equivalent dose in the case of uptakes in certain organs, shall be carried out for all personnel working in controlled areas. This monitoring shall be performed as per procedures laid down. The type of internal dose monitoring and periodicity that may be needed depend on the radiological conditions in the work place.

- 5.2.2 The internal contamination shall be assessed by the use of methods such as bio-assay, whole body counting or counting of particular organs of the body. For this, adequate facilities such as bio-assay laboratory and whole body or single organ counters should be available. The periodicity of bio-assay sampling should be such that internal dose can be evaluated properly.

## **6. MANAGEMENT OF RADIOACTIVE WASTES**

### **6.1 General**

- 6.1.1 All operations in the plant shall be carried out in such a way that the amount of wastes generated is minimised by appropriate methods and management practices. The plant management shall develop an integrated strategy for the management of radioactive wastes. This should include collection, characterisation, segregation, handling, treatment, conditioning, storage (with due precautions to fire, flood, earthquake and other site characteristics), transport and disposal.
- 6.1.2 The plant management shall ensure that gaseous and liquid effluents from NPPs shall be controlled, monitored and recorded to ensure that the authorised limits are not exceeded.
- 6.1.3 Monitoring data should be suitably documented, reported and retained in accordance with the policies of the operating organisation and the requirements of the AERB. These data should be routinely analysed to establish trends in relation to radioactive releases and may be used for optimisation purposes.
- 6.1.4 The instruments used should be appropriate for the radiation and energies to be measured and should be routinely calibrated for radiation, energy and effluent flow rate. The monitoring system should be maintained to provide high reliability. There should be back up methods for assessing the release in the event of system failure.
- 6.1.5 The radiation protection requirements in the handling of radioactive wastes shall be in accordance with AERB's Safety Guide "Operational Management of Radioactive Effluents and Wastes Arising in NPPs" (AERB/SG/O-11) [6].
- 6.1.6 The infrastructure available at site shall be compatible with the scheme of management of radioactive wastes.

### **6.2 Monitoring of Solid Wastes**

Radioactive solid waste should be characterised, segregated, packed, monitored, labelled and transported in accordance with the regulations.

### **6.3 Monitoring of Liquid Wastes**

The liquid wastes from the plant shall be segregated depending on their radioactive characteristics and chemical composition and monitored at appropriate location to assess the amount of radioactive release. It should be done by on-line monitoring and by representative sampling. The on line monitors

should have provision for alarms in the control room, in addition to local alarms, to ensure that the set discharge limits are not exceeded.

#### 6.4 **Monitoring of Gaseous Wastes**

6.4.1 Gaseous radioactive effluents released through the stack (the preferred single point exit route) shall be continuously monitored. The radionuclides that are to be monitored should be identified. The stack monitoring system should provide plant operators with information on airborne release rates that will assist them in the control of releases.

6.4.2 The stack monitoring system should provide an accurate measure of the quantity released for each category of radionuclide that is monitored. These releases shall be in compliance with regulatory limits.

#### 6.5 **Control of Releases**

6.5.1 In order to comply with the specified dose limits for the members of the public, prescribed limits for discharge for gaseous and liquid effluents and release rates should be established, with the approval of AERB. Reference levels appropriate for the plant to meet the regulatory requirements also shall be established.

6.5.2 The discharge of gaseous and liquid effluents shall be controlled taking into account the characteristics of the local environment and the possible bio-accumulation of the radionuclides therein. Release of radioactive effluents into the environment should be kept under control by the following means:

- (1) Development of reference levels for releases/release rates from the plant;
- (2) Proper sampling of the effluents and analysis of the constituent radionuclides and their amounts at the discharge points;
- (3) Development of approved procedures for releasing radioactive materials, for monitoring the releases and for recording data on each release; and
- (4) Assurance of required dilution in the case of liquid wastes.

6.5.3 In the case of gaseous release, equipment such as the following should be used for source control as appropriate.

- High Efficiency Particulate Air (HEPA) filters for the removal of particulate activity
- Impregnated charcoal filter beds for the removal of radioactive iodines
- Dryer systems to remove tritiated water vapour from air in Pressurised Heavy Water Reactors (PHWR)



They must be regularly tested and maintained to ensure optimum performance. The testing of filters should include in-situ testing for integrity and efficiency of the filter bank as a whole.

6.5.4 If an uncontrolled release occurs, plant management shall:

- (1) Estimate the amount of the release by taking appropriate steps such as sampling, monitoring, etc., in a timely manner appropriate to the severity of the case;
- (2) If required, initiate emergency actions, as specified in AERB's Safety Guide "Preparedness of the Operating Organisation for Emergencies at NPPs" (AERB/SG/O-6) [7];
- (3) Report to AERB in accordance with applicable requirements; and
- (4) Investigate the event, identify and implement suitable corrective actions.

## **7. STORAGE, HANDLING AND TRANSPORTATION OF RADIOACTIVE MATERIALS**

### **7.1 General**

7.1.1 Radiological control measures shall be established for the storage and handling of radioactive materials including wastes, within the plant and for their transportation from the plant in order to prevent the spread of contamination and to limit the exposure of site personnel and the general public. This should be in accordance with the provisions of Safety Code for Safe Transport of Radioactive Materials (AERB/SC/TR-1), Safety Guide on Procedures for Forwarding, Transport, Handling and Storage of Radioactive Consignments (AERB/SG/TR-3) and Safety Guide "Operational Management of Radioactive Effluents and Wastes Arising in NPPs" (AERB/SG/O-11) [8,9,6].

7.1.2 The personnel involved in the transport of radioactive materials should have appropriate training to handle an emergency situation during handling or transport as per Codes and Guides mentioned above.

### **7.2 Radiological Control Measures**

7.2.1 The control measures developed or adopted should be appropriate to the type of radiation and quantity of radioactive material involved, to its physical and chemical form.

7.2.2 The following radiation control measures should be used in the safe handling of radioactive materials at the plant site:

- (1) Radiation monitoring to control personnel exposures;
- (2) Radiation warning signs, labels and tags;
- (3) Separate storage room for radioactive materials and use of approved containers with due precautions against floods, fire and earthquake;
- (4) Procedures for storage and handling;
- (5) Procedures for handling emergency situations while storage or transport;
- (6) Maintaining an inventory of radioactive materials;
- (7) Records of radioactive shipments;
- (8) Gate monitors at the exit point, to detect movement of unshielded radioactive materials if any; and
- (9) Review and audits to establish compliance with Radiation Protection Programme.

## 8. ENVIRONMENTAL SURVEILLANCE

- 8.1 An environmental monitoring programme shall be established and implemented in accordance with the requirements of AERB to assess the dose to the members of the public due to plant operation. This programme should include comprehensive monitoring of radionuclide contents in different environmental matrices from aquatic, atmospheric and terrestrial domains to obtain activity distribution pattern and to estimate intake of radionuclides by man through inhalation and ingestion routes towards assessing dose to the member of the public due to plant releases.
- 8.2 The environmental surveillance shall include the collection and analyses of various samples such as vegetation, sediment, fish, milk, air, water and other environmental matrices. The samples should be collected routinely from specified locations and analysed for any radioactivity which may be attributable to radioactive releases from the plant.
- 8.3 A Micro Meteorological Laboratory (MML) also should be established for conducting the pre-operational studies to establish base line data and for continued meteorological surveillance. The MML make measurements of meteorological parameters such as wind speed and direction, temperature, relative humidity, atmospheric pressure, solar radiation and rain fall. On the basis of real-time meteorological parameters, the MML can identify the worst affected sector due to normal and accidental releases. MML data evaluate radiation dose to the population from radioactive discharges from the plant through air route.
- 8.4 The staff of Environmental Survey Laboratory (ESL) and MML should undergo an orientation course on station design features, potential accidents and their scenarios, source terms, release fractions and environmental behaviour of released activity.
- 8.5 Public exposure due to radioactive releases from the NPP shall be evaluated by ESL at the site. Based on diet survey and the radioactivity data in various dietary components both from terrestrial (air route) and aquatic sources (water route), effective dose to local population due to radioactive releases shall be estimated.
- 8.6 A summary of the environmental surveillance including the public exposure assessment due to the radioactive releases and micro meteorological measurements for the year shall be submitted to AERB in addition to informing the plant management. Based on this report the plant management should plan and implement corrective measures, if necessary, and send compliance reports to AERB.

## 9. FUNCTIONAL INFRASTRUCTURE AND EQUIPMENT

### 9.1 Health Physics Facilities

9.1.1 Functional infrastructure and equipment such as health physics facilities, instrumentation and protective equipment shall be provided by the plant management for effective radiological control. Availability of adequate qualified persons should also be ensured.

9.1.2 The health physics facilities with adequate space and ventilation that are required to be provided should include the following:

- (1) Health Physics Operations Office: Sufficient office space to accommodate the health physics staff, permanent records and technical literature;
- (2) Personnel monitoring facilities including thermoluminescent dosimeter (TLD) storage/issue room, whole body monitoring facilities and exit monitoring facilities;
- (3) Place for storage of TLD racks;
- (4) Area for installation of portal surveillance monitors at the final exit point;
- (5) Counting Room: A low radiation background counting room for performing analysis of air, water and swipe samples;
- (6) Sample Preparation Laboratory with fume hood facility for preparation of samples;
- (7) Instrumentation Calibration Facility: Designed and located such that radiation in the calibration area should not interfere with low level monitoring or counting systems;
- (8) Source Room with adequate shielding; and
- (9) Computerised centre for data storage management, retrieval of station radiological and personnel dose and other safety related data.

9.1.3 The other facilities that are required to be provided with adequate space and ventilation shall include the following:

- (1) Change Room: Change room with personnel decontamination facility, lockers, receptacles for contaminated clothing etc.;
- (2) Personnel Decontamination Facility with showers, wash basins and contamination monitors;
- (3) Equipment Decontamination Facility to clean, and decontaminate equipment and hand tools;
- (4) Transit waste storage room;
- (5) Storage Facility for contaminated equipment/tools;
- (6) Active Workshops;

- (7) First Aid Room;
- (8) Laundry;
- (9) Meteorological Data Collection Facility;
- (10) Servicing & Testing of protective equipment; and
- (11) Communication Facilities.

## 9.2 **Equipment**

9.2.1 The plant management shall provide equipment necessary for the Radiation Protection Programme, such as various monitoring and analysis instruments, and other protective equipment. The selection and quantity of instrumentation and equipment should be based on the anticipated needs of the NPP during normal operations, major outages and anticipated operational occurrences and accident conditions.

9.2.2 The instruments and equipment provided shall include:

- (1) Counting and analysis instruments;
- (2) Portable radiation monitoring instruments;
- (3) Personnel dose measuring instruments;
- (4) Protective Clothing:
  - (a) Protective clothing such as coveralls, lab. coats, plastic suits ventilated plastic suits gloves, shoe covers, gum boots etc.
  - (b) Respiratory protective equipment: Oro-nasal respirator, full face respirator, air-line respirator, tritium respirator and self-contained breathing apparatus.
- (5) Contamination monitors for installation at rubber areas, interzonal and final exit points;
- (6) Standard sources for calibration of instruments; and
- (7) Air sampling devices.

## **10. TRAINING AND QUALIFICATION**

- 10.1 Training in radiation protection is a basic requirement for personnel working in the station. The access and the type of work permitted depend on the established levels of plant system training, skills and qualification in radiation protection courses. The training should include radiation protection procedures and radiation emergency procedures.
- 10.2 Job oriented training is necessary to ensure that everyone attains and maintains the level of competence required for his duties and for his level of responsibility. This will help to minimise exposure times and to have better contamination control to achieve lower individual and collective doses.
- 10.3 The operating organisation shall make the necessary arrangements to train its site personnel. All plant personnel must attain and maintain an adequate level of capability in radiation protection in accordance with the requirements of their job functions.
- 10.4 The radiation protection training programme should also address the training needs of temporary workers. The temporary workers must possess adequate knowledge and skills for the work they are to perform. Only after pre-employment medical examination and training in radiation protection, the individuals should be permitted to work in controlled areas. They shall be directly supervised by personnel qualified in Radiation Protection Procedures for jobs in radiation areas.
- 10.5 Training courses should also be held periodically for doctors and para-medical personnel covering all aspects of radiation protection and handling of contaminated/exposed persons.
- 10.6 Training objectives shall be reviewed periodically to ensure that they take into account any change in requirements. The training programme should reflect the contemporary knowledge and techniques. This should be an on going programme. Periodic refresher course shall be conducted to keep qualification up-to-date. The record of the training and qualification status for all the personnel should be maintained at the station.

## 11. EMERGENCY PREPAREDNESS

### 11.1 Emergency Plan

- 11.1.1 The plant management shall develop its respective emergency preparedness plans to handle any emergency arising out of a potential accident. The emergency plan shall have provisions to take necessary measures for coping with such situation and ensure readiness of persons, facilities and equipments and for effective co-ordination between various groups at site and off-site including public authorities. The emergency plan forms a part of the requirements to be satisfied for granting operating licence by the AERB.
- 11.1.2 Separate but inter connected emergency plans shall be prepared to handle plant, site and off-site emergencies. The plant and site emergency plan shall be prepared by the plant management as per AERB Safety Guide "Preparedness of the Operating Organisation for Emergencies at NPPs" (AERB/SG/O-6) [7].
- 11.1.3 In the case of multi-facility site an integrated emergency plan shall be available which should include actions by personnel at different facilities in the event of an accident at any plant.
- 11.1.4 The guidelines to prepare site emergency plan are given in AERB Safety Manual "Site Emergency Plan for Nuclear Installations" (AERB/M/NISD-1) [10]. The plan shall be periodically reviewed and updated. The procedures for handling off-site emergencies are given in the AERB Safety Manual "Off-Site Emergency Plan for Nuclear Installations" (AERB/M/NISD) [11].

### 11.2 Facilities and Equipment Provided at Site for Handling Emergency:

- 11.2.1 Adequate facilities and equipment for handling emergency at site as necessary shall be provided by the plant management.
- 11.2.2 The facilities located within the site shall include a first-aid room and facilities for decontamination of personnel, equipment and areas.
- 11.2.3 The personnel handling an emergency shall be provided with dosimeters and appropriate protective clothing and equipment. Sufficient equipment should be readily available as per approved list to meet the minimum requirements envisaged during an emergency situation.
- 11.2.4 High-range radiation instruments, including direct reading dosimeters and self powered air samplers shall be readily available for use during an emergency situation. High-range fixed area gamma monitors with recorder facility also should be provided at selected locations for rapid assessment of an emergency

situation. Provisions should be available to obtain information on the radiological status (both radiation field and airborne activity concentration) inside the containment without entry into the containment in the case of accidental situations.

11.2.5 A radiation emergency vehicle equipped with radiation monitoring equipments and communication facility shall be available.

11.2.6 All equipment for emergency situations shall be periodically inspected and tested, as necessary to ensure that they are functionally available on demand.

### 11.3 **Training and Exercises**

Emergency exercises shall be conducted at regular intervals as stipulated by AERB. Provision shall be made for training of the personnel who would be involved in implementation of the plan. There should be a post exercise critique to review all the positive points and deficiencies observed during the exercise. Records of all exercises along with deficiencies observed shall be maintained for review and rectification.

### 11.4 **Intervention Levels (IL)**

11.4.1 The intervention levels as specified by AERB shall be applied for implementation of appropriate counter measures such as, use of protective equipments, introduction of prophylaxis, sheltering, or evacuation in the case of radiation emergencies. The intervention levels (ILs) and derived intervention levels (DILs) given in the AERB Safety Guide "Intervention Levels and Derived Intervention Levels for Off-Site Radiation Emergency" (AERB/SG/HS-1)[12] shall be incorporated in Radiation Emergency Procedures.

### 11.5 **Limitation of Exposure in Emergency**

11.5.1 Accident analysis of the plant shall demonstrate that the dose resulting from the Design Basis Accident (DBA) at the site boundary is not in excess of the values stipulated by the AERB in this regard.

11.5.2 In an emergency situation, some people would be exposed to doses exceeding the prescribed limits for occupational workers, for saving life, preventing serious injury or to prevent substantial increase in the scale or magnitude of the accident. The exposures of such personnel should not be allowed to exceed the values prescribed by AERB in this regard.

11.5.3 Such exposures shall be duly authorised and purely voluntary. The volunteers should be informed about the risk involved in such exposures. They shall be provided with adequate monitoring devices and protective equipments. The doses



received by such personnel shall be entered in the dose records along with the cross-reference to the report on emergency conditions.

#### 11.6 **Assessment and Monitoring**

Radiological conditions in the plant site areas shall be assessed in the event of an emergency as appropriate towards confirming the radiological conditions for the purposes of exposure control. The monitoring shall include assessment of radiation levels, airborne contamination, surface contamination and effluent releases.

## **12. DOCUMENTATION**

### **12.1 General**

Records shall be kept in order to maintain up-to-date information concerning important aspects of the Radiation Protection Programme. The information retained will be of great aid in reviewing and assessing the Radiation Protection Programme.

### **12.2 Types of Records**

The relevant documents be maintained should include:

- (1) Health physics reports;
- (2) Personnel dose and previous radiation history;
- (3) Radiation surveys and monitoring;
- (4) Radiation Work Permits;
- (5) Instrument calibration;
- (6) Inventory of protective equipment and their periodic verification and test results;
- (7) Inventory of sources and radioactive materials;
- (8) Radioactive shipments;
- (9) Radioactive liquid, gaseous and solid waste storage and disposal;
- (10) Medical surveillance;
- (11) Bio-assay and whole body counting;
- (12) Over exposure and unusual occurrence reports;
- (13) Emergency exercise records; and
- (14) Training and qualification records.

### **12.3 Criteria for Preparing and Maintaining Records**

12.3.1 Records should be prepared in a systematic manner and as per the requirement of the AERB.

12.3.2 The dose records of the temporary workers should be maintained separately. Exposures received prior to employment should be supported by valid documents.

12.3.3 The dose and health records of all the occupational workers shall be maintained by the plant management for the duration of the working life of each worker and afterwards until the worker attains or would have attained the age of 75 years, and for not less than 30 years after the termination of the work involving occupational exposure whichever is later.

12.3.4 The records classified as long term, medium term and short term shall be kept in a safe and protected environment for specified periods. The long term records shall be maintained for the life of the plant, medium term for a period of 10 years and short term for a period of 3 years.

## APPENDIX-I

### EXPLANATORY NOTES ON RADIATION PROTECTION CONCEPTS AND TERMS USED IN THIS GUIDE

#### I-1 Introduction

I-1.1 The radiation protection concepts and terms used in this Guide are based on the "Recommendations of the International Commission on Radiological Protection" (ICRP-60, 1990) [3] and the International Basic Safety Standards for Protection against Ionising Radiation and for the Safety of Radiation Sources (IAEA Safety Series No. 115, 1996) [2].

#### I-1.2 Practices and Intervention

Any human activity which increases the overall exposure to radiation is called a "practice". Any human action intended to reduce or avert exposure to sources which are not part of controlled practices or which are out of control as a consequence of an accident is called "intervention".

I-1.3 Radiation protection is concerned with the protection of the individuals, their progeny and mankind as a whole, while still allowing necessary activities from which radiation exposure might result.

#### I-2 Biological Aspects of Radiological Protection

The harmful biological effects of exposure to ionising radiation have been divided into two types (1) Deterministic (Non-stochastic) effects and (2) Stochastic effects. The aim of radiation protection is to limit the probability of stochastic effects to an acceptable level and to avoid deterministic effects by setting dose limits below the thresholds for such effects.

#### I-3 Dosimetric Quantities used in Radiation Protection

##### I-3.1 Absorbed Dose ( $D_T$ )

The fundamental dosimetry quantity  $D$  defined as  $D = d\epsilon/dm$ , where  $d\epsilon$  is the mean energy imparted by ionising radiation in a volume element and  $dm$  is the mass of matter in the volume element. The energy absorbed per unit mass in a tissue or an organ is called the absorbed dose of the tissue. The SI unit of the absorbed dose is joule per kilogram, termed the gray (Gy).

$$1 \text{ Gy} = 1 \text{ J.kg}^{-1}$$

### I-3.2 Equivalent Dose ( $H_{T,R}$ )

The quantity  $H_{T,R}$ , defined as:

$$H_{T,R} = D_{T,R} \cdot w_R$$

where  $D_{T,R}$  is the absorbed dose delivered by radiation type R averaged over a tissue or organ  $T$  and  $w_R$  is the radiation weighting factor for radiation type  $R$ .

When the radiation field is composed of different radiation types with different values of  $w_R$ , the equivalent dose is:

$$H_T = \sum_R w_R \cdot D_{T,R}$$

The unit of equivalent dose is  $\text{J.kg}^{-1}$ , termed the sievert (Sv).

$$1 \text{ Sv} = 1 \text{ J.kg}^{-1}$$

### I-3.3 Radiation Weighting Factor ( $w_R$ )

The probability of biological effect of radiation is found to depend not only on the absorbed dose, but also on the type and energy of the radiation causing the dose. This is taken into account by weighting the absorbed doses by a factor called radiation weighting factor  $w_R$ , related to the quality of the radiation (previously known as quality factor). The values of  $w_R$  for different types of radiation are given in Table-1.

*Definition:* Multipliers of absorbed dose used for radiation protection purposes to account for the relative effectiveness of different types of radiation in inducing health effects.

### I-3.4 Effective Dose

The quantity  $E$ , is defined as a summation of the tissue equivalent doses, each multiplied by the appropriate tissue weighting factor:

$$E = \sum_T w_T \cdot H_T$$

where  $H_T$  is the equivalent dose in tissue  $T$  and  $w_T$  is the tissue weighting factor for tissue  $T$ . From the definition of equivalent dose it follows that:

$$E = \sum_T w_T \cdot \sum_R w_R \cdot D_{T,R}$$

where  $w_R$  is the radiation weighting factor for radiation  $R$  and  $D_{T,R}$  is the average absorbed dose in the organ or tissue  $T$ . The unit of effective dose is  $\text{J.kg}^{-1}$ , termed the sievert (Sv).

### I-3.5 Tissue Weighting Factor ( $w_T$ )

The probability of stochastic effect due to a given dose differs from one organ or tissue to another. In order to combine the effect of doses to different tissues in a way which will likely correlate well with the total of the stochastic effects, a weighting factor called tissue weighting factor,  $w_T$  is used. This factor represents the relative contribution of the organ or tissue to the total detriment resulting from uniform irradiation of the whole body. The values of  $w_T$  are given in Table-2.

*Definition:* Multipliers of the equivalent dose to an organ or tissue used for radiation protection purposes to account for the different sensitivities of different organs or tissues to the induction of stochastic effects of radiation.

### I-3.6 Committed Equivalent Dose $H_T(\tau)$

Tissue irradiation from incorporated radionuclides is spread out in time, energy deposition occurring as the radionuclide decays. The time integral of the equivalent dose rate in an organ or tissue  $T$ , following intake of a radionuclide is called committed equivalent dose.

The quantity  $H(\tau)$ , defined as:

$$H_T(\tau) = \int_{t_0}^{t_0 + \tau} H_T(t) dt$$

where  $t_0$  is the time of intake,  $H_T(t)$  is the equivalent dose rate at time  $t$  in an organ or tissue  $T$  and  $\tau$  is the time elapsed after an intake of radioactive substances. When  $\tau$  is not defined it will be taken to be 50 years for adults and to age 70 years for intakes by children.

### I-3.7 Committed Effective Dose $E(\tau)$

The time integral of the effective dose rate following an intake of a radionuclide is called the committed effective dose.

The quantity  $E(\tau)$ , defined as:

$$E(\tau) = \sum_T w_T H_T(\tau)$$

where  $H_T(\tau)$  is the committed equivalent dose to tissue  $T$  over the integration time  $\tau$ . When  $\tau$  is not specified, it will be taken to be 50 years for adults and to age 70 years for intakes by children.

### I-3.8 **Collective Effective Dose ( $S$ )**

The total effective dose of a group of persons on which the total biological effect in that group would depend is called the collective effective dose.

The total effective dose  $S$  to a population, defined as:

$$S = \sum_i E_i \cdot N_i$$

where  $E_i$  is the average effective dose in the population subgroup  $i$  and  $N_i$  is the number of individuals in the subgroup.

**Table 1**

**Radiation Weighting Factors ( $w_R$ )**

| Type and energy range                             | $w_R$ |
|---|-------|
| Photons, all energies                             | 1     |
| Electrons, and muons, all energies                | 1     |
| Neutrons, energy                                  |       |
| < 10 keV  | 5     |
| 10 keV to 100 keV                                 | 10    |
| > 100 keV to 2 MeV                                | 20    |
| > 2 MeV to 20 MeV                                 | 10    |
| > 20 MeV  | 5     |
| Protons, other than recoil protons energy > 2 MeV | 5     |
| Alpha particles, fission fragments, heavy nuclei  | 20    |



**Table 2**

**Tissue Weighting Factors ( $w_T$ )**

| Tissue or organ | $w_T$ |
|-----------------|-------|
| Gonads          | 0.20  |
| Bone marrow     | 0.12  |
| Colon           | 0.12  |
| Lung            | 0.12  |
| Stomach         | 0.12  |
| Bladder         | 0.05  |
| Breast          | 0.05  |
| Liver           | 0.05  |
| Oesophagus      | 0.05  |
| Thyroid         | 0.05  |
| Skin            | 0.01  |
| Bone surface    | 0.01  |
| *Remainder      | 0.05  |

## APPENDIX-II

### DOSE LIMITS AND CONSTRAINTS

- II-1        **Occupational Dose Limits**
- II-1.1     **Primary Limits**
- II-1.1.1   *Limit on Life-time Dose*
- (a)        The cumulative life-time occupational effective dose of a worker shall not exceed 1 Sv.
- (b)        Dose Constraint: Medical review shall be undertaken at cumulative occupational effective dose of 0.5 Sv to the workers.
- II-1.1.2   *Effective Dose Limit:* The cumulative effective dose constraint for five years from January 1, 1994 to December 31, 1998 is 100 mSv for individual radiation workers. The annual effective dose to individual workers in any calendar year during the five-year block shall not exceed 30 mSv. This is given in Appendix-III.
- II-1.1.3   *Dose Limits for the lens of eye, skin and hands and feet:* For the lens of the eye and the skin the dose limit shall be 150 mSv and 500 mSv of equivalent dose in a year respectively. The equivalent dose limit for hands and feet also shall be 500 mSv in a year. The skin dose shall be averaged over 1 cm<sup>2</sup>, if the exposed area is ≤10 cm<sup>2</sup>. It shall be averaged over the actual exposed area if it is >10 cm<sup>2</sup>.
- II-1.1.4   *Dose Limit for Female Workers:* There is no special occupational dose limit for women in general. However, once pregnancy is declared the equivalent dose limit to the surface of the woman's abdomen shall be 2 mSv for the remainder of the pregnancy and the limit on intake of radionuclides shall be 1/20 of the Annual Limit on Intake (ALI).
- II-1.1.5   *Dose Limit for Apprentices and Trainees:* Apprentices and trainees in nuclear installations, if any, shall be of age not less than 16 years. For the apprentices of age between 16 and 18 years the annual dose limits shall be an effective dose of 6 mSv, an equivalent dose of 50 mSv to the lens of the eye an equivalent dose of 150 mSv to the extremities or skin.
- II-1.1.6   *Dose Limit for Temporary Workers:* For temporary workers employed, the dose received shall not exceed the limit stipulated by the AERB. Temporary workers shall be employed as per approved procedures.

## II-1.2 Dose Limits (Internal Exposure)

II-1.2.1 **Annual Limit on Intake (ALI):** The internal exposures are to be controlled by applying the secondary limit called annual limit on intakes (ALI). This would correspond to an intake which would result a committed effective dose of 20 mSv. The limit on internal exposures for individual radionuclides shall be 1 ALI for each year. If the intake is from more than one radionuclide, total intake during any one year shall be limited such that :

$$\frac{\sum_i I_i}{(ALI)_i} \leq 1$$

where  $I_i$  refers to intake of  $i$  th radionuclide to which a worker is exposed and  $(ALI)_i$  is the annual limit on intake for radionuclide  $i$  . The limits on some specific radionuclides as prescribed by AERB are given in Appendix-IV.

II-1.3 **Derived air concentration (DAC):** DAC values of individual radionuclides should be used for controlling the internal exposures due to inhalation. DAC of a radionuclide in Bq m<sup>-3</sup> of air is given by

$$DAC = \frac{\text{ALI of the given radionuclide}}{2.4 \times 10^3}$$

where  $2.4 \times 10^3$  m<sup>3</sup> is the volume of the air inhaled by ICRP reference man in a working year.

However in the case of HTO, the DAC value has to be obtained by multiplying the above value by 2/3 for accounting 50% absorption through skin.

## II-2 Dose Limits for Members of the Public

II-2.1 Control of public exposures under all normal operations of the plant shall be exercised by application of controls at source rather than in the environment. Limits are applied to doses incurred as a result of practices. The public exposure limits do not include occupational exposure and exposures from the natural environment and medical exposures.

II-2.3 The limit of public exposure shall be an effective dose of 1 mSv in a year for external exposure. If the exposures are both external and internal, the limit of

1 mSv in a year shall be applicable to the sum of the effective dose from external exposure and 70 year committed effective dose from the intake incurred during the year.

## **APPENDIX-III**

### **DOSE LIMIT FOR OCCUPATIONAL EXPOSURES AS APPROVED BY AERB IN MARCH 1994.**

#### **I. Effective Dose Limits**

- (i) The cumulative effective dose constraint for five years from January 1, 1994 to December 31, 1998 will be one hundred milliSievert (100 mSv) for individual radiation workers.
- (ii) The annual effective dose to individual workers in any calendar year during the five-year block shall not exceed the limit of thirty milliSievert (30 mSv).

#### **II. Investigation Levels**

- (i) Individual effective dose exceeding twenty milliSievert (20 mSv) in a year shall be investigated by a committee to be constituted by Chairman, AERB for this purpose. The committee shall ensure that the five-year constraint of not exceeding one hundred milliSievert (100 mSv) is met in all cases.

(Ref.: AERB Safety Directive 6/1994 dated March 10. 1994)

## APPENDIX-IV

### ANNUAL LIMIT OF INTAKE (ALI) (INHALATION) VALUES FOR RADIONUCLIDES OF COMMON INTEREST

| Nuclide                      | Aerosol class | ALI (1991)<br>(Bq) |
|------------------------------|---------------|--------------------|
| H-3 (tritiated water vapour) | D             | $1 \times 10^9$    |
| Co-60                        | W             | $2 \times 10^6$    |
|                              | Y             | $4 \times 10^5$    |
| Sr-90                        | D             | $4 \times 10^5$    |
|                              | Y             | $6 \times 10^4$    |
| I-131                        | D             | $1 \times 10^6$    |
| Cs-137                       | D             | $2 \times 10^6$    |
| Th-232                       | W             | $9 \times 10^1$    |
|                              | Y             | $9 \times 10^1$    |
| U-238                        | D             | $9 \times 10^4$    |
|                              | W             | $1 \times 10^4$    |
|                              | Y             | $6 \times 10^2$    |
| Pu-239                       | W             | $3 \times 10^2$    |
|                              | Y             | $3 \times 10^2$    |
| Am-241                       | W             | $3 \times 10^2$    |

Ref.: AERB Safety Directive 2/91 dated July 22, 1991

**Note:** D, W and Y represent the retention half-times of inhaled radioactive materials from the pulmonary region

D < 10 days  
W 10-100 days  
Y > 100 days

## REFERENCES

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4. ATOMIC ENERGY REGULATORY BOARD, Radiation Protection for Nuclear Facilities; AERB Safety Manual. (1996)
5. ATOMIC ENERGY REGULATORY BOARD, Design Aspects of Radiological Protection for PHWR based Nuclear Power Plants; AERB Safety Guide No. AERB/SG/D-12 (under preparation)
6. ATOMIC ENERGY REGULATORY BOARD, Operational Management of Radioactive Effluents and Wastes Arising in NPPs; AERB Safety Guide No. AERB/SG/O-11 (under preparation).
7. ATOMIC ENERGY REGULATORY BOARD, Preparedness of the Operating Organisation for Emergencies at NPPs; AERB Safety Guide No. AERB/SG/O-6 (under preparation).
8. ATOMIC ENERGY REGULATORY BOARD, Safe Transport of Radioactive Materials; AERB Safety Guide No. AERB/SG/TR-1.
9. ATOMIC ENERGY REGULATORY BOARD, Procedures for Forwarding, Transport, Handling and Storage of Radioactive Consignments; AERB Safety Guide No. AERB/SG/TR-3.
10. ATOMIC ENERGY REGULATORY BOARD, Site Emergency Plan for Nuclear Installations; AERB Safety Manual No. AERB/M/NISD-1.
11. ATOMIC ENERGY REGULATORY BOARD, Off-Site Emergency Plan for Nuclear Installations; AERB Safety Manual No. AERB/M/NISD.
12. ATOMIC ENERGY REGULATORY BOARD, Intervention Levels and Derived Intervention Levels for Off-Site Radiation Emergency; AERB Safety Guide No. AERB/SG/HS-1.





## **LIST OF PARTICIPANTS OF WORKING GROUP**

Dates of meeting:       October 18 & 19, 1993  
                              April 04 & 05, 1994  
                              August 02 & 03, 1994

|                                       |                                  |
|---------------------------------------|----------------------------------|
| Shri M. Sundaram (Convenor)           | Head, PPSS, HPD, BARC            |
| Shri R.M. Sharma                      | Health Physicist-in-Charge, RAPS |
| Shri S.K. Fotedar                     | Directorate of Operations, NPC   |
| Shri K.K. Narayanan (Co-opted)        | PPSS, HPD, BARC                  |
| Shri S.A. Hussain (Co-opted)          | Health Physics Unit (BARC), KAPP |
| Shri George Thomas (Member-Secretary) | HSD, AERB                        |

**ADVISORY COMMITTEE ON CODES, GUIDES AND  
ASSOCIATED MANUALS FOR SAFETY IN OPERATION OF  
NUCLEAR POWER PLANTS (ACCGASO)**

Dates of Meeting:           February 23 & 24, 1995  
                                  September 19 & 20, 1995  
                                  November 27 & 28, 1995

|                                     |                                 |
|-------------------------------------|---------------------------------|
| Shri G.V.Nadkarni (Chairman)        | Formerly Director E & PA, NPCIL |
| Shri V.S.Srinivasan                 | NPCIL                           |
| Shri Y.K.Joshi                      | RAPS, NPCIL                     |
| Shri Ravindranath                   | TAPS, NPCIL                     |
| Shri V.V.Sanathkumar                | MAPS, NPCIL                     |
| Shri R.S.Singh                      | AERB                            |
| Shri Ram Sarup                      | AERB                            |
| Shri S.T.Swamy (Co-opted)           | AERB                            |
| Shri S.K.Warrier (Member-Secretary) | AERB                            |

## **ADVISORY COMMITTEE ON NUCLEAR SCIENCES (ACNS)**

Dates of Meeting:                      January 11, 1997  
  February 22, 1997

|                           |                            |
|---------------------------|----------------------------|
| Shri S.K.Mehta (Chairman) | Formerly Director RG, BARC |
| Shri S.M.C.Pillai         | President, Nagarjuna Group |
| Prof. M.S.Kalra           | IIT, Kanpur                |
| Prof. U.N.Gaitonde        | IIT, Mumbai                |
| Shri S.K.Goyal            | BHEL                       |
| Shri Ch.Surendar          | NPCIL                      |
| Shri S.K.Sharma           | BARC                       |
| Dr. V.Venkatraj           | BARC                       |
| Shri V.K.Chaturvedi       | NPCIL                      |
| Shri M.S.Kumra            | BARC                       |
| Shri S.P.Singh            | Formerly Head, NSD, AERB   |
| Shri G.K.De               | AERB                       |
| Smt. Usha A Menon         | AERB                       |

**PROVISIONAL LIST OF SAFETY GUIDES ON OPERATION OF NUCLEAR  
POWER PLANTS**

| <b>Safety Series No.</b> | <b>Provisional Title</b>  |
|--------------------------|---|
| AERB/SG/O-1              | Training and Qualification of Operating Personnel of NPPs                 |
| AERB/SG/O-2              | In-Service Inspection of NPPs   |
| AERB/SG/O-3              | Operational Limits and Conditions for NPPs                                |
| AERB/SG/O-4              | Commissioning Procedures for NPPs   |
| AERB/SG/O-5              | Radiation Protection during Operation of NPPs                             |
| AERB/SG/O-6              | Preparedness of the Operating Organisation for Emergencies at NPPs        |
| AERB/SG/O-7              | Maintenance and Modifications of NPPs                                     |
| AERB/SG/O-8              | Surveillance of Items Important to Safety in NPPs                         |
| AERB/SG/O-9              | Management of NPPs for Safe Operation                                     |
| AERB/SG/O-10             | Core Management and Fuel Handling for NPPs                                |
| AERB/SG/O-11             | Operational Management of Radioactive Effluents and Waste Arising in NPPs |