



GOVERNMENT OF INDIA

**AERB SAFETY CODE**

**RADIATION PROCESSING FACILITIES**



**ATOMIC ENERGY REGULATORY BOARD**

**AERB SAFETY CODE NO. AERB/RF-RPF/SC-1 (Rev. 1)**

## **RADIATION PROCESSING FACILITIES**

**Approved by the Board in November 2015**

**Atomic Energy Regulatory Board  
Mumbai-400 094  
India**

**October 2016**

Price:

Order for this 'Safety Code' should be addressed to:

The Chief Administrative Officer  
Atomic Energy Regulatory Board  
Niyamak Bhavan  
Anushaktinagar  
Mumbai-400 094  
India

## FOREWORD

Activities concerning establishment and utilization of nuclear facilities and use of radioactive sources are to be carried out in India in accordance with the provisions of the Atomic Energy Act, 1962. In pursuance of the objective of ensuring safety of occupational workers, members of the public and protection of the environment, the Atomic Energy Regulatory Board (AERB) has been entrusted with the responsibility of laying down safety standards and enforcing rules and regulations for such activities. The Board has, therefore, undertaken a programme of developing safety standards, safety codes, and related guides and manuals for the purpose. While some of these documents cover aspects such as siting, design, construction, operation, quality assurance and decommissioning of nuclear and radiation facilities, other documents cover regulatory aspects of these facilities.

Safety codes and safety standards are formulated on the basis of internationally accepted safety criteria for design, construction and operation of specific equipment, structures, systems and components of nuclear and radiation facilities. Safety codes establish the objectives and set requirements that should be fulfilled to provide adequate assurance for safety in nuclear and radiation facilities. Safety guides elaborate various requirements and furnish approaches for their implementation. Safety manuals deal with specific topics and contain detailed scientific and technical information on the subject. These documents are prepared by experts in the relevant fields and are extensively reviewed by advisory committees of the Board before they are published. These documents are revised, when necessary, in the light of experience and feedback from users as well as new developments in the field.

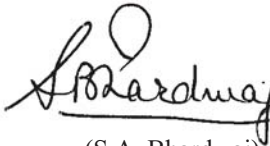
AERB Safety Code titled 'Operation and Maintenance of Land Based Stationary Gamma Irradiator'(AERB/SC/IRRAD), published in 1993 was applicable to the users of the Gamma Radiation Processing Facilities (GRAPF) only. However, in the recent past, various new designs of GRAPF have emerged and installed in the country. At the same time, industrial accelerator radiation processing facilities (IARPF) utilizing the radiation generating equipment such as e-beam and X-rays are also gaining momentum for radiation processing applications. The design requirements for GRAPF are covered in the AERB Safety Standard titled 'Land-Based Stationary Gamma Irradiators' [AERB/RF-IRRAD/SS-6 (Rev-1), 2007].

This safety code is effective from the date of issue and supersedes the earlier safety code on the subject 'Operation and Maintenance of Land Based Stationary Gamma Irradiators' (AERB/SC/IRRAD; 1993) and it consolidates all the regulatory requirements relevant to radiation processing facilities utilising sources of ionizing radiation including radioactive sources and radiation generating equipment (GRAPF & IARPF) in a single document. Appendices are an integral part of the document, whereas bibliography is included to provide further information on the subject that might be helpful to the user(s).

The first draft of Safety code was prepared by a consultant experienced in the safety review of Radiation Processing Facilities. It has been reviewed experts in the field, AERB Safety Review Committee for Radiation Processing Plants (SRC-RPP),

Standing Committee for Review and Revision of AERB Radiation Safety Documents (SC-RR-RSD) and Advisory Committee on Radiological Safety (ACRS) have further reviewed and vetted it for issue. The draft safety code was placed on AERB website for public comments and the same was suitably modified considering the comments.

AERB wishes to thank all individuals and organisations who have prepared and reviewed the draft and helped in its finalisation. The list of experts, who have participated in this task, along with their affiliations, is included for information.



(S.A. Bhardwaj)  
Chairman, AERB

## DEFINITIONS

### Activity

The quantity 'A' for an amount of radio nuclide 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 a time interval 'dt'. The SI unit of activity is the reciprocal of second ( $s^{-1}$ ), termed the Becquerel (Bq).

### ALARA

An acronym for 'As Low As Reasonably Achievable'. A concept meaning that the design and use of sources, and the practices associated therewith, should be such as to ensure that exposures are kept as low as reasonably achievable, with economic and social factors taken into account.

### Applicant

Any person who applies to the Competent Authority for consent to undertake any of the actions for which the consent is required.

### Approval

A type of regulatory consent issued by the Regulatory Body to a proposal.

### Atomic Energy Regulatory Board (AERB)

A national authority designated by the Government of India having the legal authority for issuing regulatory consent for various activities related to the nuclear and radiation facility and to perform safety and regulatory functions, including their enforcement for the protection of site personnel, the public and the environment against undue radiation hazards.

### Commissioning

The process during which structures, systems and components of a nuclear and radiation facility, on being constructed, are made functional and verified to be in accordance with design specifications and to have met the performance criteria.

### Competent Authority

Any official or authority appointed, approved or recognised by the Government of India for the purpose of the Rules promulgated under the Atomic Energy Act, 1962.

### Consent

It is a written permission, issued to the 'Consentee' by the regulatory body to perform specified activities related to nuclear and radiation facilities. The types of Consent are 'Licence' 'Authorisation', 'Registration', and 'Approval' and will apply according to the category of the facility, the particular activity, and radiation source involved.

**Consentee**

A person to whom consent is granted by the Competent Authority under the relevant Rules.

**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.

**Decommissioning**

The process by which a nuclear or radiation facility is finally taken out of operation, in a manner that provides adequate protection to the health and safety of the workers, the public and the environment.

**Disposal**

The emplacement of waste in a repository without the intention of retrieval or the approved direct discharge of waste into the environment with subsequent dispersion

**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 necessary for defining the quantity of interest.

**Dose Limit**

The value of the effective dose or the equivalent dose to individuals from controlled practices that should not be exceeded.

**Emergency**

A situation which endangers or is likely to endanger safety of the site personnel, the nuclear/radiation facility or the public and the environment.

**Emergency Plan**

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

**Employer**

Any person with recognised responsibility, commitment and duties towards a worker in

his or her employment by virtue of a mutually agreed relationship. (A self-employed person is regarded as being both a worker and employer).

**Exposure**

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

**Handle**

Manufacture, possess, store, use, transfer by sale or otherwise export, import, transport or dispose of.

**Inspector (Regulatory)**

A person authorised by the Regulatory Body to carry out regulatory inspection.

**Irradiation Cell**

An enclosed area in the irradiator where the product is irradiated.

**Irradiator**

A facility that houses a particle accelerator, X-ray machine or large radioactive sources for imparting high radiation dose to materials.

**Licence**

A type of regulatory consent, granted by the regulatory body for all sources, practices and uses for nuclear facilities involving the nuclear fuel cycle and also certain categories of radiation facilities. It also means authority given by the regulatory body to a person to operate the above said facilities.

**Monitoring**

The continuous or periodic measurement of parameters for reasons related to the determination, assessment in respect of structure, system or component in a facility or control of radiation.

**Person**

Any individual, or a company, or association, or body of individuals, whether incorporated or not or central government or a state government.

**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.



**Quality Assurance**

Planned and systematic actions necessary to provide adequate confidence that an item or a facility will perform satisfactorily in service as per design specifications.

**Radiological Safety Officer (or Radiation Safety Officer)**

Any person who is so designated by the employer and who, in the opinion of the Competent Authority, is qualified to discharge the functions outlined in the Atomic Energy (Radiation Protection) Rules, 2004.

**Radiation Generating Equipment**

Device capable of generating radiation, such as X-rays, neutrons, electrons or other charged particles.

**Regulatory Body**

(See 'Atomic Energy Regulatory Board')

**Sealed Source**

Radioactive source material that is either permanently sealed in a capsule or is closely bounded and in solid form. The capsule or material of a sealed source shall be strong enough to maintain leak tightness under conditions of wear and tear for which the source was designed and also under foreseeable mishaps.

**Source**

Anything that causes radiation exposure, either by emitting ionising radiation or releasing radioactive substances or materials.

**Radiation Cell**

(See 'Irradiation Cell')

**Radiation Worker**

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

**Regulatory Constraints**

Restrictions on radiation protection parameters specified by the regulatory body.

**Supervised Area**

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

**Worker**

Any person who works, whether full-time, part-time or temporarily, for an employer and who has recognised rights and duties in relation to occupational radiation protection. (A self-employed person is regarded as having the duties of both an employer and a worker).

## **SPECIAL DEFINITIONS**

### **(Specific for the Present Safety Code)**

#### **Facility Operator**

Facility operator is a person who is certified in compliance with the eligibility criteria as specified by the Regulatory Body and is required to operate the facility as per written instructions and established standard operating procedures.

#### **Gamma Irradiation Chamber**

Gamma Irradiation Chamber is a type of Self-Contained Dry Source Storage Gamma Irradiator. In this irradiator sealed gamma sources are completely contained in a dry container constructed of solid materials. The sealed sources are shielded at all times, and human access to the sealed sources and the volume undergoing irradiation is not normally possible in its design configuration.

#### **Gamma Radiation Processing Facility (GRAPF)**

A radiation processing facility containing radioactive sources emitting gamma radiation and associated systems used for delivering prescribed dose to a specified target in a preset time.

#### **Industrial Accelerator Radiation Processing Facility (IARPF)**

A radiation processing facility containing radiation generating equipment such as an electron-beam accelerating device and emitting electron beam or X-rays. It also consists of associated systems for delivering prescribed radiation dose to a specified target in a preset time.

#### **Licensee**

A person to whom license is granted by the Competent Authority under the relevant Rules.

#### **Radiation Processing Facility (RPF)**

A facility containing radiation sources and associated systems used for delivering prescribed dose to a specified target in a preset time. GRAPF and IARPF are referred to as radiation processing facilities. The term 'facility' used in this safety codes shall mean an RPF, unless specified otherwise.

#### **Safety Interlock**

A safety interlock is an engineered device for precluding likely exposure of an individual to ionizing radiation, either by preventing entry to the controlled area or by automatically removing the cause of the exposure.

## CONTENTS

FOREWORD .....	i
DEFINITIONS .....	iii
SPECIAL DEFINITIONS .....	vii
1. INTRODUCTION .....	1
1.1 General .....	1
1.2 Objective .....	1
1.3 Scope .....	2
2. REQUIREMENTS FOR OBTAINING LICENCE .....	3
2.1 General Requirements .....	3
2.2 Regulatory Requirements for Obtaining Licence .....	3
2.3 Site Approval .....	3
2.4 Approval for Design and Construction .....	4
2.5 Consent for Commissioning/Approval for First Source Loading .....	4
2.6 Licence for Operation .....	5
2.7 Additional Requirements .....	5
3. RESPONSIBILITIES OF PERSONNEL .....	6
3.1 Employer .....	6
3.2 Licensee .....	7
3.3 Radiological Safety Officer (RSO) .....	9
3.4 Operator .....	10
3.5 Manufacturer/Supplier .....	11
4. RADIATION MONITORING .....	13
4.1 Work Place Monitoring .....	13
4.2 Individual Monitoring .....	13
5. SOURCE LOADING/UNLOADING IN GAMMA RADIATION PROCESSING FACILITY (GRAPF) .....	15
5.1 Preparation .....	15
5.2 Source Loading/Unloading Operation .....	15
5.3 Emergency .....	16
5.4 After Completion of Source Loading/Unloading .....	16
6. MODIFICATIONS IN RADIATION PROCESSING FACILITY .....	17
6.1 Approval for Modifications .....	17
6.2 Consultation for Modification .....	17
6.3 Re-commissioning after Modification .....	17

7.	SECURITY OF THE RADIATION PROCESSING FACILITY	18
7.1	Security of Sources .....	18
7.2	Security Guidelines .....	18
8.	EMERGENCY PREPAREDNESS AND RESPONSE PLANS	19
8.1	Emergency Response Plan .....	19
8.2	Response Measures .....	20
8.3	Emergency Preparedness .....	20
9.	DECOMMISSIONING .....	21
9.1	Approval for Decommissioning .....	21
9.2	Decommissioning Report .....	21
9.3	Financial Provisions for Decommissioning .....	21
	APPENDIX A : REQUIREMENTS FOR INDUSTRIAL ACCELERATOR RADIATION PROCESSING FACILITY (IARPF) .....	22
	APPENDIX B : QUALITY ASSURANCE DURING OPERATION OF RADIATION PROCESSING FACILITY .....	30
	BIBLIOGRAPHY.....	36
	LIST OF PARTICIPANTS .....	38
	SAFETY REVIEW COMMITTEE FOR RADIATION PROCESSING PLANTS (SRC-RPP) .....	38
	STANDING COMMITTEE FOR REVIEW AND REVISION OF AERB RADIATION SAFETY DOCUMENTS (SCRRRSD) .....	39
	ADVISORY COMMITTEE ON RADIOLOGICAL SAFETY (ACRS) ..	40
	LIST OF REGULATORY SAFETY DOCUMENTS ON RADIATION PROCESSING FACILITIES .....	41

# 1. INTRODUCTION

## 1.1 General

Radiation Processing facilities that utilize ionizing radiations are used for a variety of beneficial applications such as sterilization of medical products, food processing, mutation breeding and industrial processing. The amount of radioactivity in a gamma radiation processing facility (GRAPF) is typically about  $10^{15}$ - $10^{17}$  Bq (1 PBq-100 PBq). The industrial accelerator radiation processing facilities (IARPF) included in this safety code are all electron accelerator based radiation processing facilities. IARPF use either electron beam generated from machine sources operated at or below an energy level of 10 MeV and/or X-rays generated from machine sources operated at or below an energy level of 7.5 MeV. As with any other industrial equipment or plant, the radiation processing facility also has some potential hazards during operation. These hazards are related to unintended exposure to radiation, fire and breaches in security.

The requirements for radiation processing facilities are intended to prevent accidents and to provide for the protection and safety measures. The magnitudes and likelihood of exposures and the number of individuals exposed are required to be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account.

The terms 'ionizing radiation' and 'radiation' are used interchangeably in this safety code, and both mean the same thing unless specified as otherwise.

## 1.2 Objective

The purpose of this safety code is to prescribe all safety requirements for design, construction, operation, emergency management, servicing, maintenance and decommissioning of a radiation processing facility (RPF). These include:

- (i) Prevention of undue exposure of workers and members of the public to ionizing radiation, non-ionizing radiation and noxious gases- achieved through engineered safety features (such as protective barriers, interlocks, ventilation), compliance with approved administrative controls and appropriate monitoring.
- (ii) The magnitudes and likelihood of exposures and the number of individuals exposed are required to be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account.
- (iii) Prevention of environmental and facility contamination with radioactive substances- achieved through engineered safety features, compliance with approved administrative controls and appropriate monitoring.

### 1.3 Scope

- (i) This safety code covers radiation safety requirements for Radiation Processing facilities i.e. GRAPF and IARPF operated on commercial scale or for research and development.
- (ii) This safety code is applicable to siting, commissioning, operation, maintenance and decommissioning of the radiation processing facilities (RPF).
- (iii) The siting and design requirements of IARPF are explicitly covered in this document under Appendix-A. However, the design requirements for GRAPFs are specified in the AERB Safety Standard on 'Land-based Stationary Gamma Irradiators' [AERB/RF-IRRAD/SS-6 (Rev.1), 2007].
- (iv) This safety code is applicable for radiation processing facilities using following radiation sources:
  - (a)  $^{60}\text{Co}$
  - (b) Electrons generated from machine sources operated at or below an energy level of 10 MeV
  - (c) X-rays generated from machine sources operated at or below primary electron beam energy level of 7.5 MeV.
- (v) This safety code is not applicable to Gamma Irradiation Chambers (GIC).

## 2. REQUIREMENTS FOR OBTAINING LICENCE

### 2.1 General Requirements

- (i) The title of the land, on which the facility is intended to be set up, shall be in the name of the applicant prior to obtaining site approval from the regulatory authority. If the title of the land is not in the name of the applicant, then there shall be a legal agreement between the applicant and the owner of the land covering in its scope the setting up, operation and decommissioning of the radiation processing facility. In case of GRAPF, the provisions of para (iii) below shall be clearly defined in the agreement.
- (ii) The applicant shall be registered with local statutory body as a legal entity.
- (iii) In the case of a GRAPF, details specifying the responsibility and the procedure for the removal of the radioactive sources from the facility to an approved agency, in the event of decommissioning of the facility or any kind of disruption to the continued safe operation of the facility or bankruptcy shall be furnished to the Competent Authority.
- (iv) In the case of a GRAPF, prior to obtaining the licence, a separate fund shall be earmarked by the employer (in the form of bank guarantee) towards expenditure for removal and transport of the sources. The bank guarantee for such purposes shall be deposited in consultation with source supplier. The quantum of the fund shall be reviewed periodically by the source supplier.

### 2.2 Regulatory Requirements for Obtaining Licence

The licensing process<sup>1</sup> includes issuance of consent by the Competent Authority at various stages such as siting, construction, commissioning for operation of the facility, source replenishment, modification during routine operation, and Decommissioning.

### 2.3 Site Approval

- (i) The applicant shall submit details of the proposed site to the Regulatory Body in the prescribed format.
- (ii) The applicant shall demonstrate that the site meets the requirements specified in the AERB Safety Standard on 'Land-based Stationary Gamma Irradiators' [No. AERB/RF-IRRAD/SS-6 (Rev.1), 2007] for GRAPF installation. The site requirements of IARPF are provided in Appendix-A of this safety code.

---

<sup>1</sup> The process proceeds in conformity with the relevant provisions of the AERB Safety Guide titled 'Consenting Process for Radiation Facilities' (AERB/RF/SG/G-3).

#### **2.4 Approval for Design and Construction**

- (i) The GRAPF shall be designed as per the requirements stipulated by AERB Safety Standard on 'Land-based Stationary Gamma Irradiators' [AERB/RF-IRRAD/SS-6 (Rev.1), 2007]. The design requirements of IARPF are provided in **Appendix-A** of this safety code.
- (ii) An application in the prescribed format shall be submitted to the Regulatory Body along with Preliminary Safety Analysis Report (PSAR) including the quality assurance program during construction.
- (iii) Construction of the facility shall not be undertaken before obtaining approval from the Regulatory Body.
- (iv) The facility shall be constructed in accordance with the design approved by the Regulatory Body.
- (v) Quality assurance program shall be ensured during construction of the facility. The reports on the same shall be submitted periodically to the Regulatory Body.
- (vi) Approval from Regulatory Body shall be obtained for any modifications of approved design, if required to be done during construction.
- (vii) The Regulatory Body should carry out inspection of the facility during its construction to check the quality assurance documents and to verify that the facility is constructed in accordance with the approved design.

#### **2.5 Consent for Commissioning/Approval for First Source Loading**

- (i) The applicant shall perform functional tests on each operating and safety systems as specified by the manufacturer/designer after completion of installation of facility. The applicant shall ensure that the built-in design safety features are incorporated in the facility as per the Preliminary Safety Analysis Report (PSAR) approved by the Regulatory Body.
- (ii) Acceptance Test Reports (ATR) specifying the results of the functional tests conducted on all the systems of the facility shall be submitted to the Regulatory Body in the prescribed format.
- (iii) Appropriately trained and certified facility operators and a Radiological Safety Officer shall be available while submitting the application for obtaining initial radioactive source procurement and loading permission from Regulatory Body.
- (iv) Authorized inspectors of the Regulatory Body carries out an inspection of the facility to verify the submitted ATR. Based on the findings of the inspection approval may be issued to the applicant for:



(a) initial source loading at the facility for carrying out commissioning trial operations such as radiation protection survey and dosimetry studies in case of GRAPF and (b) carrying out trial operations with accelerated electron beam in case of IARPF.

## **2.6 Licence for Operation**

- (i) The application for obtaining the licence for operation of the RPF shall be submitted to the Regulatory Body in the prescribed format. The application shall be accompanied by the Final Safety Analysis Report (FSAR) along with Quality Assurance Manual (QAM) of the design and systems installed in the facility and the Radiation Protection Manual (RPM) in the prescribed formats.
- (ii) The facility should conform to the security guidance as provided in the AERB Safety Guide on 'Security of Radioactive Sources in Radiation Facilities' [No. AERB/RF-RS/SG-1]
- (iii) Based on the review of information provided in the application and the inspection carried out by the authorized inspectors of the Competent Authority, licence may be issued to the applicant for operation of the facility under the provisions of the Atomic Energy (Radiation Protection) Rules, 2004.

## **2.7 Additional Requirements**

- (i) Radiation processing facilities planning to carry out radiation processing of food and allied products shall comply with additional provisions as prescribed in the Atomic Energy (Radiation Processing of Food and Allied Products) Rules, 2012.
- (ii) All applicable statutory requirements of other relevant authorities shall be duly satisfied by the Radiation Processing Facility before commencing the routine operation of the facility.

### 3. RESPONSIBILITIES OF PERSONNEL

#### 3.1 Employer

The employer shall have responsibilities specified in Rule 20 of the Atomic Energy (Radiation Protection) Rules, 2004. The employer shall:

- (i) Designate, with the written approval of the Competent Authority, a person having qualifications as specified in this safety code, as Radiological Safety officer (RSO).
- (ii) Ensure the availability of adequate number of trained/certified operators for the operation of the facility.
- (iii) Ensure that the provisions of this safety code are implemented by the licensee, Radiological Safety Officer and other worker(s).
- (iv) Provide necessary facilities and equipment to the licensee, Radiological Safety Officer, trained certified operators and other worker(s) to carry out their functions effectively in conformity with the regulatory requirements.
- (v) Procure from the former employer, where applicable, the dose records and health surveillance reports of a worker prior to his employment in the facility.
- (vi) Provide personnel monitoring devices to workers, and ensure that they are worn as required, and also ensure that individual dose records are maintained as prescribed by the Competent Authority.
- (vii) Upon termination of service of a worker provide to his new employer, on request, his dose records and health surveillance reports.
- (viii) Furnish to each worker dose records and health surveillance reports of the worker in his employment annually, as and when requested by the worker and at the termination of his service.
- (ix) Inform the Competent Authority if the licensee or the Radiological Safety Officer (RSO) or any facility operator leaves the employment.
- (x) Constitute a local safety committee (LSC) to review the safety status of the facility periodically in terms of operational safety, servicing and maintenance and regulatory compliance. The Radiological Safety Officer shall be the Member-Secretary of the LSC. The Committee shall include members familiar with and experienced in the operation of the facility as well as members not directly connected with day to day operation of the facility. Competent Authority shall be informed about the Committee and its work.
- (xi) Ensure that the quality assurance program for servicing and maintenance of the facility is established. Records of the QA shall be maintained for inspection/audit by the Regulatory Body.

- (xii) Report to the Competent Authority of any change in the safety organisation of the facility.
- (xiii) Ensure that the operating and servicing manual is revised taking into consideration the operating experience and that the designer and manufacturer are advised accordingly. Revision of manuals shall incorporate any safety directive issued by the Regulatory Body.
- (xiv) Inform the Competent Authority, within twenty four hours of occurrence, of any accident involving radiation injury, a source or loss of source of which he is the custodian.
- (xv) Arrange for health surveillance of workers as specified under Rule 25 of Atomic Energy (Radiation Protection) Rules, 2004.
- (xvi) Obtain prior Approval from the Regulatory Body for any modifications, if required to be done in the facility.
- (xvii) Obtain prior Approval from the Regulatory Body for decommissioning the facility and, in the case of a GRAPF, disposal of the source.

### **3.2 Licensee**

The licensee shall have responsibilities specified in Rule 21 of the Atomic Energy (Radiation Protection) Rules, 2004. The licensee shall ensure that:

- (i) All systems/components features are regularly serviced and maintained in good working order. Servicing and maintenance are carried out and as per the manual provided by the manufacturer/designer and records are maintained. All component replacement record are maintained in the log book.
- (ii) All applicable provisions specified in this safety code are established and maintained.
- (iii) The necessary equipment to enable the working rules and emergency procedures to be efficiently carried out is readily available.
- (iv) Radiation monitoring is carried out in accordance with the requirements of this safety code.
- (v) Radiation monitoring equipment and any other equipment provided to limit radiation exposure is regularly inspected, maintained and calibrated.
- (vi) Periodic tests and inspections of safety systems and control mechanisms are carried out.
- (vii) Spares of critical components are available in workable condition.
- (viii) Records are maintained and are available for inspection by the relevant statutory authority.
- (ix) Adequate instruction is given to employees concerning any radiation hazards associated with their work, and precautions necessary to

limit radiation exposure of persons and to avoid radiation accidents and injuries.

- (x) No person is permitted to operate the radiation processing facility until he has been adequately trained and is competent to operate the radiation processing facility in accordance with the safety procedures.
- (xi) The necessary supervision is provided to all employees in the performance of their work in accordance with the provisions of this safety code.
- (xii) In case of actual or suspected exposure exceeding the prescribed dose limits to personnel, the Competent Authority is informed without delay in the prescribed format.
- (xiii) In the event of exposure received by any person in excess of the regulatory limits, Competent Authority is informed promptly of the occurrence of the incident, investigation and follow up actions including steps to prevent recurrence of such incidents.
- (xiv) In case of actual or suspected exposure exceeding the prescribed dose limits, appropriate medical procedures are carried out, medical reports are retained and full details of the incident are reported to the Competent Authority as soon as possible.
- (xv) Periodic safety status report of the facility in the prescribed format is submitted to the Competent Authority.
- (xvi) Loading, replenishment, redistribution or disposal of sources is carried out only by the authorized source supplier.
- (xvii) Installation, repair and service of parts of the facility, which may affect radiation safety, are carried out through the original designer/supplier/manufacture of the facility or by a qualified person in consultation with the Competent Authority.
- (xviii) Standard Operating Procedures (SOP), a display board listing of emergency contact numbers and a copy of emergency action plan are available in the control room.
- (xix) Training and retraining of the operators in the safe operation of the facility are conducted periodically and records are maintained.
- (xx) Appropriate fire authority is notified of the location of all radiation sources installed and is informed about the potential hazards at the facility.
- (xxi) Response procedures for handling an emergency situation are prepared in accordance with section 8 of this safety code and a copy is submitted to the Competent Authority.
- (xxii) Internal inspection/audit or other management control is established so that the safe operating procedures are implemented and the emergency procedures are rehearsed by workers.

### **3.3 Radiological Safety Officer (RSO)**

#### **3.3.1 Qualification**

- (i) A Degree in Engineering or in Science from a recognized university/institution with Physics as one of the subjects.

or

A Diploma in Engineering from a recognized university/institution with a minimum of five years of experience in radiation surveillance in a radiation processing facility supported by personnel monitoring (TLD) service.

and

Successful completion of radiation safety course recognized by the Competent Authority.

OR

A Post Graduate Diploma/Degree in Radiological Physics from a recognized university/institution.

- (ii) Approval from the Competent Authority to function as a Radiological Safety Officer in an RPF.

#### **3.3.2 Responsibilities of the Radiological Safety Officer**

The RSO shall have responsibilities specified in Rule 22 of the Atomic Energy (Radiation Protection) Rules, 2004. The RSO shall:

- (i) Carry out routine measurements and analysis of radiation levels in the controlled area, supervised area of the radiation facility and maintain records of the results thereof.
- (ii) Investigate any situation that could lead to potential exposures.
- (iii) Advise the employer regarding:
  - (a) The necessary measures aimed at ensuring that the regulatory constraints and the terms and conditions of the licence are adhered to.
  - (b) The safe storage and movement of radioactive material within the radiation facility.
  - (c) Initiation of suitable remedial measures in respect of any situation that could lead to potential exposures.
  - (d) Routine measurements and analysis of radiation and radioactivity levels in the off-site environment of the radiation processing facility and maintenance of the records thereof.
- (iv) Ensure that test and maintenance schedules for safety related components and systems are carried out in accordance with the schedule provided in Table-1 (a) and 1 (b) of Appendix-B.

- (v) Report on all hazardous situations along with details of any immediate remedial actions taken are made available to the employer and licensee for submitting to the Competent Authority.
- (vi) Ensure that personnel monitoring devices are provided to workers in the facility, used as required and securely stored in a radiation-free area.
- (vii) Supervise during maintenance and test procedures on systems and components or in areas where radiation safety may be affected or where service/maintenance personnel may need to be given special protection.
- (viii) Ensure that monitoring instruments are calibrated periodically.
- (ix) Maintain servicing, operation log books and associated QA records.
- (x) Assist the employer in:
  - (a) Instructing the workers on hazards of radiation and on suitable safety measures and work practices aimed at ensuring that exposure to radiation is kept as low as reasonably achievable.
  - (b) The safe disposal of radioactive wastes.
  - (c) Developing suitable emergency response plans to deal with accidents and maintaining emergency preparedness.
- (xi) Advise the licensee on:
  - (a) The modifications in working conditions of a pregnant worker.
  - (b) The safety and security of radioactive sources.
- (xii) Furnish to the licensee and the Competent Authority periodic reports on the safety status of the radiation installation.
- (xiii) Inform the Competent Authority when he leaves the employment.

### **3.4 Operator**

#### 3.4.1 Qualifications

- (i) Degree in Science from a recognized University/Institution.  
or  
Diploma in Engineering from a recognized University/Institution.
- (ii) Successful completion of radiation safety course recognized by the Competent Authority.

#### 3.4.2 Responsibilities of Operator

The Operator shall:

- (i) Operate the facility as per written instructions and established Standard Operating Procedures.

- (ii) Assist in servicing/maintenance and testing.
- (iii) Use personnel dosimeter in correct manner at all times while working within the facility.
- (iv) Always be available in the control room when radiation processing facility is in operation.
- (v) Make complete and correct entries in the operation logbook.
- (vi) Promptly report to RSO of any malfunction (actual & suspected) of any system or deviation from any operating parameter.
- (vii) Report to the RSO in writing of any unusual occurrence or suspected exposure above normal levels and seek advice on remedial action.
- (viii) Assist the RSO to analyse and prevent such situations.

### **3.5 Manufacturer/Supplier**

Manufacturer/Supplier shall ensure that:

- (i) Radiation processing facilities are supplied only to users who have been authorised in writing by the Competent Authority to operate such facilities.
- (ii) RPF is constructed as per the design approved by the regulatory body.
- (iii) Operating instructions which include a general description of the radiation processing facility and detailed operating procedures are supplied to the user.
- (iv) Adequate training is provided to the personnel of the radiation processing facility in the operation and maintenance of the facility. The records for the same shall be provided to the facility.
- (v) Instructions for the periodic inspection and maintenance of the radiation processing facility, including test procedures for contamination detection are supplied to the user.
- (vi) Instructions specifying procedures to be implemented in an emergency situation, which has caused or may cause a radiation hazard to any individual, are provided to the user.
- (vii) Copies of all drawings, operating and service manuals, radiation surveys, and other records held by the supplier relating to the radiation processing facility and its source of radiation, are maintained until such time that the facility has been decommissioned.
- (viii) Services are available to maintain and repair the facility.
- (ix) Prompt corrective action is taken in the case of emergencies relating to the facility and its source of radiation.

- (x) Assistance is provided to the radiation processing facility in the event of an emergency.
- (xi) Assistance is provided to the employer/licensee during source augmentation, commissioning and disposal of the source as and when needed.



## 4. RADIATION MONITORING

### 4.1 Work Place Monitoring

- (i) Radiation surveys shall be carried out by Radiological Safety Officer or an authorised person who has the knowledge and training necessary to select and use suitable survey instruments.
- (ii) Periodic radiation protection survey shall be carried out at locations in and around the facility.
- (iii) Continuous radiation surveillance shall be provided during loading and unloading of radioactive sources in the facility.
- (iv) Work place monitoring shall be provided during the handling of an unusual or abnormal event.
- (v) Extensive radiation monitoring shall be provided during the handling of any emergency situation.
- (vi) Proper functioning of installed radiation monitors at personnel access door, product exit door and at resin bed of DM plant shall be ensured all the time.
- (vii) A radiation survey shall be performed to confirm continued compliance with standards when changes to the radiation processing facility have been made such as:
  - (a) An increase in the amount of activity above the previous maximum in case of a GRAPF
  - (b) Sealed source rearrangement in case of a GRAPF
  - (c) An increase in the performance specifications, such as energy or beam current, of a machine source above the previous maxima in case of an IARPF
  - (d) A decrease in shielding
  - (e) Any other change which may have increased the leakage radiation levels.
- (viii) If the survey indicates the need for corrective action, another survey shall be performed after appropriate modifications have been made.
- (ix) Records for all type of radiation monitoring shall be maintained and made available for regulatory inspection.

### 4.2 Individual Monitoring

- (i) Adequate number of passive personnel dosimeters shall be made available and used by all workers employed with the facility.
- (ii) The control badge shall be placed/stored in a radiation-free zone in the facility.

- (iii) Workers shall be informed of the dose received by them.
- (iv) Active personnel monitors such as pocket dosimeters or alarm-based dosimeters shall be used by all personnel involved in the following situations:
  - (a) Loading and unloading of radioactive sources in the GRAPP
  - (b) While working near beam components in IARPF
  - (c) Handling of any unusual or abnormal event in the facility
  - (d) Handling of emergencies.
- (vi) Records for all type of personnel monitoring shall be maintained and made available for regulatory inspection.

## **5. SOURCE LOADING/UNLOADING IN GAMMA RADIATION PROCESSING FACILITY (GRAPF)**

### **5.1 Preparation**

- 5.1.1 Loading, unloading and handling of radioactive sources shall be undertaken under close supervision of Radiological Safety Officer under a well-defined radiation protection program.
- 5.1.2 Source loading/unloading operations shall not be carried out if all the operating, control and safety systems are not functioning in the intended manner.
- 5.1.3 Motive power for source and product movement shall be disabled during source loading/unloading operations.
- 5.1.4 Mock runs shall be carried out with dummy sources prior to undertaking actual operations using proper tool for picking & lifting of source pencils.
- 5.1.5 The hoist to be used for lifting the source transport cask shall be tested periodically through the authorised testing agency and valid certificate of testing shall be submitted to regulatory body prior to source loading operations.
- 5.1.6 Radiation safety assessment of the whole operation shall be made by Radiological Safety Officer and protection and safety shall be optimized.

### **5.2 Source Loading/Unloading Operation**

- 5.2.1 Procedures described by the manufacturer/supplier and accepted by the Competent Authority shall be strictly adhered to.
- 5.2.2 Radiation survey of the transport cask including external radiation survey and external removable contamination shall be performed prior to opening it.
- 5.2.3 Proper under water lighting system in the water pool shall be provided to facilitate smooth source handling operation.
- 5.2.4 It shall be ensured that water inside the pool remain clear for proper visibility for the operation.
- 5.2.5 It shall be ensured that no inflammable or explosive material is present in the vicinity of area of sources loading/unloading operation.
- 5.2.6 All source loading/unloading operations shall be carried out by trained personnel of source supplier.
- 5.2.7 The personnel involved in source loading/unloading operation shall use appropriate safety gears such as safety belts and helmet.

- 5.2.8 The physical barrier shall be used during source loading/unloading operation to prevent accidental fall of any personnel inside the water pool.
- 5.2.9 All personnel involved in the operation shall be monitored with personnel monitoring badges and pocket dosimeters and individual dose records shall be maintained.
- 5.2.10 Good housekeeping practices shall be observed during and after source loading/unloading operations to prevent any abnormal situations/incidents.

### **5.3 Emergency**

- 5.3.1 The source supplier shall provide assistance to handle any emergency situations involving radiation source and ensuring safe disposal, if necessary.
- 5.3.2 In case of any emergency or abnormal situation during the operation, the source shall be brought back to its fully shielded position either in the cask or shielded position in the radiation processing facility.

### **5.4 After Completion of Source Loading/Unloading**

- 5.4.1 The record of the position of each source unit in the source rack and its activity as on date shall be maintained.
- 5.4.2 Following the source loading operations, source supplier shall carry out internal contamination survey of the empty transport cask by taking swipe samples from inside the cask cavity.
- 5.4.3 After completion of source loading/rearrangement/redistribution operation, report on the above operation, radiation protection survey and product dosimetry report shall be submitted to Regulatory Body. The routine operation of the radiation processing facility shall be subject to obtaining prior licence/ permission from the Competent Authority.

## **6. MODIFICATIONS IN THE RADIATION PROCESSING FACILITY**

### **6.1 Approval for Modifications**

The licensee shall obtain approval from the Regulatory Body prior to introducing any modification which may cause a radiation hazard such as:

- (i) Modifications of operating procedures
- (ii) Modification of the safety control system
- (iii) Modifications of the infrastructure of the facility
- (iv) Loading, replenishment, removal or redistribution of sources in case of GRAPP
- (v) An increase in the performance specifications, such as energy or beam current, of a machine source above the previous maxima in case of accelerator-based facilities.

### **6.2 Consultation for Modification**

Any modifications to the operating, control and safety systems shall be carried out in consultation with the designer/manufacturer of the facility only or by a qualified person in consultation with the Competent Authority.

### **6.3 Re-commissioning after Modification**

The facility shall be re-commissioned only after obtaining approval from the Competent Authority.

## **7. SECURITY OF THE RADIATION PROCESSING FACILITY**

### **7.1 Security of Sources**

7.1.1 The employer shall ensure security of the radioactive sources at all times.

7.1.2 The facility shall be secured against all envisaged theft, sabotage or any other kind of security threat.

### **7.2 Security Guidelines**

The facility should conform to the security guidance as provided in the AERB Safety Guide on 'Security of Radioactive Sources in Radiation Facilities', [No. AERB/RF-RS/SG-1 (2011)].

## **8. EMERGENCY PREPAREDNESS AND RESPONSE PLANS**

### **8.1 Emergency Response Plan**

- 8.1.1 The licensee, in consultation with Radiological Safety Officer, shall prepare emergency response plan and ensure emergency preparedness measures.
- 8.1.2 Emergency response plans shall be made available to mitigate any consequences of emergencies. The response plan shall address the events such as:
  - (i) Radioactive source rack stuck in an unshielded position
  - (ii) Radioactive contamination- (detection of leaking radioactive sources, contamination of source storage water pool)
  - (iii) Fire, explosion or gas leakages inside the accelerator equipment area, radiation cell or product storage area
  - (iv) Loss of source shielding (e.g. very low water level in GRAPFs)
  - (v) Malfunctioning or deliberate defeat of the safety interlock systems and access control systems
  - (vi) Accidental radiation exposure of individual(s) in excess of dose limits
  - (vii) Breach of security, natural occurrences such as earthquake, flood, tornadoes, etc.
- 8.1.3 The emergency plan shall be specific to each situation and shall include, as appropriate:
  - (i) Identification of reasonably foreseeable accidents and other incidents or occurrences and their predicted consequences
  - (ii) Communication procedures, including an emergency call out list, recommended actions for specified situations, a list of persons identified for implementing the specified action plan, and specification of situations requiring evacuation together with procedures for implementation
  - (iii) A statement regarding immediate life-saving actions, statutory responsibilities and the names of persons identified for implementing actions to discharge them
  - (iv) Availability of emergency equipment, including a list of the equipment available and their locations
  - (v) Availability of first aid equipment, including a list of the equipment available, their locations and the names of persons trained to use them (where applicable)

- (vi) An outline of the post-emergency recovery procedures designed to restore normal operating conditions.

## **8.2 Response Measures**

- 8.2.1 The response measures shall be concise, unambiguous, easily practicable and aimed at restoring normal operation keeping exposures to individuals ALARA.
- 8.2.2 In case of injury to any individual, medical attention shall be accorded priority.
- 8.2.3 In case of external emergency, measures shall be taken to cordon off and decontaminate the area.
- 8.2.4 Response to an emergency shall consist of initial actions to be implemented immediately and follow up actions subsequently.

## **8.3 Emergency Preparedness**

- 8.3.1 Contact numbers of responsible emergency response persons including Licensee/Employer, RSO, fire services, ambulance, medical center, manufacturer, source supplier and the Competent Authority shall be displayed at control panel and other relevant locations.
- 8.3.2 Periodic review of emergency plans shall be carried out to enhance the effectiveness of the plans.
- 8.3.3 The employer shall report every unusual event to the Competent Authority immediately and certainly within 24 hours of its occurrence. The details shall include
  - (i) Date and time of occurrence
  - (ii) Status of RPF at the time of incident
  - (iii) Source activity at the time of incident
  - (iv) Brief description of the event
  - (v) Action implemented
  - (vi) Probable cause of the incident.
- 8.3.4 The immediate notification shall be followed by a detailed report after carrying out investigations.
- 8.3.5 The Manufacturer/Supplier shall provide assistance to handle any emergency situations involving radiation source.
- 8.3.6 The licensee shall conduct an emergency exercise at least once in a year and report of the exercise shall be prepared immediately upon completion of exercise and made available to the Competent Authority, when required.



## **9. DECOMMISSIONING**

### **9.1 Approval for Decommissioning**

- 9.1.1 The employer/licensee shall obtain prior approval from the Competent Authority for any proposal to decommission of the RPF and, in the case of GRPF, for disposal of the radioactive sources.
- 9.1.2 The employer/licensee shall provide the details of the decommissioning procedure in the prescribed format to the Competent Authority.

### **9.2 Decommissioning Report**

The employer/licensee shall submit a report to the Competent Authority on completion of decommissioning providing details of decommissioning, safe disposal of sources and personnel doses received during decommissioning operations.

### **9.3 Financial Provisions for Decommissioning**

In case of the unlikely event of bankruptcy or other constraints, financial provision shall be made to meet the cost of safeguarding radioactive source in a GRAPF. The financial provision shall be made prior to obtaining the licence. A separate fund shall be earmarked by the employer in the form of bank guarantee towards the expenditure towards removal and transportation of radioactive sources to the supplier or any other agency approved by Regulatory Body for safe custody. The bank guarantee for such purpose shall be deposited in consultation with source supplier. The quantum of the fund shall be reviewed periodically by the source supplier.

## APPENDIX-A

### REQUIREMENTS FOR INDUSTRIAL ACCELERATOR RADIATION PROCESSING FACILITY (IARPF)

#### A.1 SCOPE

- A.1.1 Industrial Accelerator Radiation Processing Facility (IARPF) uses either an electron beam directly or electron beam generated high-energy photons for radiation processing. These facilities are notable for absence of inventory of any radioactive source material in the plant, and associated handling hazards.
- A.1.2 For direct electron beam use, the beam energy shall be limited to 10 MeV; and for generating high-energy photons, the primary electron beam energy shall be limited to 7.5 MeV. A beam power of several kW is used in various radiation processing applications in an IARPF. Radiation shielding and personnel-safety interlocks shall be provided to limit the radiation exposure to workers and member of public, and prevent accidental exposure respectively.
- A.1.3 AERB Safety Guides No. AERB/SG/IS-5 and AERB/RF/SG/G-3 should be appropriately used for layout, design, construction and operation of IARPF.
- A.1.4 Electron accelerators of the following types shall be used in an IARPF:
- (i) High-voltage DC accelerator from 0.5 to 3 MeV beam energy.
  - (ii) Radio-frequency (RF) electron linear accelerator (RF Linac) from 3 MeV upwards.
  - (iii) Other electron accelerators such as microtron, betatron, rhodotron and induction-linac shall be utilized in radiation processing facility with the specific permission of Competent Authority.
- A.1.5 This Safety code shall be applicable to the land-based installations only.

#### A.2 Common Requirements

Design and operational safety details for IARPF, which are common for any of above types of accelerator, shall meet following requirements:

##### A.2.1 Siting Requirements

- (i) The applicant shall submit authenticated documents issued by relevant Government agencies showing the status of ownership/lease of the premises for the proposed IARPF. All the statutory requirements of central and state governments, as applicable for the facility, shall be complied with.
- (ii) The building of IARPF shall be engineered on the basis of seismic characteristic of the site taking into account the maximum intensity of a likely earthquake as specified in IS-1893 (Part-1), 2002 or an updated version.

- (iii) A minimum distance of 30 meters shall be maintained from the boundary wall of the IARPF to any nearby residential area and/or public places.
- (iv) Geological and geotechnical requirements for design and construction of the IARPF shall take into account all applicable requirements specified in Appendix-A of AERB Safety Standard No. AERB/RF-IRRAD/SS-6 (Rev.1), 2007.
- (v) The civil works structures of the IARPF shall be designed such that the soil and ground characteristics do not cause any deterioration in its strength and integrity during the useful life of the IARPF.
- (vi) The maximum level of ground water and design basis flood level shall be taken into account in the radiological safety aspects of the design of the IARPF.
- (vii) The access road to the site shall be strong enough to take the load of heavy parts of the IARPF.

#### A.2.2 Engineered Safety Design Requirements

##### A.2.2.1 *Biological Shielding*

- (i) Adequate thickness of biological shield around the accelerator beam channel and radiation cell shall be provided such that the dose rate in full occupancy areas does not exceed  $1 \mu\text{Sv.h}^{-1}$  while accelerator beam is in 'Switched- ON' mode.
- (ii) Any penetrations provided in biological shielding for services and access shall not cause increase in the radiation levels outside the shielding.
- (iii) Concrete used for the construction of the biological shielding shall have density stipulated in the shielding calculations. Adequate quality control shall be ensured during pouring of concrete into the walls to achieve the minimum specified density, and exclusion of formation of porosity and voids.

##### A.2.2.2 *Personnel Access Control System*

Exclusion of any personnel presence in the accelerator beam channel and radiation cell areas shall be positively achieved before the accelerator beam is 'switched-on'. This shall be achieved through a few engineered layers of barrier involving design features, provision of sensors and associated instrumentation, as well as adherence to strict procedural sequencing. Design policy of defence in depth shall be adhered to, and demonstrated in the safety assessment reports submitted to the Regulatory Body. Essential design provisions for this are outlined below:

- (i) Personnel Access Door
  - (a) Entry into accelerator beam channel and radiation cell areas shall be regulated through personnel access door/s. Each

personnel access door shall be accessible/visible to the plant operator/RSO from their respective work places, e.g. control room. In addition, CCTV surveillance shall be provided.

- (b) Material and construction of the access door shall be such that it can withstand fire in the plant for at least half an hour
- (c) The product entry/exit shall be so designed that by suitable interlocks it precludes the possibility of entry by personnel.

(ii) Beam Switch-on Interlocks

Control system for IARPF shall be designed to ensure complete exclusion of any person in the accelerator beam channel and radiation cell when electron beam is switched-on and accelerated. This shall be achieved through a series of engineered safety interlocks as mentioned below:

- (a) Provision of limit switches to ensure complete closure of access doors before beam is switched-on.
- (b) The above limit switch shall be designed to switch-off the electron beam when anyone tries to open the access door during radiation processing.
- (c) A sequential 'search and secure' procedure by the operator himself, to ensure that nobody is present in the accelerator beam channel and radiation cell, by activating the safety buttons located therein. At the end of search, the access doors shall be secured in the closure mode, and accelerator controls are activated into operational standby mode.
- (d) The standby mode shall not have dwell time lasting more than a few minutes, after which the 'search and secure' condition shall become deactivated.
- (e) The close-circuit TV monitoring of access doors and secured areas shall be provided in the control desk/console. Any unauthorized entry into the monitored areas shall prompt operator to turn the accelerator beam into 'switched off' mode, with or without rendering plant in standby mode for investigation of the incident.

(iii) Radiation Monitoring Instrumentation

All access doors to the monitored areas shall be provided with display of beam mode (OFF, STANDBY, ON) and local radiation monitoring instrumentation. Any increase above the prescribed dose rate limits shall activate audio-visual alarms at these locations and warning to the operator.

*A.2.2.3 Work Area Zoning (for graded safety)*

Radiation hazards in the IARPF plant areas shall have graded safety requirements. Access to these work areas is regulated by categorising the

areas into different zones. Access control gates shall be put at inter-zone boundaries where entry of authorised persons is regulated e.g. with finger print impression or magnetic card. Various IARPF plant areas shall be categorized into one of the following zones:

- (i) Zone-1 : Normal Area of Full Occupancy  
These places shall be accessible all the time and irrespective of whether accelerator beam is in OFF, STANDBY or ON mode. These include places such as- control room, corridors and passages, plant process equipment rooms and product loading/unloading and storage areas. The biological shielding shall be so designed as to ensure that the radiation dose rate in such areas of full occupancy at any time, is below  $1 \mu\text{Svh}^{-1}$ .
- (ii) Zone-2 : Controlled/Restricted Entry Area  
These places are accessible during beam ON mode with appropriate administrative controls in place. Appropriate area monitoring and personnel radiation monitoring shall be provided for workers visiting these areas during beam ON mode. In these places, the dose rate during beam 'ON' may exceed  $1 \mu\text{Svh}^{-1}$  but shall not exceed  $10 \mu\text{Svh}^{-1}$ .
- (iii) Zone-3 : Inaccessible Areas  
These areas, having high dose rate during beam ON mode shall be designed and engineered with safety interlocks and administrative controls to exclude access and/or breach of safety during beam STANDBY/ON mode. Such places include accelerator beam channel and irradiation cell areas that have very high dose rates during beam ON mode.
- (iv) Only authorised persons shall be allowed to enter zone-2 and 3 areas and when so allowed they shall wear appropriate personnel radiation monitoring devices.

#### *A.2.2.4 Fire Safety*

##### *A.2.2.4.1 Fire hazards in product processing*

In case of interruption of beam versus product movement, engineered safety systems shall be designed with suitable monitoring and interlocks such that:

- (i) In case of failure of scanning magnetic field, the beam shall be immediately switched off to preclude overheating of beam window and product which may lead to fire hazard.
- (ii) In case of interruption of conveyor movement for any reason, the beam shall be immediately switched off similarly.
- (iii) There shall be a suitable provision for non-interceptive monitoring of beam at or near the processing location to limit the maximum beam energy and current used in the product processing, as per specifications of the safety envelope of the IARPF.

#### *A.2.2.4.2 Plant Fire Safety*

- (i) Flammable substances, solvents, oils, hydrogen, acetylene etc. shall be carefully stored and care shall be taken in housekeeping and storage of other materials, to avoid and control fire hazard in the IARPF.
- (ii) Fire protection shall be planned in terms of prevention, provisions for prompt detection and containment. Smoke detectors shall be installed at appropriate locations with alarm annunciation in control room.
- (iii) Adequate fire extinguishers around the fire susceptible areas shall be maintained. Proper training in firefighting shall be provided to operation personnel. Periodic demonstrations and fire drills shall be conducted.
- (iv) Power cables for use in the electron beam irradiation cell shall be of cross-linked fire-retardant low-smoke (FRLS) type. Other cables shall be protected against the degrading effects of ozone present therein.

#### *A.2.2.5 Ventilation System*

##### *A.2.2.5.1 Beam Window Air-cooling*

This shall require interlocking of beam window cooling by air/water circulation with the beam switch-ON. The exhausted air from beam window cooling contains high ozone content, and this shall be led to the exhaust stack of plant ventilation system.

##### *A.2.2.5.2 Plant Ventilation System*

- (i) Ozone (O<sub>3</sub>) and nitrogen oxides (NO<sub>x</sub>) and other toxic gases generated during radiation processing shall be continuously scavenged by means of a suitable ventilation system to minimize the concentration in the irradiation cell and likely gaseous diffusion into the occupied areas.
- (ii) Air handling units (AHU) of the ventilation system shall be designed to supply fresh air to various zones such that concentration of noxious gases are within permissible limits and also ensuring dissipation of heat from various power supply equipment.
- (iii) Ventilation (induced draft type) in the radiation cell shall be achieved by providing fresh air entry through grills/louvers and also incorporating exhaust fans (with standby provision) in the system.
- (iv) There shall be adequate number of fresh air changes in the radiation cell to prevent the concentration of O<sub>3</sub>, NO<sub>x</sub> and other toxic gases exceeding three times their Threshold Limit Values (TLV) during radiation processing.

- (v) Ozone monitors shall be provided in installations where Ozone concentrations are likely to be significant.
- (vi) Discharge point of the duct (stack outlet) of exhaust fans shall be located at a height appropriate to achieve dilution of Ozone to its Threshold Limit Value (TLV) while reaching ground level, but at least 2.5 m above the tallest part of the radiation processing facility.
- (vii) Time delay interlock shall be provided to prevent personnel entry into the radiation processing cell immediately after the beam switch off. The delay time shall be adequate to allow dissociation of Ozone and bring down its concentration below TLV (i.e. below 0.1 ppm for normal human activity, and 0.05 ppm for heavy work).
- (viii) Plant ventilation system shall consist of ventilation dampers to stop and isolate air-circulation in an area affected by fire. This shall stop spread of smoke and toxic fumes to other occupied areas, which shall be subsequently scavenged in a controlled manner after extinguishing the fire.

#### *A.2.2.6 Electrical Safety*

It shall be ensured that the plant design and operation are in compliance with the safety requirements of the applicable government regulations and local statutory body/agency on electrical equipment (both high and low voltage systems, radiofrequency and magnetic devices etc.) used in the IARPF.

#### *A.2.2.7 Low-conductivity Cooling Water (LCW) System*

The following safety provisions are required in an LCW system:

- (i) Accelerating cavity and RF power system of linac and internal tank systems of DC accelerator shall use cooling water which is conditioned for very low electrical conductivity, as per limits specified by equipment supplier to minimize the leakage of current from high voltage devices to the ground.
- (ii) There shall be safety interlocks with regulating instruments for temperature, flow and pressure of LCW, such that these shut the beam current under abnormal conditions.

### **A.3 Accelerator-Type Specific Requirements**

Two types of electron accelerators shall be applicable for use in the radiation processing facilities, namely (i) the DC high-voltage accelerator and (ii) the Linear RF accelerator. Specific facility configuration of plant equipment in these two types shall conform to the requirements as specified below:

#### **A.3.1 DC High-voltage Accelerator Systems**

This system utilizes high voltage DC power supply of rectifier-multiplier enclosed in a separate or the same tank as the accelerator channel.

#### *A.3.1.1 High-voltage Power System*

High-voltage power system shall be engineered to protect against arcing, electrical discharge and inadvertent contact with live/charged components by operation and maintenance personnel.

#### *A.3.1.2 Insulation and Cover System*

Insulation and cover gas systems shall use either sulphurhexa-fluoride ( $\text{SF}_6$ ) gas or, mixture of nitrogen and carbon di-oxide ( $\text{N}_2 + \text{CO}_2$ ). For any other cover gas system, specific approval of Competent Authority shall be required.

The following provisions for safety shall be implemented in the plant while using cover gases in an IARPF:

- (i) Gases shall be monitored for maintaining their purity in usage as recommended by the equipment supplier e.g. for moisture content, impurities, products of dissociation under likely high-voltage discharges.
- (ii) Gas temperature and pressure shall be continuously monitored, recorded and maintained within maximum and minimum specified for normal operation.
- (iii) Containment pressure vessels and connecting piping shall be provided with overpressure relief devices (e.g. safety valves, rupture disks), as recommended in the certification/statutory codes applicable for pressure vessel construction and operation.
- (iv) Gas-monitoring instrumentation and oxygen deficiency monitors with alarms shall be installed at locations where the likelihood of gas leakages or release due to overpressure safety device actuation exists.
- (v) The ventilation system shall have exhaust ducts running from the lowest elevation to collect and scavenge the leaked heavier-than air gases in the plant where the such gases are concentrated.
- (vi) All pressure components of the gas handling system shall be tested periodically for integrity of pressure as per the applicable statutory regulations.

#### *A.3.2 RF Linac Systems*

*A.3.2.1* The accelerating RF cavity which is subjected to heating due to RF power dissipation in its internal walls shall be provided with air/water cooling system to accurately maintain its temperature for satisfactory operation as electron linear accelerator.

#### *A.3.2.2 RF Power System*

- (i) RF power leakages being a potential source of electromagnetic interference, causing malfunction of sensitive instrumentation for radiation monitoring and process controls, shall be checked during



testing of accelerator systems, before and during commissioning of operations.

- (ii) For human exposures, limits of allowable RF radiation leakages shall be maintained as per internationally accepted limits such as those prescribed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). In general, leakage RF radiation power density limit of  $1 \text{ mw.cm}^{-2}$  shall be maintained at all times.
- (iii) RF power system and equipment shall be provided with separate ground/earthing to avoid electromagnetic interference with other devices.

## APPENDIX-B

### QUALITY ASSURANCE DURING OPERATION OF RADIATION PROCESSING FACILITY

#### B.1 Operational Checks

- (i) The operator shall perform the following checks each time prior to start up of radiation processing facility:
  - (a) Check for an emergency display or alarm, if existing, and attend to the cause. In no case shall an interlock be bypassed by the operator.
  - (b) Verify availability of motive power to source and product movement mechanism, and exhaust fan.
  - (c) Verify correct functioning of each constituent of personnel access system including radiation detector in the irradiation cell.
  - (d) Where applicable, verify availability of requisite quantity of emergency water supply system.
  - (e) Perform a physical check of the radiation cell prior to start up in a predetermined sequence in predetermined time.
  - (f) Carry a functional portable radiation survey while entering into the radiation cell.
- (ii) Means shall be provided to record the entry of persons into the radiation cell. CCTV surveillance shall be provided.
- (iii) Water samples from the circulation system and the water pool shall be routinely monitored for pH, conductivity and radioactive contamination and records of the observations shall be maintained.
- (iv) Ozone concentration in ambient air shall be monitored and recorded.
- (v)  $\text{NO}_x$  concentration in ambient air shall be determined if concentration is expected to be significant.
- (vi) In case of IARPF using  $\text{SF}_6$  or any other inert gases, oxygen deficiency monitoring shall be carried out.

#### B.2 Servicing and Maintenance

- (i) Adequate maintenance, testing and servicing shall be carried out as needed so that the radiation processing facility remains capable of meeting its design requirement for protection and safety throughout its life time.
- (ii) A formal program for regularly testing and maintenance of all safety systems shall be set up in accordance with the procedures and

schedules recommended by the designer/manufacturer to ensure correct performance of systems, subsystems and components of the radiation processing facility. The tests shall be carried out by appropriately qualified persons in the presence of the Radiological Safety Officer.

- (iii) Preventive maintenance shall include lubrication of all moving parts, inspection of source hoist wire ropes for its loose/frayed strands, inspection of electrical/instrument cables for their deterioration of insulation, inspection of heat/smoke detectors, level indicators and associated circuits.
- (iv) Portable survey meters and area monitors shall be calibrated before their first use, after repairs and at a regular interval of two years.
- (v) Weekly examination shall be made of source hoist cables/wire ropes and guide cables. Source hoist cables shall be replaced if any deterioration is observed during the periodic examinations.
- (vi) The radiation monitors for the storage pool water or the water treatment system shall be used as indicators of source leakage, or pool water samples may be collected for analysis.
- (vii) In the event of any failure or malfunctioning of any parameter important to safety, servicing and maintenance shall be carried out promptly. The facility shall not be used until all functions are restored and operating and radiation safety systems are tested and entries are made in the log book.
- (viii) Preventive maintenance to account for radiation damage to cables in industrial accelerator radiation processing facilities shall be carried out regularly.

### **B.3 Frequency of Service and Maintenance**

- (i) The operating and safety systems of the radiation processing facility shall be monitored for their smooth and accurate functioning. These systems shall be maintained as per the manual provided by the designer/supplier.
- (ii) The smooth removal/ insertion of shielding plugs provided for emergency handling on cell roof shall be tested at least once in two years and the observations recorded.
- (iii) Preventive maintenance of water sprinklers of fire fighting systems shall be carried at least once in a year for ensuring its proper functioning.
- (iv) The various systems shall be tested/checked for their intended function at the frequencies recommended in the Tables I (A) and I (B).

**TABLE-I (a)**

**FREQUENCY OF TESTS TO BE CARRIED OUT ON  
VARIOUS SYSTEMS OF GRAPF**

<b>Daily Tests</b>	<b>Weekly Tests</b>	<b>Monthly Tests</b>	<b>Quarterly Tests</b>	<b>Half Yearly Tests</b>
Radiation detector inside the cell	Start up sequence	All installed area monitors with a check source	Electrical and instrument cables for its deterioration of insulation	Inspection of entire length of source hoist and guide cable
Normal Water level of the source storage pool	Access control systems	Radiation mode access control interlock system	Piping in water pool and its clean up system	Source guard
Emergency switch on the control panel	Source hoist wire rope and guide cable	Product exit radiation monitor	Appropriate Fire extinguisher availability	Checking for proper functioning of all instruments including radiation monitors, conductivity monitor, temperature indicators, stop watches
	Water deionizer	Irradiator shut down controls	Fire-fighting equipment	Posted notices and symbols are still present, legible and clearly visible.
	Monitoring of radiation/ radioactivity at deionizer resin bed and at exhaust system	Back up access control system(s) such as pressure plate		
	Emergency stop switch inside the cell	Source rack position switches		
	Examination of source guard	Source hoist mechanism		
	Product box/carriers	Ventilation system		
		Water level control switches		

<b>Daily Tests</b>	<b>Weekly Tests</b>	<b>Monthly Tests</b>	<b>Quarterly Tests</b>	<b>Half Yearly Tests</b>
		Emergency stop devices at all locations		
		Audio-visual warning signals		
		Heat/smoke detectors		
		Defeat approved start up procedures to verify its proper functioning		
		Power failure and functional performance of UPS		
		Safety interlocks on removable shield plugs		
		Delay timer		
		Source and product movement system		
		Trip wire		

**TABLE-I (b)**

**FREQUENCY OF TESTS TO BE CARRIED OUT ON  
VARIOUS SYSTEMS OF IARPF**

<b>Daily Tests</b>	<b>Weekly Tests</b>	<b>Monthly Tests</b>	<b>Quarterly Tests</b>	<b>Half Yearly Tests</b>
Radiation detector inside the cell	Start-up sequence	All installed area monitors with a check source	Electrical power supplies and instruments, including cable checks for deterioration of insulation	Vacuum system leakage check of accelerator beam channel.
Pressure of insulation gas, if used, in accelerator and storage tanks.	Access control systems	Irradiation mode access control interlock system for accelerator and irradiation cell areas.	Piping and valves of cooling water (LCW) system and water quality.	Checking for proper functioning of all safety monitoring instruments including radiation and gas monitors, temperature indicators.
Emergency switch on the control panel	Water (LCW) deionizer plant	Product exit radiation monitor	Appropriate fire extinguisher availability at strategic locations.	Posted notices and symbols-whether these are present, legible and clearly visible.
	Emergency stop switch inside the cell	Irradiator shut down controls	Firefighting equipment	
	Product box/carriers	Back up access control system(s)		
		Trip wire		
		Ventilation system		
		LC Water inventory, flow & pressure control switches		
		Emergency stop devices at all locations		

Daily Tests	Weekly Tests	Monthly Tests	Quarterly Tests	Half Yearly Tests
		Audio-visual warning signals for accelerator start up, high radiation level in areas.		
		Heat/smoke detectors		
		Approved start up procedures to verify its proper functioning		
		Power failure and functional performance of UPS (if any)		
		Safety interlocks on any removable shield plugs		
		Delay timer for access regulation in designated areas.		
		Safety interlocks for beam scanning and product movement system		

## BIBLIOGRAPHY

1. ATOMIC ENERGY ACT, 1962 (33 of 1962)
2. ATOMIC ENERGY (RADIATION PROTECTION) RULES, 2004 (G.S.R. 303)
3. ATOMIC ENERGY REGULATORY BOARD; its powers and functions: Constitution Order by Government of India (Order No. 25/2/83-ER dated 15.11.83), S.O. 4772, 1983.
4. ATOMIC ENERGY (SAFE DISPOSAL OF RADIOACTIVE WASTES) RULES, 1987 (G.S.R. 125).
5. ATOMIC ENERGY (RADIATION PROCESSING OF FOOD AND ALLIED PRODUCTS) RULES, 2012 (G.S.R. 158).
6. ATOMIC ENERGY REGULATORY BOARD, Safety Guide on 'Consenting Process for Radiation Facilities', No. AERB/RF/SG/G-3, Mumbai, India (2011).
7. ATOMIC ENERGY REGULATORY BOARD, Safety code for 'Operation and Maintenance of Land Based Stationary Gamma Irradiators' NO. AERB-SC-IRRAD, Mumbai, India (1993).
8. ATOMIC ENERGY REGULATORY BOARD, Safety Standard on 'Land-based Stationary Gamma Irradiators' No. AERB/RF-IRRAD/SS-6 (Rev.1), Mumbai, India, (2007).
9. ATOMIC ENERGY REGULATORY BOARD, Safety Guidelines on 'Accelerators' No. AERB/SG/IS-5, Mumbai, India, (2007).
10. ATOMIC ENERGY REGULATORY BOARD, Safety Code for 'Safe Transport of Radioactive Material', No. AERB/NRF-TS/SC-1 (Rev.1), Mumbai, India, (2015).
11. ATOMIC ENERGY REGULATORY BOARD, Safety Guide on 'Compliance Assurance Programme for Safe Transport of Radioactive Material', No. SG/TR-1, Mumbai, India (1991).
12. ATOMIC ENERGY REGULATORY BOARD, Safety Standard for 'Testing and Classification of Sealed Radioactive Sources', No. AERB/SS/3 (Rev.1), Mumbai, India (2001).
13. ATOMIC ENERGY REGULATORY BOARD, Safety Guide on 'Security of Radioactive Sources in Radiation Facilities', No. AERB/RF-RS/SG-1, Mumbai, India (2011).
14. ATOMIC ENERGY REGULATORY BOARD, Safety Guide on 'Security of Radioactive Material during Transport', No. AERB/NRF-TS/SG-10, Mumbai, India (2008).



15. INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Standard on 'Radiation Safety of Gamma, Electron and X-ray Irradiation facilities', No. SSG-8, IAEA, Vienna, Austria (2010).
16. NATIONAL HEALTH AND RESEARCH COUNCIL, Code of Practice for 'Design and Safe Operation of Non-medical Irradiation Facilities' Australia (1988).

## LIST OF PARTICIPANTS

### Initial draft Prepared by:

Shri S.P. Agarwal : AERB (Former)

### Draft Documents Review by:

Shri D.M. Rane : AERB  
(Co-ordinator for Development of Code)

Shri Pravin J. Patil : AERB

Shri J.V.K. Sunil Kumar : AERB

Shri Meghraj Singh : AERB

Smt. Kadambini Devi : AERB

Shri Ganesh Bokam : AERB

## SAFETY REVIEW COMMITTEE FOR RADIATION PROCESSING PLANTS (SRC-RPP)

Dates of meeting: September 9, 12, 16 & 25, 2014  
October 17, 2014

### Chairman and Members of SRC-RPP:

Dr. A.N. Nandakumar (Chairman) : AERB (Former)

Dr. D.N. Sharma : BARC (Former)

Dr. A.K. Sharma : BARC (Former)

Shri P.K. Nema : BARC (Former)

Dr. R. Baskaran : Indira Gandhi Centre For  
Atomic Research (IGCAR),  
Kalpakkam

Shri L.N. Bandi : BRIT

Dr. A.U. Sonawane (Member-Secretary) : AERB

Shri R.K. Yadav (Invitee) : AERB

**STANDING COMMITTEE FOR REVIEW AND  
REVISION OF AERB RADIATION SAFETY  
DOCUMENTS (SCRRSD)**

Date of meeting: December 8, 2014

**Chairman and Members of SCRRSD:**

Shri A.R. Sundararajan (Chairman)	:	AERB (Former)
Dr. D.N. Sharma	:	BARC (Former)
Dr. B.C. Bhatt	:	BARC (Former)
Shri P.K. Nema	:	BARC (Former)
Dr. M.G.R. Rajan	:	BARC
Shri D.A.R. Babu	:	BARC (Former)
Dr. A.U. Sonawane	:	AERB
Dr. (Smt.) Jain Reji George	:	BRIT
Shri V. Mohan	:	AERB
Smt. V. Anuradha	:	AERB
Shri R.K. Chaturvedi (Member Secretary)	:	AERB

**ADVISORY COMMITTEE ON RADIOLOGICAL  
SAFETY (ACRS)**

Date of meeting : February 2, 2015

**Chairman and Members of ACRS:**

Dr. U.C. Mishra (Chairman)	:	BARC (Former)
Shri A.R. Sundararajan	:	AERB (Former)
Dr. M.R. Iyer	:	BARC (Former)
Dr. D.N. Sharma	:	BARC (Former)
Dr. Sudhir Gupta	:	Directorate General of Health Services, New Delhi
Shri S.P. Agarwal	:	AERB (Former)
Dr. S. Shrivastava	:	Tata Memorial Hospital, Mumbai
Dr. A.U. Sonawane (Member-Secretary)	:	AERB
Shri R.K. Chaturvedi (Invitee)	:	AERB

**LIST OF REGULATORY SAFETY DOCUMENTS ON  
RADIATION PROCESSING FACILITIES**

Safety Series No.	Title
AERB/RF-RPF/SC-1	Radiation Processing Facilities
AERB/SC/TR-1	Transport of Radioactive Material
AERB/SC/G	Regulation of Nuclear and Radiation Facilities
AERB/RF-IRRAD/SS-6 (Rev.1)	Land-based Stationary Gamma Irradiators
AERB/RF-RPF/SG-1	Plant Commissioning/Re-commissioning Dosimetry for Food & Allied Products in Gamma Radiation Processing Facilities-Type II & IV
AERB/RF-RPF/SG-2	Gamma Irradiation Chambers
AERB/SG/IS-5	Safety Guidelines on Accelerators
AERB/RF/SG/G-3	Consenting Process for Radiation Facilities
AERB/SG/G-4	Regulatory Inspection and Enforcement in Nuclear & Radiation Facilities
AERB/SG/G-5	Role of Regulatory Body with respect to Emergency Response and Preparedness at Nuclear & Radiation Facilities
AERB/RF/SM/G-3	Regulatory Inspection and Enforcement in Radiation Facilities

**AERB SAFETY CODE NO. AERB/RF-RPF/SC-1 (Rev. 1)**

*Published by:* Atomic Energy Regulatory Board,  
Niyamak Bhavan, Anushaktinagar.  
Mumbai – 400 094