DRAFT

AERB SAFETY GUIDE NO. AERB/RF-RQTL/SG-1

QUALIFICATION AND TRAINING OF PERSONS IN RADIATION FACILITIES AND THEIR APPROVAL/ LICENSING PROCESS

Atomic Energy Regulatory Board
Mumbai 400 094
India

August 2018

This Page is intentionally kept Blank

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 come 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.

This safety guide provides the minimum desirable basic and professional qualifications for radiation professionals/workers in radiation facilities. This guide further addresses the adequacy of personnel in radiation facilities, their roles & responsibilities, approval/licensing and renewal process to ensure that the use of radioactive sources and radiation generating equipment in radiation facilities does not cause undue risk to the health of people and environment. The infrastructure requirements for institutions conducting radiation safety training courses and detailed syllabi are also provided in this safety guide.

Consistent with the accepted practice, ‘should’ is used in the safety guide for a desirable option. Appendices are integral part of the document, whereas Annexure and bibliography are included to provide further information on the subject that might be helpful to the user(s).

The guide has been prepared by AERB working group and reviewed by Safety Committees of AERB, viz. Safety Committee on Applications of Radiation (SARCAR) and Advisory Committee on Nuclear and Radiological Safety (ACNRS).

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

(S.A. Bhardwaj)
Chairman, AERB

SPECIAL DEFINITIONS

(Specific for the present 'Safety Guide)

Adequate Training

The training as mentioned in this safety guide; and the expression 'adequately trained' should be similarly construed.

Approval/Licensing

The process of registering as radiation professional/radiation worker with the Regulatory Body after successful completion of the qualification and training as mentioned in this safety guide, or its revision(s) thereof.

Auxiliary Staff

The persons' whose role is not defined in this guide but are identified as supporting staff in activities involving use of ionizing radiation and hence need training in radiation protection. These include nurses, anesthetists providing support to a patient undergoing an interventional procedure, attendants and trainees. Carers/Comforters to patients undergoing radiological procedures, although they may not be the institutional staff, are included in this definition.

Diagnostic Radiology (DR) Facilities

Diagnostic Radiology facilities comprises of various types of X-ray equipment used for different diagnostic applications. [Radiography/Fluoroscopy/Mammography/Dental/BMD/C-Arm/Computed Tomography (CT)/ Interventional Radiology (IR)].

Radiation Facility

Any installation/equipment or a practice involving use of radiation-generating equipment or use of radioisotopes in the field of research, industry, medicine and agriculture.

Radiation Professional

Radiation Professional is a person who possesses the eligibility criteria as specified by AERB for carrying out the specific roles and responsibilities with respect to safe operation of radiation source(s) in radiation facility(ies)

Radiation Professional may include:

a. *Person(s) who handle/operate the radioactive sources/radiation generating equipment as per written instructions and established standard operating procedures and who carries out any practical aspect of the device operations as per the role defined in this document (including quality assurance in case the role demands so)*
b. *Expert(s), who, as appropriate, acts or gives advice on optimization of doses, patient dosimetry, development and use of complex treatment techniques and equipment, quality assurance, and other matters relating to radiation protection within the scope of this document*

c. *Medical practitioners (including dental practitioners) registered with the appropriate Health Authorities, having specialized educational qualification (as acknowledged by the relevant professional body or health authority)and training in the medical uses of radiation and radiation protection, who is competent to perform independently or to oversee radiological procedures in a given specialty and take responsibility for an individual medical exposure*

Registered Radiation Professional

Radiation Professional who is duly registered with AERB for handling of radiation sources in radiation facilities

Radiation Safety Certification

It is the process of certification of candidates based on successful completion of class room training through recognized agency.

Radiation Safety Evaluation

It is the process of evaluation, through examination or from evidence of continuous education, to ensure that the candidates possess (and maintain) adequate training and instructions in radiation safety to perform their intended task, after acquiring the requisite professional qualification.

Radiological Safety Officer

A person technically competent in radiation protection matters relevant for a given type of practice, who is designated by the employer to oversee the application of regulatory requirements, with due approval from the Competent Authority.

Recognized Institute/Agency

Any institute or agency engaged in providing training/certification in radiation safety as per the criteria stated in this safety guide or its revision(s) thereof.

Related Medical Practitioner (Diagnostic Radiology)

A medical practitioner related to an appropriate area of expertise i.e. interventional radiologist for image guided interventional radiological procedures (diagnostic, therapeutic or both). Also included are orthopedic and radiology specialists in the case of diagnostic radiology, and cardiologists, urologists or neurologists etc. in the case of image guided interventional procedures.

Well Equipped Department

A department with requisite infrastructure for conducting radiation safety training/internship programme for the intended purpose.

CONTENTS

1. INTRODUCTION

1.1 General

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. The use of ionizing radiation for medical, industrial, research and such other purposes has been immensely beneficial to the society. While radiations have beneficial uses, the use of radiation is also associated with a potential risk. Therefore, there has been a continual attempt towards minimizing radiation doses to individuals such that the benefits accrued to the society always outweigh the risks.

In this regard, professionals who are to be responsible for use of the technology should have an adequate level of understanding of concepts relating to radiation protection and should also be acquainted with the procedures for safe and secure use of radiation sources. Some of these professionals are authorized by AERB to carry out certain functions or assume certain responsibilities. This Safety Guide addresses training in protection and safety aspects with respect to the radiation application technologies. The basic education and professional training in the use of the technology may itself, in general, be beyond the mandate of AERB. However, a certain level of education (i.e. basic qualifications) or professional training are considered a pre-requisite to be able to get trained for achieving radiation protection during the use of radiation sources.

The AERB, as per Atomic Energy (Radiation Protection) Rules, 2004 [AE(RP)R, 2004] promulgated under Atomic energy Act, 1962, is required to regulate safety from radiations as a national responsibility in activities such as medical, industrial or other uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste.

In this respect, one of the conditions precedent to issuance of license for operation of radiation facility is that workers have appropriate training and instructions in radiation safety, in addition to the appropriate qualification and training required for performing their intended tasks. Worker in the context of AE(RP)R, 2004 means a radiation worker, who is a person(s) occupationally exposed to radiation and includes persons with professional training pertaining to the relevant radiation practice and also other supporting persons who may not have undergone such training.

Radiation protection and, more generally, the achievement of a high standard of safety for all those who are likely to be exposed to radiations in various practices depends greatly on the performance of certain individuals including corresponding overall institutional arrangements. As an example for use of radiation in medical field the parties who have roles and responsibilities for safety are employers, the licensee, medical practitioners, other qualified experts (e.g. Medical Physicists, Radiation Safety Officers); manufacturers and suppliers, and other parties with specific responsibilities. Similar set of individuals and institutional arrangement exists in industrial and other practices where radiations are in use. The responsibilities of Employer, Licensee etc. are covered in AE(RP)R, 2004. Qualification, training and competencies of other main Radiation Professionals/workers who play a vital role in meeting this objective are covered in this guide.

The terminology used for addressing radiation workers in this safety guide are based on the roles and responsibilities that they are required to fulfill in their respective practice, as stipulated in this document. This has no bearing with their actual designation/nomenclature at workplace. It should be noted that their actual designation at respective institutions/ workplaces is the sole discretion of the employer and hence are outside the purview of this document. For example, the employer may designate a person carrying out a specific role such as operating a medical diagnostic X-ray equipment as *Technologist*, *Radiographer*, *Technical Officer* or any other designation as per the policies of the organization. Designations such as Operator, Site in Charge, Technologist, Medical Physicist, Radiologist, Radiation Oncologist and Nuclear Medicine Physician etc. are normally in use in radiation facilities.

In case a professional is/may be assigned multiple role(s) in a radiation facility, s/he should fulfill all the responsibilities of these roles concurrently. To further clarify, where a single person acts as employer, licensee, RSO or any other radiation worker concurrently (or in any combination of these or other roles), in addition to the responsibilities of employer as specified in AE(RP)R, 2004, s/he should comply with all the responsibilities placed on the Licensee, RSO or the radiation worker accordingly.

In addition to the radiation professionals, this safety guide also specifies the safety awareness/training to be imparted for the workers playing supporting role(s) in radiation facilities.

1.2 Objective

The radiation workers, including Radiation Safety Officer, fulfilling the practice specific qualification and training as stipulated in this safety guide are identified herein as 'Radiation Professionals' (RP). These RP register with AERB through an RP registration process available in the e-licensing platform i.e. e-Licensing of Radiation Applications (e-LORA) of AERB. The Radiation Safety Officer is also responsible to provide and monitor effectiveness of appropriate protection and safety to other radiation workers who play supporting role(s) in radiation facilities (such as nurses in Cath-lab, helpers in industrial radiography etc.).

This safety guide provides the minimum desirable basic and professional qualifications for radiation professionals/workers in radiation facilities. Although qualifications stated in this document are from a radiation safety perspective, certain desired basic and/or professional qualifications are also stated herein, keeping in view that the radiation workers have a potential to understand and relate to the radiation physics, radiation protection and safety aspects of their practice and are capable of qualifying in the required radiation protection aspects of their intended tasks. This guide further addresses the adequacy of personnel in radiation facilities, their roles & responsibilities, approval/licensing and renewal process to ensure that the use of radioactive sources and radiation generating equipment in radiation facilities does not cause undue risk to the health of people and environment. The Atomic Energy (Radiation Protection) Rules, 2004, provides the legal framework for the safe handling of radiation sources.

One of the objective is also to revise and harmonize the existing syllabi on radiation safety for various radiation practices taking into account of recent advancement in technology, regulatory aspects and other relevant aspects.

1.3 Scope

This safety guide is applicable to radiation workers, practices or radiation facilities involved in the use of radiation sources for authorized purposes including medical, industrial, agricultural, research and other such purposes. It addresses the following aspects of radiation facilities from radiological safety standpoint.

(i) Radiation professional/worker required for a particular practice
(ii) Desirable qualification of a radiation professional/worker
(iii) Qualification and training with regard to radiation protection for specific practice
(iv) Adequacy (minimum number) of radiation professionals/workers in a practice
(v) Roles and responsibilities of radiation professional/worker
(vi) Approval/Licensing and re-licensing of radiation professional/worker

For the institutions conducting educational programmes/professional courses for radiation workers and training programs in radiological safety, the following aspects are addressed in this document:

(a) Desirable entry level qualification and duration of the professional course
(b) Radiological safety syllabi to be incorporated in the professional course
(c) Infrastructure in the professional course conducting institution for imparting the requisite education and training in radiological safety.

The aspects addressed herein are the minimum essential from radiological safety perspective only. The technical and clinical aspects of the courses are beyond the scope of this Safety Guide. Qualification, training and other aspects related to radiation workers/safety personnel involved in nuclear facilities are also beyond the scope of this Safety Guide.
This safety guide is effective from the date of its issuance unless otherwise specified by the AERB and supersedes all the earlier provisions in this aspect. It may also be noted that the qualification(s) prescribed in the present document will not affect the radiation workers/ professionals currently engaged in radiation facilities, but who may not be meeting the qualifications specified in this safety guide for their respective practice, as on date.

However, the criteria as specified in this safety guide will be applicable during re-licensing of the existing radiation professionals/workers.

1.4 Structure

This document is in three sections i.e. section A, B and C. Section A consists of 13 chapters. The first chapter gives the general introduction, objective, scope and relevant terms used in this document. The subsequent chapters address the radiation workers' qualification, training, approval/licensing and renewal process and their roles & responsibilities in respective radiation facilities. Section B is consisting of 5 Appendices which mention the minimum infrastructure to be available at the institution/agency for imparting the requisite radiation safety education and training in the relevant practice(s). The infrastructure for radiation safety training for medical practitioner is not addressed, since this aspect is covered by relevant authority.

The Annexures 1 to 16 in section C prescribes the minimum radiation safety syllabi to achieve consistency and harmonized training to the concerned persons that should be included in the curricula of educational/training institutions conducting professional/radiation safety training courses.

Section A: QUALIFICATION, TRAINING, ADEQUACY, APPROVAL/LICENSIN(AND RESPONSIBILITIES OF PERSONNEL

2. PERSONNEL IN DIAGNOSTIC RADIOLOGY (DR) FACILITY AND THEIR RESPONSIBILITIES

2.1 Introduction

Diagnostic radiology (DR) accounts for the largest fraction of human exposure to ionizing radiation from man-made sources. A large number of diagnostic radiology facilities are operational all over the country which are highly diverse in nature, with respect to their application and associated hazard potential. Ionizing radiations play significant and indispensable role in diagnosis and therapy. It must be noted that excessive radiations may be harmful to the radiation workers and general public. These need to be used with due justification, optimization of radiation protection and safety based on established guidelines, so that maximum benefits are derived with acceptable radiological risk. Well qualified and train personnel are required to address clinical aspects and safe operation of the equipment. Other experts on QA and dose optimization aspects are required to ensure the radiation safety in the use of various X-ray equipment. The eligibility criteria for employing these personnel are required to be concomitant with the likely hazard potential associated with the practice.

The basic objective of the use of X-rays in diagnostic radiology is to obtain optimum diagnostic information with minimum exposure to the patient and the occupational workers. In order to achieve this objective, use of Type Approved equipment, periodic quality assurance tests of diagnostic X-ray equipment and proper training to radiological staff and service engineers/personnel are necessary. Therefore, a radiation safety module is prepared for personnel involved in operation of medical diagnostic X-ray equipment, quality assurance, servicing & maintenance and for medical practitioners involved in performing/reporting the radiology investigations.

There are two training modules designed for the radiation professionals in this field based on their roles and responsibilities. These modules are 'Basic Radiation Safety' for registration as Radiation Professional in DR and 'Advanced Radiation Safety' for acquiring eligibility to perform the role of Service Personnel/RSO in DR practice.

The detailed syllabi is provided in other section. These courses are designed to cover the syllabus with respect to radiation safety only, the syllabus with respect to other subjects of the profession should be as per the requirements of affiliating University/Board.

Regulated Utilities: X-ray user facility, Manufacturer, Supplier/Service agency of X-ray equipment.

2.2 Radiation Workers (Personnel in Diagnostic Radiology Facility)

(i) The diagnostic radiology team includes qualified and trained specialists for image acquisition, quality assurance, dose optimization and other aspects. These specialists should have appropriate qualification and training required for performing their intended task as specified by relevant authorities of India. (wherever such qualification and training are not specified by any authority, the minimum qualification specified in

this document should be considered). As mentioned in Section 1.1 of Chapter 1, the above specialists, being radiation workers, should have appropriate training and instruction in radiation safety as specified by AERB.

This team is also required to ensure that diagnostic radiology procedures are carried out with due regard to radiation safety as per AERB regulations. For this purpose, minimum of two categories of Radiation Professionals (RP) with relevant training and expertise in safe handling of radiation equipment/sources are required in DR facility. They are identified herein as Radiation Professional-DR (i.e.RP-DR-1 and RP-DR-2) as explained in subsequent sections. Further, there should be adequate number of radiation professionals to ensure that the safety is not compromised.

For dental clinics/dental hospitals where personnel requirements may be different from full-fledged DR facilities and the related medical practitioner (Dentist) generally needs to operate the unit, s/he is identified as Radiation Professional-DR-3 (RP-DR-3).

The personnel involved in servicing and maintenance of DR equipment, should also be trained in the radiation safety aspects, who are identified in the following paragraphs as Radiation Professional-DR-Service personnel (RP-DR-S).

(ii) This terminology used for addressing the roles of radiation professionals has no bearing with their actual designation/nomenclature given by the institution. It is in the prerogative of the institution to assign additional functions such as teaching, research, safety awareness training and other related activities and designate them.

(iii) The minimum desirable professional qualification for the DR facility personnel stated in this chapter are for its safe operation from a radiation protection perspective. Further, the desirable basic (entry level) academic qualifications for undergoing the professional training course is also mentioned here, keeping in view that the radiation workers have a potential to understand and relate to the radiation physics, radiation protection and safety aspects of their practice and are capable of qualifying in the required radiation protection aspects of their intended tasks.

This section provides minimum desirable qualification, radiation safety certification process, adequacy of personnel, including their approval/licensing process, roles and responsibilities of radiation professionals in DR practice. Adequacy suggested here is based on the normally encountered workload of the practice and complexity of the techniques.

The infrastructure necessary for course conducting agency and minimum radiation safety syllabi for the training courses are specified in **Appendix 1 and Annexure 2** respectively.

2.2.1 Radiation Professional-Diagnostic Radiology-1 (RP-DR-1)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) A basic degree in medicine (MBBS); and

(ii) A post-graduate degree in Radiology or related Medical Practitioner in Diagnostic Radiology or an equivalent

Radiation Safety Certification:

(i) RP-DR-1 should successfully complete 'Basic Radiation Safety Module' through radiation safety evaluation as prescribed by AERB.

Adequacy of Personnel:

(i) Every DR facility with fluoroscopy or computed tomography (CT) equipment should have the services of RP-DR-1, for interpretation and reporting.

Approval /Licensing and Renewal:

(i) The RP-DR-1 should register as radiation professional (RP) with AERB, based on successful completion of safety evaluation.
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

RP-DR-1 have a particular responsibility towards patients, their relatives and carers to practice in a way which promotes the safe use of radiation for the purposes of diagnosis and therapy. S/he should ensure that X-ray examination is carried out on the basis of medical requirement and the provisions of the current regulations or modified thereafter are complied with. Responsibilities of RP-DR-1 includes:

(i) Being able to justify the net benefit of the diagnostic investigation or therapeutic treatment that it produces sufficient benefit to the exposed individuals to offset the radiation detriment it causes, and especially in case of patients who are young or pregnant, due to the known radio-sensitivity and longer life expectancy of the embryo, fetus, or young person
(ii) Accepting referrals for diagnostic imaging only from a person authorized/competent to make such a request
(iii) Being satisfied that the necessary clinical information is not available from the patient's previous examinations, or from any other alternate medical tests or investigations not involving the use of ionizing radiation
(iv) Being conscious of the patient dose and for any given examination and should attempt to be in line with international reference levels or those recommended by the regulatory body
(v) In case of patient undergoing Interventional Radiology (IR) procedures, ensure that informed consent is obtained from the patient/relatives of the patient on the probable radiological risk
(vi) Undergoing equipment specific training through the supplier prior to commissioning of X-ray equipment, and specifically for Interventional Radiology and Computed Tomography equipment
(vii) Being aware of the radiation risk (such as skin injuries to patient) from IR procedures and take appropriate measures for avoiding the same
(viii) Monitoring the patient doses especially in CT and IR procedures for optimization and avoidance of radiation injuries during complex procedures
(ix) Periodically evaluating medical procedures for possible reduction of doses, especially for pediatric procedures

(x) Optimizing the exposure protocols during diagnostic investigation or therapeutic treatment so as to achieve good clinical outcomes and acceptable quality images with the lowest possible radiation dose to patient

(xi) Undergoing training provided by the RSO towards radiation protection and optimization of patient doses

(xii) Complying with radiation management plans/protocol established at the practitioner's place of practice

(xiii) Additionally, fulfilling all the responsibilities of RP-DR-2 as specified in the relevant section(s) of this document, in specific examinations/practices which require the equipment to be operated by him/her.

2.2.2 Radiation Professional-Diagnostic Radiology-2 (RP-DR-2)

2.2.2.1 RP-DR-2

[In Diagnostic Radiology facilities including Computed Tomography (CT) & Interventional Radiology (IR)]

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) 10+2 or an equivalent examination passed with Science subject from a recognized Board; and

(ii) Two years' Radiographer's/ X-ray Technologist's course with in-field training in all modalities of diagnostic radiology including CT & IR or an equivalent course passed from a recognized Board/University/Institution incorporating minimum radiation safety syllabi as prescribed by the AERB.

OR

(i) 10+2 or an equivalent examination passed with Science subject from a recognized Board; and

(ii) One year Radiographer's/ X-ray Technologist's course with in-field training in all modalities of diagnostic radiology or an equivalent passed from a recognized Board/University/Institution incorporating minimum radiation safety syllabi as prescribed by the AERB; and

(iii) Two years on-job training in well-equipped CT & IR facility.

Adequacy of Personnel:

(i) One RP-DR-2 per each CT/IR equipment in the Diagnostic Radiology Facility.

(ii) Number of RP-DR-2 should be proportionally enhanced with additional X-ray equipment or patient load.

2.2.2.2 RP-DR-2

(In Diagnostic Radiology facilities excluding CT& IR)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) 10+2 or an equivalent examination passed with Science subject from a recognized Board; and

(ii) One year Radiographer's/ X-ray Technologist's regular course with in-field training in all modalities of diagnostic radiology or an equivalent passed from a recognized Board/University/Institution incorporating minimum radiation safety syllabus as prescribed by AERB.
Or;
RP-DR-2 including (CT/IR) as per section 2.2.2.1

{Note: (a) The course should be a full time regular course incorporating minimum radiation safety syllabi prescribed by AERB.

(b) Professional course(s) as stated above through Distance education or correspondence mode are not acceptable.

(c) Qualification for personnel as prescribed in the present document will be implemented in a phased manner for DR facilities and will not affect the existing radiation workers/ professionals who may not be meeting these qualifications as on date. However, their re-licensing will be as per this safety guide. The implementation of this safety guide will be effective for all DR facilities one year form the date of its issuance. DR facilities should assess and align their facilities in line with this safety guide during the interim period.}

Radiation Safety Certification:

(i) RP-DR-2 (as per Section 2.2.2.1 and 2.2.2.2) should successfully complete 'Basic Radiation Safety Module' through radiation safety evaluation as prescribed by AERB.

Adequacy of Personnel:

(i) One RP-DR-2 for each facility possessing up to three X-ray equipment (conventional type)

(ii) Number of RP-DR-2 should be proportionally enhanced with additional X-ray equipment or patient load.

2.2.2.3 Radiation Professional-Dental X-ray-3 (RP-DR-3)

Minimum Qualification:

(i) Qualification recognized by the relevant authority of India for related medical practitioner in dental radiology; or

(ii) RP-DR-2 {as per above sections (2.2.2.1 or 2.2.2.2 }

Radiation Safety Certification:

(i) RP-DR-3 should successfully complete 'Basic Radiation Safety Module' through radiation safety evaluation as prescribed by AERB.

Note: Persons already registered as RP-DR-2 need not undergo additional safety evaluation to perform the role of RP-DR-3.

Adequacy of Personnel:

(i) One RP-DR-3 or RP-DR-2 for each facility possessing up to three dental X-ray equipment.
(ii) Number of above professionals should be proportionally enhanced with additional dental X-ray equipment or patient load.

Approval/ Licensing and Renewal:

(i) RP-DR-2 and RP-DR-3 should register as radiation professional (RP) with AERB, based on successful completion of safety evaluation.
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RP-DR-2 and RP-DR-3 should ensure that the provisions of the current safety regulations or modified thereafter are complied with. For safety during operation of the X-ray equipment, his/her responsibilities include:

(i) Providing to the employer information about his previous occupations including radiation work, if any
(ii) Undergoing training provided by the supplier and RSO towards appropriate exposure parameters and dose reduction protocols
(iii) Operating the DR equipment as per the standard operating procedures (SOP)
(iv) Using appropriate exposure parameters for adult and pediatric X-ray examinations
(v) Using appropriate protective devices (protective barrier/protective apron etc.) during operation of X-ray equipment
(vi) Using personnel monitoring devices appropriately and monitor dose received. Use TLD only in the facility for which it is issued and do not share it with other personnel or DR facilities. Securely stored TLD badges at a designated place away from radiation area when not in use
(vii) Informing RSO and the Licensee of any accident or potentially hazardous situation that may come to his/her notice. These may include higher leakage radiation, use of inappropriate collimators/dental cones, non-functioning of the collimator/collimator bulb etc.
(viii) Female worker notifying the employer, licensee and RSO on becoming aware of her pregnancy, in order that her working conditions may be modified, if necessary;
(ix) Undertaking periodic review of work practice (performance of the equipment, review of exposure protocols, means to avoid repeat exposures) towards optimization of patient doses and image quality, and
(x) Participating during the periodic quality assurance tests of X-ray equipment.

2.2.3 Radiological Safety Officer (RSO) for DR Facility:

Eligibility Criteria and Safety Certification:

(i) RP-DR-1, RP-DR-2 or RP-DR-3 registered as radiation professional (RP) with AERB; and

(ii) Successful completion of 'Advanced Radiation Safety Module' through radiation safety evaluation as prescribed by AERB.

Or;

(i) Registered Service personnel in DR (as per section 2.2.4); and

(ii) Successful completion of 'Radiation Safety Training Course in QA and Safety Aspects of DR Equipment' from an agency recognized by AERB

Or;

(i) Registered Radiation professional approved or eligible to function as Radiological Safety Officer in Radiotherapy/Nuclear Medicine facility.

(Note: (i) Registered RP-DR-3 is eligible to be nominated as RSO only for dental X-ray facilities

(ii) The registered RP approved or eligible to function as Radiological Safety Officer in Radiotherapy/ Nuclear Medicine facility need not to undergo 'Advanced Radiation Safety Module'.)

Adequacy of Personnel:

(i) Each Diagnostic Radiology facility including Dental X-ray facility should have a Radiological Safety Officer (RSO).

Approval/Licensing and Renewal:

(i) Registered radiation professional (RP) with safety certification should obtain an approval from Competent Authority to function as Radiological Safety Officer.

(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

2.2.4 Radiation Professional-Diagnostic Radiology Service Personnel/ RSO (for Manufacturer/ Supplier/Service Agency) (RP-DR-S)

2.2.4.1 Service Personnel:

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Basic degree in Science with physics as one of the subject from a recognized University/ Institution

Or

Diploma in Engineering in an associated discipline or an equivalent qualification from a recognized University/Institution.

(ii) Minimum 6 month field experience in Diagnostic Radiology, preferably in QA aspects.

Radiation Safety Certification:

(i) Successful completion of 'Radiation Safety Training Course in QA and Safety Aspects of DR Equipment' from an agency recognized by AERB.

Adequacy of Personnel:

(i) One registered RP-DR-S for each manufacturing site /each supplier involved in radiation testing, QA, servicing & maintenance of X-ray equipment.
(ii) Supplier/service agencies involved in providing only QA services of DR equipment should have adequate number of registered RP-DR-S to ensure that QA is carried out only by experienced and certified personnel in radiation safety and QA aspects.

Approval/Licensing and Renewal:

(i) The RP-DR-S should register as radiation professional (RP) with AERB based on successful completion of radiation safety certification and six months field experience in QA, servicing & maintenance of diagnostic equipment, supported by personnel monitoring service.
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period. The renewal is based on refresher training and evaluation.

Role and Responsibilities:

The service personnel has following responsibilities:

(i) Involve in commissioning/ servicing/ maintenance/ quality assurance/ decommissioning of X-ray equipment adhering to manufacturers specification, procedures and adhering to regulatory and radiation safety requirements
(ii) During commissioning of X-ray equipment check that:
  - shielding adequacy of the layout is verified
  - acceptance tests are carried out as per prescribed format
  - availability of protective accessories is verified.

(ii) Ensure that periodic QA/acceptance testing is witnessed by technical personnel from the user institution and the report is endorsed and handed over to the RSO/employer/licensee
(iii) Carry out all repair and maintenance procedures as per the manufacturer' specifications or applicable standards
(iv) Demonstrate the functionality of the equipment after repair or maintenance work and carry out relevant QA tests
(v) Record and communicate any design faults such as high leakage radiation of equipment, inadequate shielding, non-availability of protective accessories etc. to the employer and RSO and supplier for necessary corrective actions, and
(vi) Provide operational safety training for radiation protection to the relevant staff to ensure patient and operator safety.

2.2.4.2 Radiological Safety officers (Manufacturer/ Supplier/Service Agency)

Approval/Licensing and Renewal:

(i) RP-DR-S registered with AERB should obtain an approval from Competent Authority to function as Radiological Safety Officer (RSO).
(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Adequacy of Personnel:

(i) Each manufacturing site /supplier involved in radiation testing, QA, servicing & maintenance of X-ray equipment at their premises should have a Radiological Safety Officer (RSO).

Role and Responsibilities:

The RSO, with due adherence to the provisions of current safety regulations or modified thereafter, has the following responsibilities:

(i) Carry out routine measurements and analysis on radiation safety of the radiation installation and maintain records of the results thereof
(ii) Investigate any situation that could lead to potential exposures
(iii) Prepare and make available periodic radiation safety status report of the X-ray installation to AERB
(iv) Reports on unusual occurrences such as excessive exposures to staff/patient, radiation injuries due to such exposures, along with details of any immediate remedial actions taken are made available to the employer and licensee for reporting to the Competent Authority and a copy endorsed to the Competent Authority
(v) Report any inadvertent excessive exposure of the TLD badges due to improper use/storage promptly to the TLD service provider
(vi) Verify the performance of radiation monitoring systems, safety interlocks, protective devices such as lead (equivalent) aprons, and other safety systems such as structural shielding in the radiation installation, if any, and
(vii) Inform the Competent Authority if s/he relinquishes the responsibility as RSO in the institution.

Advise the Employer and Licensee regarding:

(a) Necessary steps to ensure that the dose of radiation workers are well within the dose limits prescribed by regulatory body
(b) Providing radiation safety training and instructions on safe work practice to all the radiation workers and auxiliary workers, as applicable, aimed at optimizing exposures to the radiation workers
(c) Provision of TLD services to radiation workers involved in operating X-ray equipment, with due justification based on workload and operating conditions and maintenance of the dose records
(d) Good work practices that ensure radiation doses are maintained As Low As Reasonably Achievable (ALARA)
(e) Carrying out periodic QA tests and radiation protection survey of the installation as prescribed by regulatory body

(f) Operation of the X-ray equipment by qualified and trained personnel provided with TLD badge and adequate protective accessories
(g) Ensuring servicing and maintenance of the equipment, which can impact radiation safety
(h) Modifications in working condition of a pregnant worker
(i) Periodic calibration of measuring and monitoring instruments, if applicable, and
(j) Decommissioning of X-ray equipment.

3. PERSONNEL IN NUCLEAR MEDICINE (NM) FACILITY AND THEIR RESPONSIBILITIES

3.1 Introduction

Nuclear Medicine is a clinical and laboratory medical specialty that employs for diagnosis, therapy and research, the nuclear properties of radioisotopes to evaluate metabolic, physiologic and pathologic conditions of the body. The practice involves administration of radioisotopes labeled to pharmaceuticals to be delivered to the organ/tissue of interest so as to get information (through imaging procedures) regarding the functionality/disorders. Nuclear medicine plays significant and indispensable role in functional imaging and targeted therapy. Considering the hazard potential of ionizing radiation, these need to be used with due justification, optimization of radiation protection and safety based on established guidelines. This is to ensure that maximum benefits are derived from the safe use of ionising radiation with acceptable radiological risk. Nuclear medicine imaging systems comprise of single photon or positron emission and associated detection modalities. Apart from diagnostic procedures, therapy procedures in oncology especially for thyroid, liver cancers, neuroendocrine tumours, treatment for pain palliation etc. are equally popular. Radioisotopes like ^{125}I, ^{131}I, ^{99m}Tc, ^{18}F, ^{68}Ga, ^{177}Lu, ^{188}Re, ^{90}Y with energies ranging from 20 to 2000 keV are prominently in this field. Radiological safety aspects in nuclear medicine need a special attention as the radioisotopes are handled in unsealed form, which present both internal as well as external radiation hazard. Patient administered with radioactivity acts as a source of radiation. Hence adequate training is required for staff working in nuclear medicine as safety is largely dependent on human performance.

Regulated Utilities: Nuclear Medicine facility, manufacturer/supplier of nuclear medicine sources and equipment

3.2 Radiation Workers (Personnel in Nuclear Medicine Facility)

(i) The nuclear medicine team includes qualified and trained specialists for carrying out nuclear medicine procedures such as dose prescription, dose administration, QA and imaging. These specialists should have appropriate qualification and training required for performing their intended task as specified by relevant authorities of India. (wherever such qualification and training are not specified by any authority, the minimum qualification specified in this document should be considered). As mentioned in Section 1.1 of Chapter 1, the above specialists, being radiation workers, should have appropriate training and instruction in radiation safety as specified by AERB.

This team is also required to ensure that nuclear medicine procedures are carried out with due regard to radiation safety as per AERB regulations. For this purpose, minimum of two categories of Radiation Professionals with relevant training and expertise in safe handling of radiation equipment/sources are required in NM facility. They are identified herein as Radiation Professional-NM (i.e. RP-NM-1 and RP-NM-2) as explained in subsequent sections. Further, there should be adequate number of radiation professionals to ensure that the safety is not compromised.

(ii) This terminology used for addressing the roles of radiation professionals has no bearing with their actual designation/nomenclature given by the institution. It is in the prerogative of the institution to assign additional functions such as teaching, research, safety awareness training and other related activities and designate them.

(iii) The minimum desirable professional qualification for the NM facility personnel stated in this section is for its safe operation from a radiation protection perspective. Further, the desirable basic (entry level) academic qualifications for undergoing the professional training course is also mentioned here, keeping in view that the radiation workers have a potential to understand and relate to the radiation physics, radiation protection and safety aspects of their practice and are capable of qualifying in the required radiation protection aspects of their intended tasks.

This section provides minimum desirable qualification, radiation safety certification process, adequacy of personnel, including their approval/licensing process, roles and responsibilities of radiation professionals in NM practice. Adequacy suggested here is based on the normally encountered workload of the practice and complexity of the techniques.

The infrastructure necessary for course conducting agency and minimum radiation safety syllabi for the training courses are specified in **Appendix 2 and Annexure 3** respectively.

3.2.1 Radiation Professional-Nuclear Medicine- 1 (RP-NM-1)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) A basic degree in medicine (MBBS); and
(ii) A post-graduate diploma/degree in Nuclear Medicine or an equivalent

Radiation Safety Certification:

(i) RP-NM-1 should successfully complete radiation safety evaluation as prescribed by AERB.

Adequacy of Personnel:

(i) One RP-NM-1 in each nuclear medicine center with Low /High Dose Therapy facility. In case of NM facilities with only imaging equipment, services of RP-NM-1 should be made available.
(ii) Number of RP-NM-1 should be proportionally enhanced with additional equipment or patient load.

Approval/Licensing and Renewal:

(i) The RP-NM-1 should register as radiation professional (RP) with AERB, based on successful completion of radiation safety evaluation.
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RP-NM-1, with due adherence to the provisions of the current safety regulations or modified thereafter, has the following responsibilities:

(i) Prescribing the dose, ensuring administration of dose by himself or person authorized by him/her and recording the name of the patient, nature of procedure, radiopharmaceutical prescribed, quantity prescribed, name of the radiological medical practitioner and the person administering the radiopharmaceutical with signature and date. The responsibility for safe administration of radiopharmaceutical lies with RP-NM-1

(ii) Prevention of any possibility of misadministration and promptly reporting to the licensee and the Competent Authority in the event of any misadministration, adverse reaction or death of a patient administered with radioactivity

(iii) Consideration of factors such as proper choice of radiopharmaceuticals, monitoring of procedure and immobilisation of the patient in order to minimize absorbed dose to the patient

(iv) Consideration of justification of diagnosis/therapy on pregnant patients/ lactating mothers in order to limit the exposure to the foetus/infant not exceeding an equivalent dose of 1 mGy

(v) Instructing patients on the time duration for avoidance of pregnancy following radionuclide therapy, such that the absorbed dose to the conceptus should not exceed 1 mGy

(vi) Consideration of appropriate measures for dose fractionisation, in order to minimize tissue reactions following radionuclide therapy

(vii) Adopting specific dosimetric consideration in pediatric patients to ascertain the risk-benefit ratio

(viii) Informing patient on safety measures to be observed to avoid radiation exposure to the family members and others

(ix) Ensuring that informed consent is obtained from the patient/relatives of the patient on the probable radiological risk prior to administration of therapeutic dose

(x) Ascertaining that in situations where the dose to a family member (other than comforter) of the patient administered with radiopharmaceutical emitting gamma radiation, prospectively estimated prior to discharge exceeds 1 mSv/year (i.e. dose limits for public), or the residual administered activity from a therapeutic radiopharmaceutical emitting beta radiation exceeds the prescribed activity limits for discharge of patient, appropriate procedures are in place such that a) that patient is hospitalised and kept isolated (b) spread of contamination is prevented and (c) exposure of staff, other patients and public is minimized, and

(xi) Instructing nursing and auxiliary staff on radiation safety and precautions in nursing and management of NM therapy patients.

3.2.2 Radiation Professional-Nuclear Medicine -2 (RP-NM-2)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as;

(i) 10+2 or an equivalent examination passed with Science subject from a recognized Board; or an equivalent basic qualification

(ii) A bachelor's degree in Nuclear Medicine Technology passed from a recognized University/Institution;
Or,

(i) A bachelor's degree in basic Sciences, from a recognized University/Institution; and

(ii) Post-graduate Diploma (of minimum one year duration) in nuclear medicine passed from a recognized University/Institution.

(Note: (a) The professional Training course should be a full time regular course incorporating the minimum radiation safety syllabi prescribed by AERB).
(b) Above professional course(s) through Distance education or correspondence mode are not acceptable.}

Radiation Safety Certification:

(i) RP-NM-2 should successfully complete radiation safety evaluation prescribed by AERB.

Adequacy of Personnel:

(i) One RP-NM-2 per Nuclear Medicine facility.
(with one imaging modality, Low Dose Therapy facility (LDTF) and High Dose Therapy Facility (HDTF))
(ii) Number of RP-NM-2 should be enhanced proportionately with the number of additional equipment or patient load.

Approval/Licensing and Renewal:

(i) RP-NM-2 should register as radiation professional (RP) with AERB, based on successful completion of radiation safety evaluation.
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RP-NM-2, with due adherence to the provisions of current safety regulations or modified thereafter, has the following responsibilities:

(i) Operating the nuclear medicine equipment as per standard operating procedures (SOP)
(ii) Check the proper functioning of all nuclear medicine equipment
(iii) Carry out periodic calibrations, quality assurance (QA) checks and maintain records thereof
(iv) Check radiopharmaceutical quality requirements, appropriate route of administration and accuracy of dosage of the radiopharmaceutical and take precautions to avoid misadministration
(v) Avoiding spillage of radioactivity or contamination of the patient, premises, persons and material by exercising care during dispensing/ administration of radioactivity
(vi) Reporting to RSO and radiological medical practitioner of any mishap in dispensing/administration of dosage to the patient or any unusual incident, and
(vii) Assisting the RSO in maintaining records of sources and radioactive waste in prescribed formats.

3.2.3 Radiological Safety officer (RSO)

Eligibility Criteria and Safety Certification:

(i) Radiation Professionals (RP-NM-1 and RP-NM-2) in Nuclear Medicine or RP-RT-2 in Radiotherapy registered with AERB.

(ii) Obtain Radiation Safety Certification, i.e. RSO (NM) or RSO (Medical) respectively from an agency recognized by AERB.

Adequacy of Personnel:

(i) Each nuclear medicine facility should have a Radiological Safety officer (RSO).

Approval/Licensing and Renewal:

(i) RP-NM-1and RP-NM-2 or RP-RT-2 with Radiation Safety Certification, (i.e. RSO (NM) or RSO (Medical) respectively) should obtain an approval from Competent Authority to function as Radiological Safety Officer.

(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RSO, with due adherence to the provisions of the current safety regulations or modified thereafter, has the following responsibilities:

(i) Advise and assist the licensee in ensuring regulatory compliance for obtaining authorisation from the Competent Authority for procurement, use, transport or disposal of radioactive material
(ii) Establish and maintain an effective radiation protection programme to ensure safety of workers, patients and public
(iii) Implement all radiation surveillance measures
(iv) Carry out radiation and contamination monitoring of work areas, patient waiting areas, radioactive waste disposal sites and public areas, and maintain records thereof
(v) Provide education and training on radiation protection and safety methodologies, beneficial and deleterious effects of radiation to all radiation workers (e.g. medical practitioners, nurses, technical staff, students and other relevant personnel)
(vi) Carry out periodic calibration of radiation monitoring and associated instruments, and keep the instruments in proper working condition
(vii) Assist the employer in developing suitable emergency response plans to deal with accidents/incidents and ensuring preparedness
(viii) Advice the licensee on safety and security of radioactive sources, establish the security plan and ensure availability of adequate security measures
(ix) Report any unusual incident in writing to the licensee, with a copy endorsed to the Competent Authority and take remedial measures to mitigate consequences of the incident and to prevent recurrence
(x) Maintain records of the sources received, used and disposed of, any unusual incident, cause of such incident and remedial measures taken

(xi) Segregate and monitor the waste prior to interim storage or final disposal

(xii) Advise the employer in carrying out personnel monitoring and maintenance of records thereof

(xiii) Take necessary actions for urgent processing of personnel dosimeters in cases of suspected overexposure

(xiv) Advise on display of notices in the nuclear medicine departments to avoid unintentional exposures to pregnant women/lactating mothers

(xv) Advise and assist the licensee in transport of radioactive material/ radioactive waste in the public domain

(xvi) Submit periodic reports to the regulatory body giving details such as safety status of the installation and inventory of sources, and

(xvii) Inform the Competent Authority if s/he relinquishes the responsibility as RSO in the institution.

RSO attached to NM therapy centers, have following additional responsibilities:

(a) Ensure that patients administered with radioisotopes for in-patient therapy are hospitalised in the approved isolation wards

(b) Carry out regular monitoring of therapy patients, patient areas and nurses' station areas

(c) Take appropriate measures so that effective dose to the patient's comforter should not normally exceed the limit prescribed by AERB during the period of a patient's treatment

(d) Ensure that dose to any family member other than comforter does not exceed the prescribed limits, prospectively estimated prior to discharge of the patient

(e) Give appropriate instructions for radiation safety and precautions to patient comforters in management of therapy patients

(f) Ensure that radiation level at 1 m from patient being discharged does not exceed the prescribed limits at the time of discharge

(g) Provide detailed instructions in English, Hindi and regional language on the safety precautions to be followed by the comforter and other family members so as to keep the doses below the prescribed levels

(h) Ensure that activity limit for discharge of patients administered with beta emitting radionuclides is as prescribed by Competent Authority

(i) Ensure sampling and monitoring of effluents from therapy wards prior to their release to public sewers so that it does not exceed authorized discharge limits

(j) Maintain a separate logbook for data on monitoring of therapy patients from the time of hospitalisation until discharge from the ward

(k) Provide personnel monitoring to patient's comforter(s), if required, and maintain appropriate records

(l) Advice on safety precautions to be followed, regarding disposal of cadavers containing radionuclides in accordance with the procedures approved by the Competent Authority

(m) Segregate and monitor patient linen prior to interim storage or reuse;

(n) Restrict entry of visitors to isolation wards, and

(o) Issue necessary written instructions at the time of discharge of therapy patients to minimise radiation exposure of family members especially to children and pregnant women and lactating mother.

4. PERSONNEL IN RADIOTHERAPY (RT) FACILITY AND THEIR RESPONSIBILITIES

4.1 Introduction

Ionising radiation is being used extensively in human healthcare programmes. The medical application of ionising radiation is unique in the sense that patients are intentionally exposed for diagnosis and therapy purposes using modalities, such as diagnostic radiology, nuclear medicine and radiotherapy. Radiotherapy uses treatment modalities, which contain high activity sources (e.g. ^{60}Co, ^{192}Ir) or highly penetrating ionising radiation from medical accelerators. Various types of equipment with X-ray energy ranging from 50 kV to 15 MV are used in radiotherapy. Ionising radiations play significant and indispensable role in diagnosis and treatment of cancer. It must be borne in mind that excessive radiation may be harmful to the radiation workers and general public. These need to be used with due justification, optimization of radiation protection and safety based on established guidelines. This is to ensure safety of patients undergoing treatment, radiation workers and general public, so that maximum benefits are derived from the safe use of ionising radiation with acceptable radiological risk.

Regulated Utilities: Radiotherapy facility and manufacturer /supplier of radiotherapy equipment/sources.

4.2 Radiation Workers (Personnel in Radiotherapy Facility)

(i) The radiation therapy team includes qualified and trained specialists for performing diverse and definite roles such as prescription of radiation dose, calibration of the radiation output, treatment planning and delivery. These specialists should have appropriate qualification and training required for performing their intended task as specified by relevant authorities of India. (wherever such qualification and training are not specified by any authority, the minimum qualification specified in this document should be considered). As mentioned in section 1.1 of Chapter 1, the above specialists, being radiation workers, should have appropriate training and instruction in radiation safety as specified by AERB.

This team is also required to ensure that radiation therapy is carried out with due regard to radiation safety as per AERB regulations. For this purpose, minimum of three categories of Radiation Professionals with relevant training and expertise in safe handling of radiation equipment/sources are required in RT facility. They are identified herein as Radiation Professional-RT (i.e. RP-RT-1, RP-RT-2 and RP-RT-3) as explained in subsequent sections. Further, there should be adequate number of radiation professionals to ensure that the safety is not compromised.

In addition, there are few standalone brachytherapy facilities dealing with low hazard potential sources (such as ocular brachytherapy), where personnel requirements may be different from full-fledged radiotherapy facilities. To address the radiation safety aspects of the sources, professionals are identified as Radiation Professional-RT-Low Hazard Brachytherapy (RP-RT-OB).

The personnel involved in servicing and maintenance of radiotherapy equipment should also be trained in the radiation safety aspects, and they are identified as Radiation Professional-RT-Service (RP-RT-S).

(ii) This terminology used for addressing the roles of radiation professionals has no bearing with their actual designation/nomenclature given by the institution. It is in the prerogative of the institution to assign additional functions such as teaching, research, safety awareness training and other related activities and designate them.

(iii) The minimum desirable professional qualification for the RT facility personnel stated in this section is for its safe operation from a radiation protection perspective. Further, the desirable basic (entry level) academic qualifications for undergoing the professional training course are also mentioned here, keeping in view that the radiation workers have a potential to understand and relate to the radiation physics, radiation protection and safety aspects of their practice and are capable of qualifying in the required radiation protection aspects of their intended tasks

This section provides minimum desirable qualification, radiation safety certification process, adequacy of personnel, including their approval/ licensing process, roles and responsibilities of radiation professionals in RT practice. Adequacy suggested here is based on the normally encountered workload in the practice and complexity of the techniques.

The infrastructure for course conducting agency and minimum radiation safety syllabi for the training courses are specified in **Appendix 3A & 3B and Annexure 4** respectively.

4.2.1 Radiation Professional–Radiotherapy-1 (RP-RT-1)
Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) A basic degree in medicine (MBBS); and
(ii) A post-graduate diploma/degree in radiation therapy/radiation oncology.

Radiation Safety Certification:

(i) RP-RT-1 should successfully complete radiation safety evaluation as prescribed by AERB.

Adequacy of Personnel:

(i) One RP-RT-1 per;
  (a) Teletherapy unit (Telecobalt /Medical Accelerator) in radiotherapy facility, or
  (b) Stand-alone brachytherapy facility (except for standalone low hazard brachytherapy facility, the details for which are specified separately in this document).

Approval /Licensing and Renewal:

(i) RP-RT-1 should register as radiation professional (RP) with AERB, based on successful completion of radiation safety evaluation.
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RP-RT-1, with due adherence to the relevant provisions of the current safety regulations or modified thereafter, has the following responsibilities:

(i) Accepting referrals for diagnostic imaging or radiation therapy only from a person authorized to make such a request
(ii) Consultations with the patient, clinical evaluation of the disease and the justification for the proposed line of treatment
(iii) Establishment of treatment plan, including dose prescription
(iv) Optimize the radiation protection of the patient during diagnostic imaging and therapeutic treatment so as to achieve good clinical outcomes
(v) Execution of treatment and participation in it on a regular basis, including periodic review of the treatment delivered
(vi) On-treatment evaluations and patient monitoring
(vii) Preparation of treatment summary at the end of the treatment procedure, and
(viii) Evaluation of the treatment and follow-up.

4.2.2 Radiation Professional–Radiotherapy-2 (RP-RT-2)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) A basic degree in Science with physics as one of the main subject, from a recognized University/Institution or equivalent basic qualification
(ii) Post-graduate degree in Radiological/Medical Physics or an equivalent from a recognized University/Institution;

Or;

Post-graduate degree in Physics from a recognized University and Post M.Sc. Diploma in Radiological Physics/Medical Physics or an equivalent from a recognized University/Institution.

And;

(iii) An internship of minimum 12 months in a well-equipped radiotherapy department.

(Note: The internship should preferably also cover other medical applications such as diagnostic radiology and nuclear medicine.)

Radiation Safety Certification:

(i) RP-RT-2 should successfully complete radiation safety evaluation as prescribed by AERB.

Adequacy of Personnel:

(i) One RP-RT-2 for each teletherapy equipment with conventional treatment modalities (i.e. Telecobalt or Medical Accelerator without advanced treatment modalities).

(ii) Two RP-RT-2 for each teletherapy equipment capable of advanced treatment modalities (e.g. 3D CRT, IMRT, IGRT etc.).
(iii) One RP-RT-2 for each standalone brachytherapy facility (except for low hazard brachytherapy e.g. ocular brachytherapy), the details for which are specified separately in section 4.3).

Approval/Licensing and Renewal:

(i) The RP-RT-2 should register as radiation professional (RP) with AERB, based on successful completion of radiation safety evaluation.
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RP-RT-2, with due adherence to the provisions of the current regulations or modified thereafter, has the following responsibilities:

(i) Preparation of technical specifications of the equipment, acceptance testing and commissioning of equipment, quality assurance (including calibration of therapy equipment) and establishment of criteria for acceptance performance for treatment and dosimetric equipment
(ii) Involvement in shielding designing of installation, commissioning of new equipment with regard to radiation protection of patients, workers and the public
(iii) Optimizing the use of radiation to ensure the safety and quality of therapeutic procedures
(iv) Periodic calibration of the dosimetric equipment, traceable to national standards laboratory
(v) Measurement and analysis of beam data and tabulation of beam data for clinical use
(vi) Radiation dosimetry, evaluation and optimisation of treatment planning
(vii) Patient dose verification including in vivo dosimetry
(viii) Development and implementation of physical and technical aspects of the quality assurance (QA) protocols and procedures in radiation therapy regarding
    (a) delivery of radiation treatment;
    (b) radiation safety and control and regulatory compliance; and
    (c) supervision of patient treatment in radiation protection perspective, equipment operation, servicing and maintenance and maintain the records.
(ix) Implementation of policies, guidelines and measurement techniques for determination of patient dose.

{Note: In addition to the above, these personnel may also be involved in other medical applications of radiation such as diagnostic radiology and nuclear medicine for the purposes of quality assurance, patient dosimetry, evaluation of examination efficacy and image quality for optimization of doses.}

4.2.3 Radiological Safety Officer (Medical) (RSO-Medical)

Eligibility Criteria and Safety Certification:

(i) RP-RT-2 registered as radiation professional (RP) with AERB.
(ii) Obtain Radiation Safety Certification, i.e. RSO (Medical) from an agency recognized by AERB.

Adequacy of Personnel:

(i) Each radiotherapy facility should have a Radiological Safety Officer (RSO).

Approval/ Licensing and Renewal:

(i) Registered RP-RT-2 with radiation safety certification (i.e. RSO -Medical) should obtain an approval from Competent Authority to function as Radiological Safety Officer.
(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RSO, with due adherence to the provisions of the current safety regulations or modified thereafter, has the following responsibilities:

(i) Establishing and maintaining an effective radiation protection programme (RPP) to ensure safety of workers and public
(ii) Implementing all radiation surveillance measures
(iii) Providing education, training/instruct on radiation protection and safety methodologies, beneficial and deleterious effects of radiation to all radiation workers (eg. medical practitioners, nurses, technical staff, students and other relevant personnel)
(iv) Advising employer/licensee on carrying out personnel monitoring and maintain of records thereof
(v) Assisting the employer in developing suitable emergency response plan to deal with accidents/incidents and ensuring appropriate emergency preparedness
(vi) Advising the licensee on safety and security of radioactive sources, establish the security plan and ensure availability of adequate security measures
(vii) Conducting periodic radiation protection surveys to verify compliance with the regulatory requirements
(viii) Ensuring safe work practices during procedures such as source transfer, target replacement and disposal of disused sources
(ix) Periodic calibration of radiation measuring, monitoring and associated instruments;
(x) Submission of periodic reports to the Competent Authority giving details such as safety status of the installation and inventory of sources
(xi) Investigation of radiation incidents and accidents and submit the report to licensee/employer with a copy endorsed to the Competent Authority, and
(xii) Inform the Competent Authority if s/he relinquishes the responsibility as RSO in the institution.

4.2.4 Radiation Professional –Radiotherapy-3 (RP-RT-3)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) 10+2 or an equivalent examination passed with Science subjects and physics as one of the subject; from a recognized Board; or an equivalent basic qualification

(ii) Minimum two years' course in radiation therapy technology including in-field training in radiotherapy department, passed from a recognized University/ Institution incorporating minimum radiation safety syllabi as prescribed by AERB.

{Note: (a) The professional Training Course should be a full time regular course incorporating the minimum radiation safety syllabi prescribed by AERB.

(b) Above professional course(s) through Distance education or correspondence mode are not acceptable.}

Radiation Safety Certification:

(i) RP-RT-3 should successfully complete the Radiation Safety evaluation as prescribed by AERB.

Adequacy of Personnel:

(i) Two RP-RT-3 for each Teletherapy equipment with conventional treatment modalities (i.e. Telecobalt or Medical Accelerator without advanced treatment modalities).
(ii) Three RP-RT-3, for each Teletherapy equipment capable of advanced treatment modalities (e.g. 3D CRT, IMRT, IGRT etc.)

Approval/ Licensing and Renewal:

(i) RP-RT-3 should register as radiation professional (RP) with AERB, based on successful completion of radiation safety evaluation.
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RP-RT-3, with due adherence to the provisions of current safety regulations, or modified thereafter, has the following responsibilities:

(i) Adhering to standard operating procedures (SOP) and follow safe work practice
(ii) Following the radiation safety instructions, stated by RSO from time to time
(iii) Set-up of patient in accordance with the prescription chart
(iv) Selection of treatment parameters on the machine and the treatment control panel as defined in the prescription chart
(v) Delivery of correct dose to the planning treatment volume
(vi) Stopping further treatment(s), when a fault/emergency condition develops in the equipment and not to proceed with further treatment, unless the RSO/ responsible technical personnel certifies, in writing, that the fault condition has been rectified, and it is safe to commence the treatment after re-setting of the treatment parameters on the control panel
(vii) Intimating the licensee/RSO immediately regarding unusual incidents, and
(viii) Undergoing periodic training for updating knowledge in the field of radiation safety, advancement in treatment modalities, technology, patient safety and current safety regulations.

4.2.5 Radiation Professional-Radiotherapy-Service Engineer (RP-RT-S)
(for RT Equipment Manufacturer/Supplier Facility)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Diploma in Engineering or an equivalent from a recognized University/Institution;

(Note: Qualification should supported by certification from original equipment manufacturer (OEM) about successful completion of training on servicing/ maintenance and installation of RT equipment.)

Radiation Safety Certification:

(i) The service engineer should obtain the 'Radiation Safety Certification in Servicing of RT Equipment' from an agency recognized by AERB.

Adequacy of Personnel:

(i) One certified RP-RT-S for each manufacturer site /supplier of RT equipment involved in radiation testing at their premises.

(Note: The manufacturer/ supplier should ensure that radiation testing, QA, servicing & maintenance of radiotherapy equipment should be carried out only by trained and certified service engineer.)

Approval /Licensing and Renewal:

(i) RP-RT-S should register as radiation professional (RP) with AERB, based on successful completion of radiation safety certification.
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RP-RT-S, with due adherence to the provisions of the current safety regulations or modified thereafter, has the following responsibilities:

(i) Involvement in commissioning/service/maintenance/quality assurance/ decommissioning of RT equipment adhering to manufacturers' specification, procedures and adhering to regulatory and radiation safety requirements
(ii) During commissioning of RT equipment, check that:
- the equipment is installed in approved room,
- acceptance tests are carried out as per prescribed format,
- installation of safety interlocks, emergency switches and other safety devices in compliance with prevailing regulatory requirements.

(iii) Carry out all repair and maintenance procedures as per the manufacturer' specifications or applicable standards

(iv) Ensure that after repair or maintenance work, the functionality of the equipment is demonstrated and the equipment is handed over to the concerned technical person for carrying out necessary QA tests

(v) Record and communicate any design faults in the equipment, malfunction or non-availability of safety interlock etc. to the employer and RSO of the institution and the supplier for necessary corrective actions, and

(vi) Provide operational safety training to the relevant staff to ensure patient and operator safety.

4.3 Radiation Worker [Personnel in Low Hazard Brachytherapy Facility (eg. Ocular Brachytherapy)]

4.3.1 The services of a qualified medical practitioner (such as ocular surgeon) and radiation professional (RP-RT-1 and RP-RT-2) should be made available in the facility for carrying out low hazard brachytherapy procedures.

4.3.2 Radiological Safety Officer (RSO)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Basic degree in Science with physics as one of the subject from a recognized University/Institution;
Or;
Basic degree in Optometry or equivalent from a recognized University/Institution;
Or;
RP-RT-2 with successful completion of Radiation Safety Certification, i.e. RSO (Medical) from an agency recognized by AERB.

Radiation Safety Certification:

(i) Successful completion of Radiation Safety Certification i.e. 'RSO for Low hazard Brachytherapy (eg. Ocular Brachytherapy) from an agency recognized by AERB.

{Note: Candidates who are already eligible to be nominated as RSO (Medical) need not undergo additional safety certification for low hazard brachytherapy}

Adequacy of Personnel:

(i) Each low hazard brachytherapy (eg. ocular brachytherapy) facility should have a Radiological Safety Officer.

Approval/Licensing and Renewal:

(i) Designated RSO should register as radiation professional (RP-RT-OB) with AERB, based on successful completion of radiation safety certification.

(ii) Obtain an approval from Competent Authority to function as a Radiological Safety Officer

(iii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

{Note: RP-RT-2 candidates who has already registered with AERB for Radiotherapy Facility need not register again for low hazard brachytherapy}

Role and Responsibilities:

The RSO, with due adherence to the provisions of current safety regulations or modified thereafter, has the following responsibilities:

(i) Maintaining the source inventory
(ii) Carrying out periodic radiation protection survey and maintain the records thereof
(iii) Safely transport sources within the hospital premises and for disposal
(iv) Submitting periodic safety status reports
(v) Establishing and maintain an effective radiation protection programme (RPP) to ensure safety of workers, public
(vi) Providing education, training/instruct on radiation protection and safety methodologies, beneficial and deleterious effects of radiation to all radiation workers
(vii) Implementing all radiation surveillance measures, and
(viii) Informing the Competent Authority if s/he relinquishes the responsibility as RSO in the institution.

5. PERSONNEL IN MEDICAL CYCLOTRON FACILITY AND THEIR RESPONSIBILITIES

5.1 Introduction

Medical Cyclotron is used for the production of radionuclides which are used for Positron Emission Tomography/CT (PET/CT) and Single Photon Emission Computed Tomography/CT (SPECT/CT) imaging. Apart from these, cyclotron produced isotopes are finding also their use in some therapeutic applications. Most of the cyclotrons installed in the country are utilized for the production of ^{18}F labelled radiopharmaceuticals, or other positron emitting radiopharmaceuticals, either for own use at the center or for distribution to other PET centers. There has been a steady increase in the number of cyclotrons installed in the country due to the increasing demand for PET radionuclides. Radiation safety aspects related to safe operation of medical cyclotron need to be duly addressed since in addition to the isotopes generated, routine operation of medical cyclotron also results in accumulation of induced activity in critical components which needs to be handled safely

Regulated Utility: Medical Cyclotron facility

5.2 Radiation Workers (Personnel in Medical Cyclotron Facility)

The efficient utilization of a Medical Cyclotron facility for production of radioisotopes and radiopharmaceuticals requires availability of a Radiological Safety Officer (RSO) and other trained personnel for operating the equipment and preparation of radiopharmaceuticals. These personnel are identified in this section as Radiation Professional-Medical Cyclotron-1 (RP-MC-1), RP-MC-2 and RP-MC-3 respectively.

This section also provides the minimum desirable qualification, radiation safety certification process, adequacy of personnel, including their approval/licensing process and role and responsibilities in Medical Cyclotron facility.

The minimum radiation safety syllabi for the training courses is specified in **Annexure 5.**

5.2.1 Radiological safety Officer (RSO)

Eligibility Criteria and Safety Certification:

(i) RP-RT-2 with RSO (Medical) or RP-NM-2 with RSO (NM) certification; or RSO (Medical) or RSO (NM), registered as Radiation Professional-Medical Cyclotron-1 (RP-MC-1)
(ii) Successful completion of specialized training and certification on 'Operational and Safety Aspects of Medical Cyclotron' in a well-equipped medical cyclotron facility (as applicable).

Adequacy of Personnel:

(i) Each medical cyclotron facility should have a Radiological Safety Officer (RSO).

Approval /Licensing and Renewal:

(i) Registered RP-RT-2 or RP-NM-2 with radiation safety certification (i.e. RSO (Medical) or; RSO (NM) respectively or RP-MC-1 and Safety certification in operational safety of Medical Cyclotron should obtain an approval from Competent Authority to function as a Radiological Safety Officer.

(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

(Note: Registration as RP-MC-1 *is applicable for Medical cyclotron facility which are not associated with hospitals and hence the role of RP-RT-2 and RP-NM-2 is not applicable here.)*

Role and Responsibilities:

The RSO, with due adherence to the provisions of the current safety regulations or modified thereafter, has the following responsibilities:

(i) Advise and assist the licensee to formulate and implement a radiation protection programme appropriate for the facility and ensure that the staff observe safe work practices
(ii) Impart in-house radiation safety training to the operators and radio-chemist and other auxiliary staff working in the facility
(iii) Ensure safety, security and containment of radioactive sources, carry out radiation and contamination monitoring of the facility and maintain records of the same
(iv) Ascertain that radiation monitoring instruments are kept in proper working condition and are periodically calibrated
(v) Report any unusual incident in writing to the licensee, with a copy endorsed to the Competent Authority within time frame followed by the detailed report, and take remedial measures to mitigate consequences of the incident and to prevent recurrence
(vi) Advise licensee for maintaining records of the radiation dose to workers, inventory of radioactive sources including sources received, in use and disposed of
(vii) Investigate any unusual exposure incident, cause of such incident and advice on any remedial measures taken
(viii) Segregate and monitor the radioactive waste prior to interim storage or final disposal;
(ix) Advise the licensee on safety and security of radioactive sources, establish the security plan and ensure availability of adequate security measures
(x) In consultation with licensee, establish emergency response plan and procedures for management of emergency situations and conduct periodic drills to ensure their effectiveness
(xi) Advise and assist the licensee in ensuring regulatory compliance for obtaining authorization from the Competent Authority for procurement, use, transport or disposal of radioactive material
(xii) Advise the licensee on compliance to all the transport regulations when supplying radioactivity to radiation facility to ensure safe and secure transport of radioactive

material including in-transit loading/unloading, security during transport and trustworthiness of carrier, and

(xiii) Informing the Competent Authority if s/he relinquishes the responsibility as RSO in the institution.

5.2.2 Radiation Professional-Medical Cyclotron-2 (RP-MC-2)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Diploma/ degree in nuclear medicine technology or Basic degree in physics or Diploma in Engineering passed from a recognized University/Institution.

Radiation Safety Certification:

(i) RP-MC-2 should successfully complete 'Basic Radiation Safety Module' in Medical Cyclotron through safety evaluation prescribed by AERB.

Adequacy of Personnel:

(i) One RP-MC-2 for each medical cyclotron facility.
(ii) Number of RP-MC-2 should be enhanced proportionately with number of medical cyclotron equipment or work load.

Approval /Licensing and Renewal:

(i) The RP-MC-2 should register as radiation professional (RP)/ radiation worker (RW) with AERB, based on successful completion of radiation safety evaluation as prescribed by AERB.
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RP-MC-2, with due adherence to the safety provisions in the current regulations or modified thereof, has the following responsibilities:

(i) Operate the medical cyclotron as per the Standard Operating Procedures (SOP) approved for the facility
(ii) Fulfill the radiation safety requirements during operation and maintenance of the cyclotron
(iii) Report any unusual incidents / occurrences to the licensee and RSO
(iv) Maintain daily record of all the cyclotron operation(s) including record of various parameters during operation
(v) Check that there is no unauthorized bypass of the interlocks & other safety features mandatory for safe operation of cyclotron
(vi) Check that the filter banks and stack monitor are working satisfactorily

(vii) If required to carry out preventive, planned and emergency maintenance involving radioactive material, the operator should do so with the concurrence of RSO

(viii) Coordinate with other radiation workers to ensure that the cyclotron produced radioactivity is safely transferred and received in the desired synthesis module, and

(ix) Inform RSO/Licensee in case of any malfunctioning of the system and its components and make modifications, if needed.

5.2.3 Radiation Professional-Medical Cyclotron-3 (RP-MC-3):

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Basic degree in Chemistry or B. Pharm or an equivalent from recognized University/Institution.

Radiation Safety Certification:

(i) RP-MC-3 should successfully complete the 'Basic Radiation Safety Module' in Medical Cyclotron through safety evaluation prescribed by AERB.

Adequacy of Personnel:

(i) One RP-MC-3 for each medical cyclotron facility.

(ii) Number of RP-MC-3 should be enhanced proportionately with number of medical cyclotron equipment or work load.

Approval/Licensing and Renewal:

(i) RP-MC-3 should register as radiation professional (RP)/radiation worker (WR) with AERB, based on successful completion of radiation safety evaluation as prescribed by AERB.

(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RP-MC-3, with due adherence to the safety provisions in the current regulations or modified thereof, has the following responsibilities:

(i) Operate the synthesis module as per the Standard Operating Procedure (SOP) for the equipment

(ii) Verify that synthesis module is ready to receive the radioactivity from the cyclotron safely

(iii) Check that the hot cell housing the synthesis module has the required negative pressure and is connected to a suitable radioactive waste gas handling system

(iv) Safely dispense the radioactivity, after synthesis

(v) Ensure that the laboratory procedures required for the Quality Control (QC) of the product is done with due attention to radiation safety, and

(vi) In case radioactive material is sent outside the facility, it is with the concurrence of RSO.

6. PERSONNEL IN RADIATION PROCESSING FACILITY AND THEIR RESPONSIBILITIES (RPF)

6.1 Introduction

Radiation processing facilities (RPF) utilize ionizing radiation for a variety of beneficial applications such as sterilization of medical products, food processing, mutation breeding and cross linking. The amount of radioactivity in a gamma radiation processing facility (GRAPF) is typically of the order of 10^{15}-10^{17}Bq (1 PBq-100 PBq). Accelerators are also used in radiation processing application and use either electron beam from a machine operated at or below 10 MeV and/or X-rays generated from a machine operated at or below 7.5 MeV.

In view of the high hazard potential, RSO and personnel involved in operation must possess adequate knowledge of radiation safety, including design and operational aspects of the equipment/facility. They need to undergo effective training programme for safe operation of the RPF.

Regulated Utilities: Radiation processing facilities, manufacturer/ supplier of sources/equipment.

6.2 Radiation Workers (Personnel in Radiation Processing Facility)

This section provides the minimum desirable qualification, radiation safety certification process, adequacy of professionals, including their approval process and role and responsibilities in RPF. The operating and safety personnel are identified in this section as Radiation Professional -Radiation Processing Facility -1 and 2 (RP-RPF-1 and 2) respectively.

The infrastructure for course conducting agency and syllabus for the training courses covering radiation safety aspects and operational features of radiation processing facility are specified in **Appendix 5 and Annexure 6** respectively.

6.2.1 Radiation Professional -Radiation Processing Facility -1 (RP-RPF-1)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Basic degree in Science or equivalent from a recognized University/Institution;
Or
Diploma in Engineering from a recognized University/Institution;

Radiation Safety Certification:

(i) Successful completion of 'Radiation Safety Certification for Operator of Radiation Processing Facilities (Operator-RPF)', from an agency recognized by AERB.

Adequacy of Personnel:

(i) One RP-RPF-1 per shift for each radiation processing facility.

Approval /Licensing and Renewal:

(i) Certified RP-RPF-1 should register as radiation professional (RP) with AERB, based on successful completion of radiation safety certification (Operator-RPF);
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The responsibilities of RP-RPF-1 include the following, in addition to the provisions of the current safety regulations or its modifications thereof:

(i) Operate the facility as per written instructions and established Standard Operating Procedures (SOP)
(ii) Be present in the control room when radiation processing facility is in operation
(iii) Make complete and correct entries in the operational logbook
(iv) Provide assistance, in servicing/maintenance and testing of various systems
(v) Use personnel dosimeter appropriately at all the time while working within the facility and store the same away from radiation area
(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, and
(viii) Provide assistance to the RSO to analyse and prevent such situations.

6.2.2 Radiation Safety Officer (RSO): (RP-RPF-2)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Basic degree in Science with physics as one of the subject from a recognized University/ Institution;
Or;
Degree in Engineering from recognized University/Institution;
Or;
Certified RP-RPF-1with minimum of three years' experience in field of radiation surveillance supported by personnel monitoring service in a radiation processing facility;
Or;
Post-graduate Diploma in Radiological Physics leading to RSO (Industry & Research) certification from a recognized University/Institution.

Radiation Safety Certification:

(i) Successful completion of Radiation Safety Certification (i.e. RSO-Radiation Processing Facilities (RSO-RPF)), from an agency recognized by AERB.

(Note: Candidates who are eligible to be nominated as RSO (Industry & Research) need not undergo additional radiation safety certification.)

Adequacy of Personnel:

(i) Each radiation processing facility should have a Radiological Safety officer (RSO).
(ii) Each manufacturer/supplier of devices/sources should have a Radiological Safety officer (RSO).

Approval/ Licensing and Renewal:

(i) Designated RSO should register as Radiation Professional-RPF-2 (RP-RPF-2) with AERB, based on successful completion of radiation safety certification.
(ii) Obtain an approval from Competent Authority to function as Radiological Safety Officer (RSO).
(iii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RSO, with due adherence to the provisions of the current safety regulations or modified thereafter, has the following responsibilities:

(i) Advice and assist the employer and licensee in ensuring regulatory compliance for obtaining consent from the Competent Authority for procurement, use, transport or disposal of radioactive material
(ii) Implement all radiation surveillance measures including display of radiation symbol and warning signs
(iii) Establish and maintain an effective radiation protection programme to ensure safety of workers, members of the public and the environment
(iv) Train the operators and associated servicing /maintenance personnel on basic radiation safety, hazard potential and biological effects of radiation
(v) Instruct all operators/users on relevant safety measures, provide adequate training in radiation protection and safety methodologies, use of personnel monitoring devices (TLD badges)
(vi) Advice employer for provision of personnel monitoring devices to radiation workers in the facility, used as required and are securely stored in radiation-free zone
(vii) Ensure that radiation monitoring instruments are kept in proper working condition and are periodically calibrated
(viii) Assist the licensee in developing suitable emergency response plans to deal with emergencies and ensuring appropriate emergency preparedness
(ix) Conduct periodic radiation protection surveys and maintain records
(x) Maintain inventory of sources including initial and present activity, operational logbook and associated QA records, as applicable
(xi) Furnish to the licensee and the Competent Authority periodic reports on safety status of the facility

(xii) Investigate any situation that could lead to potential exposures and submit report to the Competent Authority

(xiii) Advice employer on physical security measures

(xiv) Analyse personnel exposure records to ensure that there are no abnormal exposure trends

(xv) Prepare the standard operating procedures (SOP) from detailed instruction manual provided by manufacturer/supplier, as applicable

(xvi) Ensure periodic servicing and preventive maintenance and maintain records

(xvii) Advise employer on safe disposal of disused sources

(xviii) Report on all hazardous situations along with details of any immediate remedial actions taken are made available to the employer and licensee for reporting to the Competent Authority

(xix) Advise the licensee on the modification in the working condition of female worker after her notification about pregnancy, and

(xx) Inform the Competent Authority when s/he relinquishes as RSO in the institution.

7. PERSONNEL IN INDUSTRIAL RADIOGRAPHY AND THEIR RESPONSIBILITIES

7.1 Introduction

Radiography using Industrial Radiography Exposure Device (IRED), is one of the important non-destructive (NDT) methods used for study of weld joints, casting in steel and light alloy in fabrication industries. Pipelines too are prime NDT candidates, both during installation & maintenance to ensure that welds remain intact. Radioisotopes like ^{192}Ir, ^{60}Co and ^{75}Se are mostly used for radiography purposes. The activity range is from few TBq to few tens of TBq. In addition to radioactive sources, different energies of X-rays ranging from few hundreds of keV to few MeV are used in the field of industrial radiography. Therefore requirements for safe handling need to be complied with.

The personnel for handling radiography exposure devices, which include industrial radiography institutions, suppliers of radiography sources, manufacturers/ vendors of radiography exposure devices, are specified in this section.

Utilities Regulated: Industrial radiography facilities such as industrial radiography institutions, manufacturer/ supplier of radiography sources/devices.

7.2 Radiation Workers (Personnel in Industrial Radiography Facility)

This section provides the minimum desirable qualification, radiation safety certification process, adequacy of radiation safety professionals, including their approval/licensing process and role and responsibilities. The operating and safety personnel are identified in this section as Radiation Professional-Industrial Radiography-1(RP-IR-1) and RP-IR- 2 respectively.

The infrastructure for course conducting agency and minimum radiation safety syllabi for the training courses is specified in **Appendix 4 and Annexure 7** respectively.

7.2.1 Radiation Professional –Industrial Radiography-1 (RP-IR-1)
Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) 10+2 or an equivalent examination passed with Science subjects, and Mathematics in 10th standard or an equivalent from a recognized Board.
Or;
One year ITI in any Trade from a recognized Board, and Mathematics in 10th standard or an equivalent from a recognized Board.

Radiation Safety Certification:

(i) Successful completion of Radiation Safety Certification in 'Industrial Radiography Testing and Safety' (RT Level-1 or equivalent) from an agency recognized by AERB.

Adequacy of Personnel:

(i) One registered RP-IR-1 for each industrial radiography exposure device (IRED) in operation.

Approval /Licensing and Renewal:

(i) RP-IR-1 on successful completion of radiation safety certification (RT-1) and minimum six months internship in industrial radiography institution working under the supervision of registered RP-IR-1 or RSO, should register as radiation professional (RP) with AERB.

(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period. Renewal is based on radiation safety evaluation.

Role and Responsibilities:

The RP-IR-1, with due adherence to the safety provisions in the current regulations or its modifications thereof, has the following responsibilities:

(i) Provide to licensee information about his/her past radiation work, if any
(ii) Comply with instructions of RSO /licensee concerning radiation protection
(iii) Be familiar with the IRED and its technical specification, safety interlocks, safety accessories and its routine use, safe radiography work procedures, emergency procedures and relevant requirements
(iv) Be aware on physical security measures as appropriate
(v) On removing an IGRED from the storage room or vice-a-versa, verify that the source is duly contained in the device with a proper survey meter and maintain the record
(vi) Prior to operating the equipment, check that all interlocks, shielding, collimators, sign boards, barriers and other protective devices are properly positioned and suitable radiation survey meter is available
(vii) Ensure that all persons not involved in the operation are at safe locations
(viii) Make proper use of protective equipment, radiation monitors and personnel monitoring devices provided
(ix) Operate the equipment in accordance with the operating instructions recommended by the device manufacturer and RSO
(x) Refrain from operating any equipment which is known or suspected to be malfunctioning, to have deteriorated or to be damaged, and report such circumstances promptly to the RSO for appropriate investigative action
(xi) Immediately cease operation of industrial radiography equipment by returning the source to its fully shielded position or by de-energising the X-ray tube, as applicable in case of :
  (a) malfunction occurs during operation;
  (b) any unauthorised person entering the controlled area;
  (c) available survey meter fails to function;
  (d) unfavorable environmental conditions.
(xi) Promptly inform the RSO of any accident or potentially hazardous situation that may come to his/her notice, and

(xii) After completion of each exposure, check using an appropriate radiation survey meter, that the source has been returned to the fully shielded position in the case of IGRED or, in the case of X-ray radiography equipment, that the equipment is no longer energized.

7.2.2 Radiological Safety Officer (RSO):
Radiation Professional-Industrial Radiography-2 (RP-IR-2)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Diploma in Engineering or Basic degree in Science with physics and mathematics from recognized University/Institution;

Or;

Certified RP-IR-1 (with qualification as mentioned in this document) registered as radiation professional (RP) with AERB, and having minimum experience of three (3) years or as specified by Competent Authority, in radiation surveillance of industrial radiography, supported by personnel monitoring services.

(Note: Experience for certified RP-IR-1/ direct access to RSO–Industrial Radiography (RT-2) course is based on applicable national or international standard (e.g. ISO-9712, IS-13805 or equivalent).

Radiation Safety Certification:

(i) Successful completion of Radiation Safety Certification, i.e. RSO in Industrial Radiography Testing Level-2 (RT-2) from an agency recognized by AERB.

Adequacy of Personnel:

(i) Each radiography site should have a Radiological Safety officer.
(ii) Each manufacturer / supplier of IREDs / radiography sources should have a Radiological Safety officer.

Approval/Licensing and Renewal:

(i) Designated RSO should register as RP-IR-2 with AERB, based on successful completion of radiation safety certification;
(ii) Obtain an approval from Competent Authority to function as Radiological Safety Officers (RSO).
(iii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The following are the responsibilities of RSO, in addition to those specified in the current safety regulations or its modifications thereof:

(i) Provide to the licensee information about his/her past radiation work, if any

(ii) Advise and assist the licensee on all aspects of radiation safety

(iii) Obtain and maintain knowledge of the principles and practices of radiation protection and of the potential radiation hazards associated with industrial radiography equipment, which is sufficient to undertake measurements of radiological parameters, investigations and assessments and other duties required of him or her

(iv) Ensure that each radiation worker who may be exposed to radiation in the course of radiography operations uses appropriate radiation monitoring devices, including a personnel radiation monitoring device, a survey meter and a personnel dosimeter issued for the worker's exclusive use

(v) Be familiar with the provisions of relevant regulation, radiation monitoring and protective equipment, nature and physical appearance of any gamma-radiography sources and the detailed working rules and emergency procedures

(vi) Establish and maintain an effective radiation protection programme to ensure safety of workers, members of the public and the environment

(vii) Assist the licensee in developing suitable emergency response plans to deal with emergencies and ensuring appropriate emergency preparedness

(viii) Carry out radiation surveys periodically, to ensure that safe radiography work procedures are being followed at the site(s)

(ix) Ensure that personal radiation monitoring equipment, survey meters, source containers, shutters and source control mechanisms, X-ray equipment indicators and interlocks, door interlocks of enclosed radiation installation and area monitors, and other appropriate equipment related to radiation safety are inspected and tested regularly

(x) Instruct workers on safety measures and safe work practices aimed at minimizing exposure to radiation and contamination

(xi) During movement of IRED, ensure that packages containing radiography sources are properly packed, labelled and declared as per the national/international requirements for the safe transport of radioactive material

(xii) Comply with regulation for safe transport of radioactive material

(xiii) Investigate and initiate suitable remedial measures in situations that could lead to potential radiological risk

(xiv) Make available reports to the employer/licensee on all hazardous situations along with details of any immediate remedial actions taken, for further transmitting to the Competent Authority

(xv) Advise employer /license on safe disposal of disused radioactive source (s) and other decayed

(xvi) Maintain operational logbook

(xv) ensure that:

(a) all necessary personal radiation monitoring devices and radiation survey meters are available and are in good working order, and that the survey meters are periodically calibrated;

(b) no person receives radiation exposure in excess of the limits prescribed by the Competent Authority and that all radiation exposures are kept as low as reasonably achievable (ALARA);

(c) direct reading dosimeters are issued, as necessary, used properly, collected and assessed;

(a) personal dosimeters are promptly submitted for assessment after use, in accordance with the applicable requirements;

(b) investigation of reported occupational exposure in a monitoring period is carried out and the investigation report submitted to employer/licensee with a copy to Competent Authority;

(c) all radiographic equipment and emergency handling tools are periodically serviced and maintained in proper working condition.

(xvii) Carry out QA tests for the IGRED before re-loading of source and ensure that the safety systems and shielding of the exposure device are functional, as required

(xviii) Advise the licensee about the modifications in working condition of a pregnant Worker, and

(xix) Inform the Competent Authority when s/he relinquishes as RSO in the institution.

8. PERSONNEL IN GAMMA/X-RAY IRRADIATION CHAMBER FACILITY AND THEIR RESPONSIBILITIES

8.1 Introduction

The Self-contained Dry Source Storage Gamma Irradiator is also known as Gamma Irradiation Chambers (GIC), Gamma Chambers, Blood Irradiators (BI) or Gamma Cells. Such irradiators are being extensively used in various universities, academic and research institutions for research and development purposes. Also used in hospitals and blood banks for irradiation of blood and blood products/components, for clinical and research purposes. GIC unit mainly houses either ^{60}Co or ^{137}Cs radiation sources with typical radioactivity ranging from tens to hundreds of TBq.

X-ray irradiation chambers (XIC) with operational rating in terms of hundreds of kV, are also used for these purposes. These units are generally self-shielded and inherently safe for operation. Radiation safety aspects for these facilities include safe handling of radioactive sources and safety aspects to be addressed during operation of these facilities and decommissioning after their useful life.

Regulated Utilities: Gamma/X-ray Irradiation chamber facility and manufacturer/supplier of these devices.

8.2 Radiation Workers (Personnel in GIC/XIC Facility)

This section provides the minimum desirable qualification, radiation safety certification process, adequacy of radiation safety professionals, including their approval/licensing process and role and responsibilities. The safety personnel is identified as Radiation Professional-Irradiation Chamber-1 (RP-IC-1).

The infrastructure for course conducting agency and minimum radiation safety syllabi for the training courses is specified in **Appendix 5 and Annexure 8** respectively.

8.2.1 Radiological Safety Officer (RSO)
(Radiation Professional-Irradiation Chamber-1 (RP-IC-1)
Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Basic degree in Science or Health Science or Paramedical Science from a recognized University/Institution
Or;
Diploma in Engineering from a recognized University/Institution

Radiation Safety Certification:

(i) Successful completion of Radiation Safety Certification i.e. 'RSO Certification for Gamma/X-ray Irradiation Chamber' from AERB recognized agency.

Adequacy of Personnel:

(i) Each GIC/XIC facility should have a Radiological Safety Officer.
(ii) Manufacture/supplier of GIC/XIC should have a Radiological Safety Officer.

Approval/Licensing and Renewal:

(i) Designated RSO should register as RP-IC-1 with AERB, based on successful completion of radiation safety certification and obtain an approval from Competent Authority to function as a Radiological Safety Officer (RSO).
(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RSO, with due adherence to the current safety regulations or are its modifications thereof, has the following responsibilities:

(i) Advice and assist the employer and licensee in ensuring regulatory compliance for obtaining consent from the Competent Authority for procurement, use, transport or disposal of radioactive material
(ii) Implement all radiation surveillance measures including display of radiation symbol and warning at the entrance door of room where unit is installed
(iii) Implement continuous display of the radiation symbol, warning, marking and labeling on the unit
(iv) Establish and maintain an effective radiation protection programme to ensure safety of workers, members of the public and the environment
(v) Train the operators and associated servicing /maintenance personnel on basic radiation safety, hazard potential and biological effects of radiation
(vi) Instruct all operators/users on relevant safety measures, provide adequate training in radiation protection and safety methodologies, use of personnel monitoring devices (TLD badges)
(vii) Ensure that personnel monitoring devices are provided to radiation workers in the facility, used as required and are securely stored away from radiation area
(viii) Ensure that radiation monitoring instruments are kept in proper working condition and are periodically calibrated
(ix) Assist the licensee in developing suitable emergency response plans to deal with emergencies and ensuring appropriate emergency preparedness
(x) Conduct periodic radiation protection surveys and maintain records
(xi) Maintain inventory of sources including initial and present activity, operational logbook and associated records
(xii) Furnish to the licensee and the competent authority periodic reports on safety status of the unit
(xiii) Investigate any situation that could lead to potential exposures and submit report to the employer/licensee with a copy to competent authority
(xiv) Advice employer on physical security measures

(xv) Advise employer on maintaining personnel monitoring records, analyse personnel exposure records to ensure that there are no abnormal exposure trends

(xvi) Prepare the standard operating procedures (SOP) from detailed instruction manual provided by manufacturer/supplier of the unit

(xvii) Ensure periodic servicing and preventive maintenance of the unit as prescribed by manufacturer/supplier and maintain records

(xviii) Ensure safe work practices during source replenishment and safe disposal of disused sources

(xix) Report on all hazardous situations along with details of any immediate remedial actions taken are made available to the employer and licensee for reporting to the competent authority

(xx) Advice the licensee on the modification in the working condition of female worker after her notification about pregnancy, and

(xxi) Inform the Competent Authority when s/he relinquish as RSO of the institution.

9. PERSONNEL IN NUCLEONIC GAUGE AND WELL LOGGING FACILITY AND THEIR RESPONSIBILITIES

9.1 Introduction

Nucleonic measurement and control systems, popularly known as nucleonic gauges (NG) or Ionising Radiation Gauging Devices (IRGD), are used in several industries for the measurement and control of process parameters such as thickness, density, level and material composition. The nucleonic gauge incorporates radiation sources of activity typically of the order of a few GBq or X-ray operated from low kV upto 160 kV. In view of the built-in safety of the IRGD and the low activity of the source, fulfillment of certain basic safety requirements in working with IRGD need to be implemented to ensure its safe use, which can be implemented by trained RSO in the facility.

Well logging (WL) technique with radioisotopes is used for oil and gas exploration to obtain a continuous record of a rock formation properties, which are used to infer characteristics, such as hydrocarbon saturation and formation pressure, and to make further drilling and production decisions. Well logging tool use a gamma source (^{137}Cs) and a neutron source (^{241}Am-Be) together with appropriate detectors.

Although for NG practice, RSO can address the radiation safety aspects, but in well logging practice, the operators who handle the sources for fitting in the logging tool work in close proximity to sources and likely to receive exposure. Presently, the institution (mainly Multi-National Companies) give in-house training and engage them in the radiation work. This guide includes a separate basic radiation safety training module for the operators to be imparted by the RSO of the WL facility. The syllabus is prescribed in the relevant section.

Regulated Utilities: IRGD and well logging facilities, manufacturer/supplier of sources /devices.

9.2 Radiation Workers (Personnel in Nucleonic Gauge and Well Logging Facility)

This section provides the minimum desirable qualification, radiation safety certification process, adequacy of radiation safety professionals, including their approval/licensing process and role and responsibilities. The safety personnel in NG & WL and operator in well logging are identified as Radiation Professional-Nucleonic Gauges-1 (RP-NG-1) and Radiation Professional-Well Logging -1 (RP-WL-1) respectively.

The infrastructure for course conducting agency and minimum radiation safety syllabi for the training courses and basic radiation safety certification is specified in **Appendix 5 and Annexure 9** respectively.

9.2.1 Radiological Safety Officer (RSO)

(Radiation Professional-Nucleonic Gauges-1 (RP-NG-1)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Basic degree in Science from a recognized University/Institution
Or;
Diploma in Engineering from recognized University/Institution.

Radiation Safety Certification:

(i) Successful completion of radiation safety certification i.e. 'RSO Certification for Nucleonic Gauges/Well Logging Applications' from an agency recognized by AERB.

Adequacy of Personnel:

(i) Each nucleonic gauge institution and logging base possessing radiation sources should have a Radiological Safety officer.
(ii) The number of RSO may preferably be more than one (with clearly identified responsibilities) in case of institutions in possession of a large number of NGs/WL sources.
(iii) Each manufacturer/supplier of NG devices/sources and Well Logging sources should have a Radiological Safety Officer.

For nucleonic gauge institution possessing only low energy beta/gamma emitters (e.g. ^{147}Pm, ^{204}Tl for coating thickness measurement and ^{55}Fe/^{109}Cd in XRF gauges), the employer can designate himself or any of his employee as responsible person for safety and security of the sources, and separate RSO approval process may not be required.

Approval/ Licensing and Renewal:

(i) RP-NG-1should register as radiation professional with AERB, based on successful completion of radiation safety certification and obtain an approval from Competent Authority to function as Radiological Safety Officer (RSO).
(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:
The RSO, with due adherence to the relevant provisions of the current safety regulations or modified thereafter, has the following responsibilities:

(i) Advice and assist the employer and licensee in ensuring regulatory compliance for obtaining consent from the Competent Authority for procurement, use, transport or disposal of radioactive material
(ii) Implement all radiation surveillance measures including display of radiation symbol and warning signs
(iii) Establish and maintain an effective radiation protection programme to ensure safety of workers, members of the public and the environment
(iv) Train the operators and associated servicing /maintenance personnel on basic radiation safety, hazard potential and biological effects of radiation
(v) Instruct all operators/users on relevant safety measures, provide adequate training in radiation protection and safety methodologies
(vi) Advice employer for provision of personnel monitoring to radiation workers in the facility, as applicable, and ensure that they are used as required and are securely stored away from radiation area

(vii) Ensure that radiation monitoring instruments are kept in proper working condition and are periodically calibrated
(viii) Assist the licensee in developing suitable emergency response plans to deal with emergencies and ensuring appropriate emergency preparedness
(ix) Conduct periodic radiation protection surveys and maintain records
(x) Maintain inventory of sources including initial and present activity, operational logbook and associated QA records, as applicable
(xi) Furnish to the licensee and the Competent Authority periodic reports on safety status of the facility
(xii) Investigate any situation that could lead to potential exposures and submit report to the Competent Authority
(xiii) Advise employer on physical security measures
(xiv) Analyse personnel exposure records to ensure that there are no abnormal exposure trends
(xv) Prepare the standard operating procedures (SOP) from detailed instruction manual provided by manufacturer/supplier, as applicable
(xvi) Ensure periodic servicing and preventive maintenance and maintain records
(xvii) Advise employer on safe disposal of disused sources
(xviii) Report on all hazardous situations along with details of any immediate remedial actions taken are made available to the employer and licensee for reporting to the Competent Authority
(xix) Advice the licensee on the modification in the working condition of female worker after her notification about pregnancy, and
(xx) Inform the Competent Authority when she/he relinquishes as RSO in the institution.

9.2.2 Radiation Professional-Well Logging-1 (RP-WL-1):

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) 10+2 science or an equivalent examination from a recognized Board/University;
Or
Diploma in Engineering from recognized University/Institution.

Radiation Safety Certification:

(i) RP-WL-1should successfully complete 'Basic Radiation Safety Module' in Well Logging through radiation safety evaluation as prescribed by AERB.

Adequacy of Personnel:

(i) Each Well Logging base possessing radiation sources should have appropriate numbers of RP-WL-1 for carrying out their logging activities.

Approval/Licensing and Renewal:

(i) RP-WL-1 in well logging should register as radiation professional (RP)/radiation worker (RW) with AERB, based on successful completion of radiation safety evaluation.
(ii) The RP registration is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RP-WL-1, with due adherence to the provisions of the current safety regulations or its modifications thereof, has the following responsibilities:

(i) Handle the well logging sources as per written instructions and established Standard Operating Procedures (SOP)
(ii) Make complete and correct entries in the operation logbook
(iii) Adhere with safe work practices and instructions of RSO
(iv) Use personnel dosimeter appropriately at all times while working and store the same away from radiation area, and
(v) Report to the RSO in writing of any unusual occurrence or suspected exposure above normal levels and seek advice on remedial action.

10. PERSONNEL IN UNIVERSITY, ACADEMIC AND RESEARCH INSTITUTIONS AND THEIR RESPONSIBILITIES

10.1 Introduction

A. Institution Possessing other than Reference Sources

Radioisotopes have wide spectrum of applications in research studies especially in physio-chemical, bio-medical, agricultural, veterinary sciences, pharmaceuticals and industrial research. Sealed/unsealed radiation sources of different strength and physical forms are handled in laboratories as well as studies in open field. Different types of radiation sources with activity ranging from several kBq to few MBq are being used in research applications. These include mainly ^{3}H, ^{14}C, ^{35}S, ^{32}P, ^{125}I, ^{60}Co, ^{137}Cs etc.

Similarly, radiation sources are used in university/academic institution for research and other activities such as nuclear physics experiments, activation studies etc. Although medium to low activity sources are used in these institutions, but they still have the potential to cause radiological hazards, contamination, if not handled safely. Handling of radiation sources in such applications necessitates supervision from radiological safety standpoint. Hence, it requires radiation safety certification of the personnel through appropriate training programme.

B. Institution Possessing Reference Sources

The university/ academic institution also used number of check/reference source of very low activity for laboratory experiments/demonstration in nuclear physics and other relevant subjects for the students in Graduate and Post Graduate programmes. In view of negligible hazard potential, exclusive safety training may not be required. However, user department should identify a suitable personnel(s) and assign them the responsibility for safety, security and inventory control of radiation sources. These personnel should undergo basic radiation safety evaluation, with syllabi as prescribed in the relevant section.

On successful completion of this module the personnel may become eligible to be designated as RSO in academic institution. The safety personnel in University, Academic and Research Institution is identified as Radiation Professional-University Research-1 (RP-UR-1).

Regulated Utilities: University, Academic and Research institution handling radiation sources.

10.2 Radiation Workers (Personnel in University, Academic and Research Institutions)

This section provides the minimum desirable qualification, radiation safety certification process and adequacy of radiation safety professionals, including their approval/licensing process and role and responsibilities.

The infrastructure for course conducting agency is given in **Appendix 5**. The minimum radiation safety syllabi for the training courses (Part A) and basic radiation safety certification (Part B) is as specified in **Annexure 10A and 10B** respectively.

10.2.1 Radiological Safety Officer (RSO): Radiation Professional-University Research-1(RP-UR-1)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Basic degree in Science or Health Sciences or an equivalent from a recognized University/ Institution
Or;
Diploma in Engineering from recognized University/Institution.

Radiation Safety Certification:

A. For Institution Possessing other than Reference Sources:

(i) Successful completion of Radiation Safety Certification i.e. 'RSO Certification for Research Application of Ionizing Radiation' from an agency recognized by AERB.

B. For Institution Possessing Reference Sources:

(i) Successful completion of 'Basic Radiation Safety Module' through radiation safety evaluation as prescribed by AERB.

Adequacy of Personnel:

(i) Each institution possessing radiation sources for research, academic purpose should have a Radiological Safety Officer.

Approval/ Licensing and Renewal:

(i) RP-UR-1 should register as radiation professional with AERB, based on successful completion of radiation safety certification and obtain an approval from Competent Authority to function as a Radiological Safety Officer.
(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RSO, in addition to implementing the relevant safety provisions of the current regulations or its modifications thereof, has the following responsibilities:

(i) Train the research students, laboratory technicians and associated personnel on basic radiation safety, hazard potential and biological effects of radiation
(ii) Instruct the workers on radiation safety and safe work practice
(iii) Submit the periodic safety status report to AERB
(iv) Maintain inventory of sources available in the institution
(v) Report any unusual incidents, loss/theft of source(s) promptly to the licensee and to the Competent Authority
(vi) Advise the employer on safe disposal of decayed and disused sources
(vii) Perform any other such functions identified in the licensing conditions to ensure safety and security in the use of radioactive sources, and
(viii) Inform the Competent Authority when s/he relinquishes as RSO of the institution.

11. PERSONNEL IN RADIOLOGICAL CALIBRATION LABORATORIES AND THEIR RESPONSIBILITIES

11.1 Introduction

Different types of radiation sources are being used for various applications in medicine, industry, agriculture and research depending on the application and characteristics of sources. Monitoring the radiation levels during handling of radiation sources is a part of radiological surveillance procedures, which is carried out with the help of radiation monitoring instruments (RMI). With increase in the number of radiation facilities, the availability of calibrated radiation monitoring instruments needs to be ensured at all the time. To cater to the need for calibration of these instruments, the manufacturers/suppliers of RMIs and other interested agencies may setup the calibration facilities for RMIs with due regulatory approval. There is also scope for interested agencies to setup calibration facilities for measuring instruments used in medical applications.

Routine monitoring of the radiation workers is the regulatory requirement for assessing their occupational doses at the workplace, TLD badges are used for this purpose. Accredited personnel monitoring laboratories cater to the need of providing personnel monitoring service (PMS) to the workers. These laboratories need to possess and handle the radiation source with activity in the range MBq to GBq for routine calibration of personnel monitoring badge reader system.

Handling of radiation sources in calibration laboratories for measuring, monitoring instruments and Personnel monitoring service providers requires the availability of adequately trained safety personnel.

Regulated Utilities: Calibration and PMS laboratories possessing radiation sources.

11.2 Radiation Workers (Personnel in Calibration Facilities)

This section provides the minimum desirable qualification, radiation safety certification process, adequacy of radiation safety professionals, including their approval/licensing process and role and responsibilities. The safety personnel in radiological calibration facilities are identified as Radiation Professional-Calibration Laboratories (RP-CL-1).

The infrastructure for course conducting agency and minimum radiation safety syllabi for the training courses is as specified in **Appendix 5 and Annexure 11** respectively.

11.2.1 Radiological Safety Officer (RSO):

Radiation professional –Calibration Laboratories-1 (RP-CL-1)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Basic degree in Science or an equivalent from recognized University/Institution;
Or;
Diploma in Engineering from recognized University/Institution.
Or;

RP-RT-2 registered as radiation professional with AERB.

Radiation Safety Certification:

(i) Successful completion of radiation safety certification i.e. 'RSO Certification for Calibration of RMIs and PMS Facility' from an agency recognized by AERB;
or;

RP-RT-2 with successful completion of RSO (Medical/ Industry & Research) examination from an agency recognized by AERB.

Adequacy of Personnel:

(i) Each calibration facility possessing radiation sources should have a Radiological Safety Officer.

Approval/ Licensing and Renewal:

(i) RP-CL-1 should register as radiation professional with AERB, based on successful completion of radiation safety certification and obtain an approval from Competent Authority to function as Radiological Safety Officer.
(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

(Note: Registration as RP-CL-1 is *also applicable for RP-RT-2* with successful completion RSO (Med/Industry& Research), who is *not associated with any medical radiation facility)*

Role and Responsibilities:

The RSO, with due adherence to the provisions of the current safety regulations or modified, has the following responsibilities:

(i) Advice and assist the employer and licensee in ensuring regulatory compliance for obtaining consent from the Competent Authority for procurement, use, transport or disposal of radioactive material
(ii) Implement all radiation surveillance measures including display of radiation symbol and warning signs
(iii) Establish and maintain an effective radiation protection programme to ensure safety of workers, members of the public and the environment
(iv) Train the operators and associated servicing /maintenance personnel on basic radiation safety, hazard potential and biological effects of radiation
(v) Instruct all operators/users on relevant safety measures, provide adequate training in radiation protection and safety methodologies, use of personnel monitoring devices (TLD badges)
(vi) Advice employer for provision of personnel monitoring devices to radiation workers in the facility, used as required and are securely stored away from radiation area
(vii) Ensure that radiation monitoring instruments are kept in proper working condition and are periodically calibrated
(viii) Assist the licensee in developing suitable emergency response plans to deal with emergencies and ensuring appropriate emergency preparedness

(ix) Conduct periodic radiation protection surveys and maintain records

(x) Maintain inventory of sources including initial and present activity, operational logbook and associated QA records, as applicable

(xi) Furnish to the licensee and the Competent Authority periodic reports on safety status of the facility

(xii) Investigate any situation that could lead to potential exposures and submit report to the Competent Authority

(xiii) Advice employer on physical security measures

(xiv) Analyse personnel exposure records to ensure that there are no abnormal exposure trends

(xv) Prepare the standard operating procedures (SOP) from detailed instruction manual provided by manufacturer/supplier, as applicable

(xvi) Ensure periodic servicing and preventive maintenance and maintain records

(xvii) Advice employer on safe disposal of disused sources

(xviii) Report on all hazardous situations along with details of any immediate remedial actions taken are made available to the employer and licensee for reporting to the Competent Authority

(xix) Advice the licensee on the modification in the working condition of female worker after her notification about pregnancy, and

(xx) Inform the Competent Authority when she/he relinquishes as RSO of the institution.

12. PERSONNEL IN SCANNING FACILITIES AND THEIR RESPONSIBILITIES

12.1 Introduction

Baggage scanning machines also known as X-ray baggage scanner is the X-beam investigation system that is regularly utilized for security screening of baggage at various locations such as airports, railway stations and commercial complexes. X-ray based food scanners are used in the food industry to enhance the product purity and improves the quality of the end product by detecting foreign objects in the packaged products, missing products in packing, broken products etc. Portable scanners are used by Law Enforcement Authority for security purposes. X-ray and radioactive source based cargo scanners are used for scanning of cargo containers. With the increasing use of scanning systems, the suppliers/ applicable end users need appropriate training and instructions in radiation safety during the use of such systems.

Regulated Utilities:

(i) Supplier & manufacturer of scanning equipment (X-ray baggage inspection, food inspection scanners, portable X-ray scanner, vehicle scanner etc.)
(ii) Supplier & manufacturer of X-ray based analytical and research equipment (XRF/XRD).
(iii) End user of vehicle scanner and portable X-ray scanner.

12.2 Radiation Workers (Personnel in Scanning Facility)

This section provides the minimum desirable qualification, radiation safety certification process, adequacy of radiation safety professionals, including their approval/liceinsing process and role and responsibilities. The safety personnel in scanning facility is identified as Radiation Professional-Scanning Facility-1 (RP-SF-1).

The infrastructure for course conducting agency and minimum radiation safety syllabi for the training courses is as specified in **Appendix 5 and Annexure 12** respectively.

12.2.1 Radiological Safety Officer (RSO)

Radiation Professional-Scanning Facility-1 (RP-SF-1)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Basic degree in Science or equivalent from a recognized University/Institution
Or;
Diploma in Engineering from recognized University/Institution.

Radiation Safety Certification:

(i) Successful completion of Radiation Safety Certification i.e. 'RSO Certification for Scanning Facility' from an agency recognized by AERB.

Adequacy of Personnel:

(i) Each institution operating vehicle scanner and portable X-ray scanner should have a Radiological Safety Officer.

(ii) Each manufacturer/ suppliers of scanning equipment and X-ray based analytical and research equipment should have a Radiological Safety Officer.

Approval/ Licensing and Renewal:

(i) RP-SF-1 should register as radiation professional with AERB, based on successful completion of radiation safety certification and obtain an approval from Competent Authority to function as Radiological Safety Officer.
(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RSO, with due adherence to the provisions of the current safety regulations or modified thereafter, has the following responsibilities:

(i) Advice and assist the employer and licensee in ensuring regulatory compliance for obtaining consent from the Competent Authority for procurement, use, transport or disposal of radioactive material
(ii) Implement all radiation surveillance measures including display of radiation symbol and warning signs
(iii) Train the operators and associated servicing /maintenance personnel on basic radiation safety, hazard potential and biological effects of radiation
(iv) Instruct all operators/users on relevant safety measures, provide adequate training in radiation protection and safety methodologies
(v) Advice employer on provision of personnel monitoring, as applicable
(vi) Ensure that radiation monitoring instruments are kept in proper working condition and are periodically calibrated
(vii) Assist the licensee in developing suitable emergency response plans to deal with emergencies and ensuring appropriate emergency preparedness
(viii) Conduct periodic radiation protection surveys and maintain records
(ix) Maintain inventory of sources including initial and present activity, operational logbook and associated QA records, as applicable
(x) Furnish to the licensee and the Competent Authority periodic reports on safety status of the facility
(xi) Investigate any situation that could lead to potential exposures and submit report to the Competent Authority
(xii) Prepare the standard operating procedures (SOP) from detailed instruction manual provided by manufacturer/supplier, as applicable
(xiii) Ensure periodic servicing and preventive maintenance and maintain records
(xiv) Report on all hazardous situations along with details of any immediate remedial actions taken are made available to the employer and licensee for reporting to the Competent authority
(xv) Advice the licensee on the modification in the working condition of female worker after her notification about pregnancy, and
(xvi) Inform the Competent Authority when s/he relinquishes as RSO of the institution.

13. PERSONNEL IN SUPPLIER(S) OF CONSUMER PRODUCTS AND SOURCES (LOW ACTIVITY) FACILITY AND THEIR RESPONSIBILITIES

13.1 Introduction

Consumer products such as smoke detector, lamp starters etc. are used in various equipment/systems and contain low activity radiation sources mostly in exempt quantity and not requiring regulatory control at end user level. The basic safety instructions in their use are addressed through the suppliers' instruction manuals. However, suppliers are handling large number of devices with sources in bulk quantities and hence need to be aware about the safe handling, storage, supply/transport and safe disposal of radioactive waste arising from it. Further, the suppliers of low activity sources, normally used as check/reference sources in university, research and academic institutions is also addressed in this section. The personnel from suppliers of sources of higher activities for specific practices/facilities are already addressed in the relevant practice specific sections.

Regulated Utilities:

(i) Manufacturer and suppliers of consumer products/ equipment with radiation sources (eg. Smoke detector, lamp starters)

(ii) Manufacturer and suppliers of other similar products containing sealed sources (eg. ECD/Explosive Detector/Narcotic, Chemical or Contraband Detector).

(iii) Supplier of low activity sources.

13.2 Radiation Workers (Personnel from suppliers of consumer products and sources (low activity)

This section provides the minimum desirable qualification, radiation safety certification process, adequacy of radiation safety professionals, including their approval/licensing process and role and responsibilities. The safety personnel in Supplier of Consumer Products and Sources is identified as Radiation Professional-Consumer Product (RP-CP-1).

The infrastructure for course conducting agency and minimum radiation safety syllabi for the training courses is as specified in **Appendix 5 and Annexure 13** respectively.

13.2.1 Radiological Safety Officer (RSO)

Radiation Professional-Consumer Product (RP-CP-1)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) Basic degree in Science or equivalent from a recognized University/Institution;
Or;
Diploma in Engineering from recognized University/Institution;

Radiation Safety Certification:

(i) Successful completion of radiation safety certification i.e. 'RSO Certification for Consumer Products Applications' from an agency recognized by AERB.

Adequacy of Personnel:

(i) Each institution involved in manufacturing/supply of consumer products and sources should have a Radiological Safety Officer.

Approval/ Licensing and Renewal:

(i) RP-CP-1 should register as radiation professional with AERB, based on successful completion of radiation safety certification and obtain an approval from Competent Authority to function as a Radiological Safety officer.
(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RSO, with due adherence to the provisions of the current safety regulations or modified thereafter, has the following responsibilities:

(i) Advice and assist the employer and licensee in ensuring regulatory compliance for obtaining consent from the Competent Authority for procurement, use, transport or disposal of radioactive material
(ii) Implement all radiation surveillance measures including display of radiation symbol and warning signs
(iii) Train the operators and associated servicing /maintenance personnel on basic radiation safety, hazard potential and biological effects of radiation
(iv) Instruct all operators/users on relevant safety measures, provide adequate training in radiation protection and safety methodologies and on the use of personnel monitoring devices (if applicable)
(v) Advice employer for provision of personnel monitoring to radiation workers in the facility
(vi) Ensure that radiation monitoring instruments are kept in proper working condition and are periodically calibrated
(vii) Assist the licensee in developing suitable emergency response plans to deal with emergencies and ensuring appropriate emergency preparedness
(viii) Conduct periodic radiation protection surveys and maintain records
(ix) Maintain inventory of sources including initial and present activity, operational logbook
(x) Furnish to the licensee and the Competent Authority periodic reports on safety status of the facility
(xi) Investigate any situation that could lead to potential exposures and submit report to the Competent Authority
(xii) Advice employer on physical security measures
(xiii) Ensure periodic servicing and preventive maintenance and maintain records
(xiv) Advice employer on safe disposal of disused sources
(xv) Advice the licensee on the modification in the working condition of female worker after her notification about pregnancy, and
(xvi) Inform the Competent Authority when she/he relinquishes as RSO of the institution.

14. PERSONNEL IN GAS MANTLE MANUFACTURING FACILITY AND THEIR RESPONSIBILITIES

14.1 Introduction

The consumer products such as gas mantles are used in various devices and contain low activity radiation sources mostly in exempt quantity and not requiring regulatory control at end users site. However, the manufacturer of these products handle bulk quantities of radioactive material and involved in processing the unsealed sources needs to be aware about the safe handling, storage, supply/transport and disposal of radioactive waste arising from the practice. Personnel need to be trained in radiation safety aspects of gas mantle manufacturing facility, so as to ensure safety in work practice.

Regulated Utilities: Manufacturers of gas mantles.

14.2 Radiation Workers (Personnel in Gas Mantle Manufacturing Facility)

This section provides the minimum desirable qualification, radiation safety certification process, adequacy of radiation safety professionals, including their approval/licensing process and role and responsibilities. The safety personnel in Gas Mantle Manufacturing Facility is identified as Radiation Professional-Gas Mantle-1 (RP-GM-1).

The infrastructure for course conducting agency and minimum radiation safety syllabi for the training courses is specified in **Appendix 5 and Annexure 14** respectively.

14.2.1 Radiological Safety Officer (RSO):

Radiation Professional-Gas Mantle -1 (RP-GM-1)

Minimum Qualification:

Qualification recognized by the relevant authority of India, such as

(i) 10+2 science or equivalent examination passed from a recognized Board/University.

Radiation Safety Certification:

(i) Successful completion of radiation safety certification i.e. 'RSO Certification for Gas Mantle Manufacturing Facility' from an agency recognized by AERB.

Adequacy of Personnel:

(i) Each facility involved in manufacturing of gas mantles should have a Radiological Safety Officer.

Approval/ Licensing and Renewal:

(i) RP-GM-1 should register as radiation professional with AERB, based on successful completion of radiation safety certification and obtain an approval from Competent Authority to function as a Radiological Safety officer.

(ii) The RP registration and RSO approval is valid for 5 years or as stipulated by AERB, and same should be renewed after validity period.

Role and Responsibilities:

The RSO, with due adherence to provisions of the current safety regulations or modifications modified thereafter, has the following responsibilities:

(i) Maintain the inventory of radioactive material
(ii) Provide instruction on safety and safe work practice to workers
(iii) Carry out periodic radiation protection survey and maintain the records
(iv) Safely transport the radioactive material during supply
(v) Ensure contamination free environment and safe disposal of contaminated objects
(vi) Submit periodic safety status report to AERB
(vii) Implement all radiation surveillance measures, and
(viii) Inform the competent Authority when s/he relinquishes as RSO of the institution.

Section B. SAFETY INFRASTRUCTURE REQUIREMENT IN INSTITUTION CONDUCTING TRAINING COURSES

APPENDIX-1: INFRASTRUCTURE FOR TRAINING COURSE FOR RP-DR-2 IN DIAGNOSTIC RADIOLOGY

1. Faculty

The institution should have;

(i) One RP-DR-1/ Medical practitioner associated with Diagnostic Radiology Facility

(ii) One full time RP-DR-2 (with minimum five years' experience) to cover the operational aspects of DR equipment, and

(iii) One RP-RT-2 or equivalent faculty to teach radiation physics and radiation safety syllabus.

In addition, faculty should be available to cover the requisite syllabi relevant to professional aspects of the Course.

The faculties proposed by the institution for delivering lectures / conducting practical on radiation safety should have adequate work experience in radiation protection and safety.

The following para specifies the minimum infrastructure for conducting a training course for a typical batch of 10 students.

2. Classrooms and Library

The course conducting institution should have adequate infrastructure for conducting the theory classes.

(i) Lecture hall with adequate seating capacity and infrastructure (eg. computers, LCD projector etc.)

(i) A library containing relevant books on Physics of Diagnostic Radiology & Imaging Technology, Radiation Biology, Detection and Measurement, DR Techniques, Radiation Protection, relevant National/ International Safety Standards & QA protocols, Operational aspects of the DR equipment and other relevant subjects.

3. Equipment/Tools

The course conducting institution should have following equipment, systems and tools for practical/ demonstration:

(i) At least one radiography and fluoroscopy equipment

(ii) Quality Assurance (QA) kit and appropriate phantoms for practical demonstration of QA tests of various types of diagnostic X-ray equipment

(iii) Appropriate radiation measuring and monitoring devices (eg. Radiation Survey meter, TLD, Direct Reading Devices (DRD)/pocket dosimeter).

(iv) Adequate number of protective accessories (eg. Lead apron, mobile protective barrier, ceiling suspended screen, couch hanging lead rubber flaps, thyroid shield etc.)

(v) Other X-ray equipment such as mammography, CT, IR, C-Arm and dental equipment required for practical/ demonstration, may be arranged in collaboration with nearby hospital.

4. Affiliation and Collaboration

Affiliation and Collaboration arrangements should address the following:

(i) The course conducting institution should be affiliated with recognized Board/University.

(ii) In case of collaboration, same should be supported by Memorandum of Understanding (MoU) with the collaborating institution. The duration of MoU should be in accordance with validity of approval / recognition of the course.

(iii) The collaborating hospital/institution should be located in the same city/town where the course is conducted.

(iv) The course conducting institution should not collaborate with more than 2 hospitals/institutions at a time.

****

APPENDIX-2: INFRASTRUCTURE FOR TRAINING COURSE FOR RP-NM-2 IN NUCLEAR MEDICINE

1. Faculty

The institution should have;

(i) One RP-NM-1 in Nuclear Medicine (NM)

(ii) One Full time RP-NM-2 with minimum five years' experience (preferably with Post-Graduate degree in science).

(iii) RSO (NM) preferably with Post- Graduation degree in science or RP-RT-2 (with 3 years of experience as RSO for NM).

In addition, faculty should be available to cover the requisite syllabi relevant to professional aspects of the training course.

The faculties proposed by the institution for delivering lectures / conducting practical on radiation safety should have adequate work experience in radiation protection and safety.

The following para specifies the minimum infrastructure for conducting a training course for a typical batch of 5 students.

2. Classrooms and Library

The course conducting institution should have adequate infrastructure for conducting the theory classes.

(i) Lecture hall with adequate seating capacity and infrastructure (eg. computers, LCD projector etc.)

(ii) A library containing relevant books on Physics of Nuclear Medicine & Imaging Technology, Radiation Biology, Detection and Measurement, NM techniques Radiation Protection, Radiochemistry relevant National/ International Safety Standards & QA protocols, Operational aspects of the NM equipment and other relevant subjects.

3. Equipment/Tools

The course conducting institution should have following equipment/system and tools for practical/demonstration.

(i) At least one imaging modality (eg. SPECT-CT/PET-CT and/or PET MRI)

(ii) Other imaging modalities (such as SPECT-CT/PET-CT and/or PET MRI and High Dose Therapy Facility) for demonstration of diagnostic, low dose therapy, high dose therapy procedures in nuclear medicine, may be arranged in collaboration with nearby institution.

(iii) Appropriate devices for measuring and monitoring of radiation (radiation survey meter, contamination monitor, DRD, well type chamber coupled with single/multi-channel analyser, isotope/dose calibrator)

(iv) QA tools and phantoms for practical/ demonstration of quality assurance tests of various type of NM equipment as per national/international protocol or as per NEMA standard.

(v) Adequate number of protective accessories (eg. Lead apron, syringe shield, L-bench, lead temporary shielding material, Fume hood etc.)

(vi) Decontamination kit.

4. Security Aspects

Adequate physical security measures should be provided for the radiation sources ensure the security of sources at all times.

5. Agreements for Collaboration

Affiliation and Collaboration arrangements should address the following:

(i) The course conducting institution should be affiliated with recognized Board/University.

(ii) In case of collaboration, same should be supported by Memorandum of Understanding (MoU) with the collaborating institutions (eg. Hospital with University, as applicable).The duration of MoU should be in accordance with validity of approval / recognition of the course.

(iii) The collaborating hospital/institution should be located in the same town/ city, where the theory/practical course is conducted.

(iv) The course conducting institution should not collaborate with more than 2 hospitals/institutions at a time.

****

APPENDIX-3A: INFRASTRUCTURE FOR TRAINING COURSE FOR RP-RT-2 IN RADIOTHERAPY

1. Faculty

A. Faculty, if course is conducted at Radiotherapy Centre

(i) Two full time RP-RT-2 (with 5 years experience) exclusively for teaching programme in addition to the adequate number of RP-RT-2 & RSO required for clinical/safety work.

B. Faculty, in case the course is conducted at University/ College

(i) Two full time RP-RT-2 (with 5 years experience) as a Medical Physics faculty for teaching purpose only. At least one of them should have successfully completed the RSO (Medical) certification.

In addition, adequate faculty should be available to cover the requisite syllabi relevant to professional aspects of the course.

The faculties proposed by the institution for delivering lectures / conducting practical on radiation safety should have adequate work experience in radiation protection and safety.

The following para specifies the minimum infrastructure for conducting a training course for a typical batch of 5 students.

2. Classrooms and Library

The course conducting institution should have adequate infrastructure for conducting the theory classes.

(i) Lecture hall with adequate seating capacity and infrastructure (eg. computers, LCD projector etc.)

(ii) A library containing relevant books on Medical Physics, Physics of Radiotherapy & Imaging, Radiation Dosimetry, Radiation Biology, Radiation Detection and Measurement, Radiation Protection, relevant National/International Safety Standards etc. relating to medical physics course.

3. Equipment/Tools

The course conducting institution should have following equipment/system and tools for practical/demonstration.

(i) Equipment for RT, DR and NM practical and demonstration purpose (For availability of the equipment, the course conducting institution may collaborate with other institutions).

- ✓ Linear Accelerator with advanced treatment modalities
- ✓ HDR Brachy therapy
- ✓ Simulator/CT Simulator

- ✓ Diagnostic radiology equipment (eg. Fixed x-ray and fluoroscopy equipment, CT, Cath Lab. etc.)
- ✓ Nuclear medicine equipment/facility (eg. SPECT-CT, PET-CT, Low Dose/High Dose therapy facility etc.)

(ii) QA tools and phantoms (eg. RFA, solid phantom) for practical demonstration and quality assurance tests of various type of RT equipment.

(iii) QA kit and phantom as per NEMA protocol or national/international standard to perform quality assurance of SPECT-CT, PET-CT, PET-MRI, SPECT equipment.

(iv) QA kit and phantom as per national / international standard to perform QA of all types of diagnostic X-ray equipment.

(v) Appropriate devices for measuring and monitoring of radiation (SSD, parallel plate chamber, radiation survey meter, contamination monitor, DRD, well type chamber, dose calibrator etc.).

(vi) Treatment planning system

(vii) TLD/OSLD Reader and Film based Dosimetry verification system

(viii) Adequate number of devices and safety accessories for conducting relevant practical/demonstrations (eg. steel and lead plates for HVT / TVT, inverse square law etc.).

(ix) Reference check sources (eg.^{137}Cs /^{60}Co).

(x) Any other instruments, accessories required for specific practical/ demonstration.

4. Security Aspects

Adequate physical security measures should be provided for the radiation sources ensure the security of sources at all times.

5. Agreements for Collaboration

Affiliation and Collaboration arrangements should address the following:

(i) The course conducting institution should be affiliated with recognized University.

(ii) In case of collaboration, same should be supported by Memorandum of Understanding (MoU) with the collaborating institutions (eg. Hospital with University, as applicable).The duration of MoU should be in accordance with validity of approval / recognition of the course.

(iii) The collaborating hospital/institution should be located in the same city/town, where the theory/practical course is conducted.

(iv) The course conducting institution should not collaborate with more than 2 hospitals/institutions at a time.

(v) Agreement with well-equipped radiotherapy departments for arranging mandatory one year internship programme for the candidates admitted in the course.

APPENDIX-3B: INFRASTRUCTURE FOR TRAINING COURSE FOR RP-RT-3 IN RADIOTHERAPY

1. Faculty

The institution should have:

(i) One full time RP-RT-2 (with 5 years experience)

(ii) One full time RP-RT-3 (with 5 years experience) exclusively for teaching programme in addition to the adequate number of RP-RT-2, RSO and RP-RT-3 required for clinical/safety work in a radiotherapy center.

In addition, faculty should be available to cover the requisite syllabus relevant to professional aspects of the course.

The faculties proposed by the institution for delivering lectures / conducting practical on radiation safety should have adequate work experience in radiation protection and safety.

The following para specifies the minimum infrastructure for conducting a training course for a typical batch of 5 students.

2. Classrooms and Library

The course conducting institution should have adequate infrastructure for conducting the theory classes.

(i) Lecture hall with adequate seating capacity and infrastructure (eg. computers, LCD projector etc.)

(ii) A library containing relevant books on Physics of Radiotherapy & Imaging, Medical Physics, Radiation Dosimetry, Radiation Biology, Detection and Measurement, Radiation Protection, relevant National/ International Safety Standards and radiation safety relating to Radiotherapy Technology, QA and Operational aspects of the radiotherapy Equipment and other relevant subjects.

3. Equipment/Tools

The course conducting institution should have following equipment/system and tools for practical/demonstration.

(i) Minimum one Telecobalt /Linear Accelerator

(ii) QA tools and phantoms (eg. RFA, solid phantom) for practical demonstration and quality assurance tests of various type of RT equipment.

(iii) Appropriate devices for measuring and monitoring of radiation (SSD, parallel plate chamber, radiation survey meter, contamination monitor, DRD, well type chamber etc.)

(iv) Adequate number of devices and safety accessories for conducting relevant practical/demonstrations (eg. steel and lead plates for HVT / TVT, inverse square law etc.)

(v) Any other instruments, accessories requires for specific demonstration / practical.

(vi) Other equipment like HDR Brachy therapy, Simulator, Diagnostic radiology equipment may be arranged in collaboration with nearby institution.

4. Security Aspects

Adequate physical security measures should be provided for the radiation sources ensure the security of sources at all times.

5. Agreements for Collaboration:

Affiliation and Collaboration arrangements should address the following:

(i) The course conducting institution should be affiliated with recognized Board/University

(ii) In case of collaboration, same should be supported by Memorandum of Understanding (MoU) with the collaborating institutions. (The duration of MoU should be in accordance with validity of approval / recognition of the course.

(iii) The collaborating hospital should be located in the same city/town, where the theory/practical course is conducted.

(iv) The course conducting institution should not collaborate with more than 2 hospitals at a time.

APPENDIX- 4: INFRASTRUCTURE FOR TRAINING COURSE FOR RP-IR-1 AND RP-IR-2 IN INDUSTRIAL RADIOGRAPHY

(Industrial Radiography Testing Level-1 (RT-1)/Industrial Radiography Testing Level-2 (RT-2)

1. Faculty

The institution should have:

(i) One full time RP-IR-2 (with 3 years experience) exclusively for teaching programme preferably approved RSO in Industrial radiography.

In addition, faculty should be available to cover the requisite syllabi relevant to professional aspects of the Course.

The faculty proposed by the institution for delivering lectures / conducting practical on radiation safety should have adequate work experience in radiation protection and safety.

Faculty for radiography technique aspects should have working experience in industrial radiography field.

The following para specifies the minimum infrastructure for conducting a training course for a typical batch of 30 students

2. Classrooms and Library

The course conducting institution should have adequate infrastructure for conducting the theory classes.

(i) Lecture hall with adequate seating capacity and infrastructure (eg. computers, LCD projector etc.)

(ii) A library containing relevant books on radiography techniques and radiation safety relating to training syllabi and other relevant subjects.

3. Equipment/Tools

The course conducting institution should have following equipment, systems and tools for practical/ demonstration:

(i) At least two industrial gamma radiography exposure devices (IGREDs) with radiography source(s) (Activity~10-20 Ci) and other accessories.

(ii) One portable industrial X-ray machine (for demonstration).

(iii) Two nos. of reference sources (^{137}Cs and ^{60}Co each of activity 5-10 mCi approx.).

(iv) Adequate numbers of calibrated radiation survey meters, low range (< 5R/hr) and high range (10 R/hr).

(v) Adequate numbers of calibrated pocket dosimeters (Range 0 - 200 mR & 0-1 R), chargers and pocket alarm.

(vi) Adequate numbers of radiation protection accessories such as remote handling tongs (C-V tong), lead containers, lead sheets and lead shot bags, radiation warning symbols, cordoning ropes, blinkers etc.

(vii) Two nos. of collimators for containing the reference source, specially designed for verification of inverse square law and HVT/TVT of lead /steel.

(viii) Adequate number of steel and lead plates with thicknesses ranging from 1-10 mm for conducting HVT / TVT practical.

(ix) QA test tools for industrial radiography exposure devices (IREDs) to verify operational performance.

(x) Accessories required for carrying out radiographic testing practical.

4. Infrastructure Requirement for Practical/ Demonstration

(i) Radiography enclosure (closed top), preferably with internal dimension 6 m x 6 m so that the exposure device and the accessories can be conveniently positioned to carry out radiography

(ii) Source storage facility with pit as per AERB specification for storage of industrial gamma radiography exposure device(s) (IGRED)

(iii) Dark room and image interpretation room with appropriate facilities

(iv) An exclusive room for conducting practical on radiation safety (with internal dimension preferably of 10 m x 10 m).

The course conducting institution may collaborate with nearby institution for providing the above infrastructure for practical demonstration.

5. Security Aspects

Adequate physical security measures should be provided for the radiation sources ensure the security of sources at all times.

6. Affiliation and Collaboration

Affiliation and Collaboration arrangements should address the following:

(i) The course conducting institution should be registered with Central Government / State Government / Local Govt. Authorities.

(ii) In case of collaboration, same should be supported by Memorandum of Understanding (MoU) with the collaborating institutions. The duration of MoU should be in accordance with validity of approval / recognition of the course.

(iii) Radiography enclosure and source storage pit should be on the land owned by or leased by course conducting institution/ collaborating institution.

(iv) The collaborating institution should be located in the same city/town, where the theory/practical course is conducted.

****

APPENDIX-5: INFRASTRUCTURE FOR RADIATION SAFETY TRAINING COURSES (OTHERS)

Following is the minimum infrastructure for short term training courses on radiation safety

(eg. Radiation Processing Facility, GIC, NG, Calibration, Research/Academic Institutions, Service Engineers, Suppliers of sources and Consumer Products, Manufacturers of Gas Mantles etc.)

1. Faculty

The institution should have:

(i) Appropriate faculty with adequate work experience and involvement in radiation safety training programmes for delivering lectures / conducting practical on radiation safety and practice specific aspects.

In addition, faculty should be available to cover the requisite syllabi relevant to professional aspects of the Course.

The following sections specifies the minimum infrastructure requirement for conducting a training course for a typical batch of 30 students.

2. Classrooms and Library

The course conducting institution should have adequate infrastructure for conducting the theory classes.

(i) Lecture hall with adequate seating capacity and infrastructure (eg. computers, LCD projector etc.)

(ii) A library containing books on radiation safety and relevant subjects (eg. practice specific)

3. Equipment/Tools

The course conducting institution should have following equipment, systems and tools for practical/ demonstration (as applicable).

(i) Adequate number of practice specific equipment /devices of various types.

(ii) Reference/ check sources sealed sources (eg. $^{137}Cs/^{60}Co$).

(iii) Adequate numbers of calibrated radiation survey meters of appropriate range.

(iv) Adequate number of calibrated pocket dosimeters with chargers and alarming pocket dosimeter.

(v) Adequate numbers of radiation protection accessories such as remote handling tongs (C-V tong), lead containers, lead sheets and lead shot bags, radiation warning symbols etc.

(vi) Adequate number of devices and safety accessories for conducting relevant practical/demonstrations (eg. steel and lead plates for HVT / TVT, inverse square law etc.)

(vii) Appropriate QA test tools, as applicable.

(viii) TLD Reader, as applicable.

(ix) Any other instruments, accessories required for specific demonstration / practical.

4. Infrastructures Requirement for Practical/Demonstration (as applicable)

(i) An exclusive room for conducting practical/demonstration on radiation safety

(ii) In case of training course for safety personnel in calibration facilities, approved calibration enclosure (closed top) with adequate internal dimension so that the exposure device and the accessories can be conveniently positioned to carry out calibration of radiation monitoring instruments (RMIs).

The course conducting institution may collaborate with nearby institution for providing the above infrastructure for practical demonstration /field training.

5. Security Aspects

Adequate physical security measures should be provided for the radiation sources ensure the security of sources at all times.

6. Affiliation and Collaboration

Affiliation and Collaboration arrangements should address the following:

(i) The course conducting institution should be registered with Central Government / State Government / Local Govt. Authorities.

(ii) In case of collaboration, same should be supported by Memorandum of Understanding (MoU) with the collaborating institutions. The duration of MoU should be in accordance with validity of approval / recognition of the course.

(iii) The collaborating institution should be located in the same city/town, where the theory/practical course is conducted.

SECTION C. SYLLABI FOR RADIATION SAFETY CERTIFICATION

ANNEXURE-1: INTRODUCTION TO TRAINING COURSES ON RADIATION SAFETY AND SYLLABI

Ionising radiation sources (radioisotopes and radiation generating equipment) are being used extensively in various fields such as medicine, industry, agriculture, research and training. While radiation sources have significant and indispensable uses in several fields, they may be harmful to the workers and members of public, if used indiscriminately and without due caution. It is therefore necessary that the sources are used with appropriate justification and ensuring safety of radiation workers, patients, members of public and the environment, so that maximum benefits are derived from the use of radiation sources with minimum risk.

This is only possible when the radiation sources are handled by the personnel who have acquired sufficient knowledge, training and skill in radiation protection and safety in addition to their professional competencies. Training is an important means of promoting safety culture and enhancing the level of competence of personnel involved in radiation protection activities.

The importance of adequate training for all those working with ionising radiation has been highlighted by AERB's operational experiences and investigations of unusual incidents. A significant contributory factor in radiation incidents is lack of adequate training, mishandling of the radiation sources, sometime leading to serious consequences.

The need for education and training in the various disciplines of radiation protection has been recognized by the authorities and this need has been partially met through many training courses undertaken by recognized organizations, either individually or in collaboration. AERB has earlier too, prescribed the minimum radiation safety syllabi for training of the personnel engaged in various radiation practices.

In line with the evolving trends in radiation applications, the syllabi has been periodically revised taking into consideration developments in technology, radiation protection, requirements of regulations, current international basic safety standards and training methodology. This safety guide prescribes the standard radiation safety syllabi to achieve both consistency and a common level in the technical content that should be included in the curricula of educational/training institutions involved in conducting radiation safety related training courses. This will be helpful in providing adequate and harmonized training to the concerned professionals.

The professional training courses are conducted by University/Institution or the specialized training agencies (which conduct training-cum-certification programs). The duration of course and its contents for various training programme ranges from a week to few months or years, based on the radiation practices. The syllabi prescribed here address the topics related to minimum radiation safety and is not specifically covering the technical aspects of the training course. These aspects should be addressed adequately by the concerned University /Institution / training agencies.

This safety guide covers the minimum syllabi to be incorporated in the academic programme by the university/institution, for long term courses such as those conducted for medical practitioners, operating and safety personnel in medical applications. The radiation safety certification of these personnel is based on their successful completion of academic programme and a radiation safety evaluation as prescribed by AERB, after which they become eligible for registration as radiation professional (RP) with AERB in respective practice.

However, to be eligible to function as RSO, the registered RP should obtain (additional) radiation safety certification and approval from Competent Authority.

For industrial practices, the training courses are of short term duration leading to safety certification, the syllabi is prescribed in detail including duration, number of lectures, practical and examination methodology. These courses are conducted by agencies recognized by AERB. Based on radiation safety certification, these personnel can register as radiation professional (RP) with AERB in respective practice and can become eligible to function as RSO with approval of Competent Authority.

It should be noted that the Post M. Sc. Diploma in Radiological Physics (Dip. R. P) conducted by BARC is historically covering medical and industrial applications of ionizing radiation. The candidates of this course after successfully completing the RSO Certification (i.e. RSO (Medical & Industrial) is eligible to be nominated as RSO in any of the radiation facility without further undergoing any additional safety certification for respective practices. Separate syllabi for RSO in industrial application is given in this document.

ANNEXURE-2: RADIATION SAFETY CERTIFICATION FOR PERSONNEL IN DIAGNOSTIC RADIOLOGY

ANNEXURE-2A

RADIATION SAFETY SYLLABI FOR POST GRADUATE MEDICAL COURSES IN DIAGNOSTIC RADIOLOGY AND MEDICAL SPECIALTIES (USING X-RAY EQUIPMENT)

Course Duration: As prescribed by University.

Faculty

The faculty proposed by the University/institution for delivering lectures and conducting practical on radiation safety should have adequate experience in relevant practice i.e. Radiation Physics / RSO (Medical).

Infrastructure: As prescribed by the relevant authority of India.

Examination

At least one mandatory separate paper on Radiation Safety should be incorporated in the University final examination pattern covering the radiation safety syllabi prescribed in this document.

The paper should have same weightage as given to other clinical papers.

Passing Criteria: As prescribed by University.

Syllabus **(40 h)**

1. **Introduction of Diagnostic X-ray (3 h)**

   Components of X-ray equipment, Influence of operating parameter (kV, mA and time) on image quality and patient dose, primary and scattered radiation, absorption and transmission, importance of X-ray beam filtration in diagnostic radiology.

2. **Introduction to Modalities of X-ray Equipment (4 h)**

   Principles of operation of various X-ray modalities- Radiography, fluoroscopy, C-Arm, Computed Tomography (CT) scan, digital subtraction angiography (DSA), mammography, interventional radiology (IR), bone densitometry, dental radiology.

3. **Quantities and Units (3 h)**

   Activity (Bq & Ci), Energy, exposure (C/kg & R), air kerma, absorbed dose (Gray & rad), radiation weighting factors (W_R), tissue weighting factors (W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

4. **Biological Effects of Radiation (4 h)**

   Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, stochastic (probabilistic) and tissue reaction (deterministic effects), correlation between radiation dose and

biological effects, effects of partial and whole body exposures, biological effects observable in diagnostic radiology practice.

5. Operational Limits (4 h)

Introduction to natural background radiation, concept of occupational risk, philosophy of radiation protection, system of dose limitation, , ALARA, dose limits to radiation workers and general public, AERB/ICRP recommendations, justification of medical exposures, introduction to diagnostic reference level for patient dose optimization in radio-diagnosis.

6. Radiation Detection & Measurement (2 h)

Instruments for measurement and monitoring of the radiation dose, personnel monitoring (TLD badges), Radiation survey meters, Direct Reading Dosimeter (DRD).

7. Radiation Safety Aspects in Diagnostic X-ray Equipment (8 h)

External hazard and their perspective, evaluation and control of hazard due to external radiation, individual and workplace monitoring- time, distance and shielding, Patient protection in diagnostic radiology, use of filters in x-ray equipment, radiation protection in diagnostic radiology and use of radiation protection accessories, Safe work practices for reduction of patient and occupational exposure.

8. Radiation Safety Aspects of Fluoroscopy, CT and IR (6 h)

CT Imaging Techniques, DSA, Interventional Radiology(IR), Patient safety considerations, operational safety requirements, comparison of doses in fluoroscopy, cine acquisition and DSA, Impact on patient and operator doses, introduction to patient dose monitoring quantities such as ESD, CTDI, DLP and DAP, and cumulative dose and its significance; requirement of monitoring and recording of patient dose quantities in CT &IR, Diagnostic reference levels and their significance for patient protection, radiation safety for comforters of patients, radiation injuries to patient during fluoroscopy procedures-identification, management and follow-up.

9. Regulatory Aspects for Diagnostic Radiology (4 h)

National Regulations with respect to use of diagnostic x-ray equipment, National regulatory authority, relevant regulatory documents such as Act, Rules, Code, responsibilities of employer, licensee, Radiological Safety Officer (RSO), medical practitioner and X-ray Technologist, regulatory requirements for installation and operation of Diagnostic Radiology equipment, Importance of QA in Diagnostic radiology and overview of QA parameters.

10. Radiation Incidents and Case Studies (2 h)

Radiation incidents during handling of X-ray equipment, excessive exposure to occupational workers, investigation of excessive exposure and case studies, prevention of excessive exposure, radiation injuries to patient- causes and prevention.

{Note: In addition to above syllabi, university may incorporate detailed topics related to radiation safety as required.}

ANNEXURE-2B

RADIATION SAFETY CERTIFICATION FOR SERVICE PERSONNEL/ RADIOLOGICAL SAFETY OFFICER (RSO) IN DIAGNOSTIC RADIOLOGY (SUPPLIER/MANUFACTURER/QA AGENCIES)

Course Duration: 6 (Six) working days

Examination:

The examination should consist of;

(i) A written paper of 80 marks (60 marks objective + 20 marks descriptive)

(ii) Viva-voce of 20 marks

Passing Criteria:

(i) Not less than 70% each in written and viva-voce examinations

(ii) Not less than 80% in aggregate.

Course Content:

A.	**Lectures (22 h)**	**Duration**
1.	Basic Radiation Physics	1 h
2.	Introduction to Diagnostic X-ray Equipment	2 h
3.	Interaction of Radiation with Matter	1 h
4.	Radiation Quantities and Units	2 h
5.	Biological Effects of Radiation	1 h
6.	Operational Limits	1 h
7.	Radiation Detection and Measurement	2 h
8.	Radiation Protection Aspects	2 h
9.	X-ray Imagining Devices & Techniques	2 h
10.	Planning of Diagnostic X-ray Installation	2 h
11.	Quality Assurance in Diagnostic Radiology	2 h
12.	Radiation Safety Aspects of Fluoroscopy, CT and IR	2 h
13.	Regulatory Aspects of Diagnostic Radiology	1 h
14.	Radiation Incidents and Case Studies	1 h

B. Practical/Demonstration : (8 h)

1. Familiarization with QA equipment and QA tools in Diagnostic Radiology (1 h)

2. Quality Assurance and radiation protection survey of a conventional X-ray installation (2 h)

3. Quality Assurance and radiation protection survey of interventional X-ray equipment (2 h)

4. Quality Assurance and radiation protection survey of a CT Scanner installation (3 h)

Syllabus:

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, bound and free electrons, binding energy, ionization, excitation, fluorescence, characteristic X-ray, stability of nucleus, isotopes, radioisotopes, types of radioactive disintegration, directly and indirectly ionizing radiations, radioactivity, X-rays and gamma rays, energy of ionizing radiation, half-life.

2. Introduction to Diagnostic X-ray Equipment

Components of X-ray equipment, production of X-ray, bremsstrahlung and characteristic X-rays, X-ray spectrum, types of X-ray tubes (anode, cathode, inherent filters, focal spot), heat production in the anode and cooling mechanism, quality and quantity of X-rays (effect of kV, mA), significance of filtration in X-ray tube,

3. Interaction of Radiation with Matter

Interaction of electrons with matter, interaction of photon with matter (photoelectric, Compton and pair production), influence of photoelectric effect and Compton effect on image quality and patient dose, absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT),

4. Radiation Quantities and Units

Activity (Becquerel & Curie), energy, exposure(C/kg &Roentgen), air kerma, absorbed dose (Gray & rad), radiation weighting factors(W_R), tissue weighting factors(W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

5. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, tissue reactions (deterministic) and stochastic (probabilistic) effects, threshold dose (partial and whole body exposures), biological effects observable in diagnostic radiology practice.

6. Operational Limits

Introduction to natural background radiation, concept of occupational risk, concept of justification, optimization and dose limitation applicable in diagnostic radiology, ALARA, AERB/ICRP recommendations on dose limits to radiation workers and general public.

7. Radiation Detection and Measurement

Principle of radiation detection, gas detectors (ionization chamber, and GM counter) solid state detectors (scintillators, semiconductors and Thermoluminescent Dosimeter {TLD}), radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, direct reading dosimeter, calibration and response of radiation monitoring instruments.

8. Radiation Protection Aspects

External hazard and their perspective, evaluation and control of hazard due to external radiation: individual and workplace monitoring, application of time, distance and shielding; Concept of Work Load, radiation protection survey and its assessment, shielding adequacy of radiation protection accessories, safe work practice, Diagnostic reference levels and their significance for patient protection, radiation safety for comforters of patients.

9. X-ray Imaging Devices and Techniques

Fundamentals of diagnostic radiology, limitations of conventional X-ray imaging, image quality characteristics (noise, contrast, resolution) parameters affecting image quality, methods to reduce scattered radiation, bucky grids, X-ray imaging devices: x-ray film, screen film system- H&D curve, image intensifier; Computed Radiography (CR) system, digital imaging system and flat panel detectors.
Radiography, fluoroscopy, Computed Tomography (CT), digital subtraction angiography (DSA), mammography, interventional radiology, bone mineral densitometry and dental radiology.

10. Planning of Diagnostic X-ray Installation

General principles of planning of diagnostic X-ray installations, site selection, workload, shielding requirements, openings and ventilation, X-ray installation layout- control console, patient waiting area, warning light and placard; model layouts of various X-ray installations.

11. Quality Assurance in Diagnostic Radiology

Importance of QA in Diagnostic radiology, test parameters and test procedures for congruence of optical and radiation fields, central beam alignment, effective focal spot size, exposure time, applied tube potential, total filtration, table top transmission, linearity of timer loading station, linearity of mA loading station, consistency of radiation output, low and high contrast resolution, table top dose rate, radiation leakage through tube housing and collimator, dark room procedures.
Quality assurance of CT (CT phantoms and measurement of CT dose index), QA of IR, QA of mammography, dental equipment and bone mineral density (BMD) analysis equipment.

12. Radiation Safety Aspects of Fluoroscopy, CT and IR

CT Imaging Techniques, DSA, Interventional Radiology **(I**R), Patient safety considerations, operational safety requirements, comparison of doses in fluoroscopy, cine acquisition and DSA, Impact on patient and operator doses, introduction to patient dose monitoring quantities such as ESD, CTDI, DLP and DAP, and cumulative dose and its significance; requirement of monitoring and recording of patient dose quantities in CT &IR, Diagnostic reference levels and their significance for patient protection, radiation safety for comforters of patients, radiation injuries to patient during fluoroscopy procedures-identification, management and follow-up.

13. Regulatory Aspects of Diagnostic Radiology

Regulations for manufacture, supply and use of X-ray equipment, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO), radiologist and Medical Technologist(DR), service personnel, Licensing requirements, regulatory requirements for import, procurement, installation, commissioning, operation, transfer, dismantling and decommissioning of diagnostic equipment, Radiation Protection Programme (RPP).

14. Radiation Incidents and Case Studies

Radiation incidents during handling of X-ray equipment, excessive exposure to occupational workers, investigation of excessive exposure and case studies, prevention of excessive exposure, radiation injuries - causes and prevention.

****

ANNEXURE-2 C

RADIATION SAFETY SYLLABI FOR TRAINING COURSE FOR RP-DR-2 IN DIAGNOSTIC RADIOLOGY (One year DR Course)

(Applicable for personnel operating X-ray equipment excluding Computed Tomography (CT) and Interventional Radiology (IR))

Minimum Radiation Safety Syllabus prescribed by AERB for RP-DR-2 professional course conducted by various teaching institutes/universities/paramedical boards.

Course Duration: As prescribed by University/Board, subject to fulfilling the minimum course duration and minimum entry level qualifications stipulated in this document.

The syllabus prescribed in this annexure is for One year course for RP-DR-2 program (Inclusive of 3 months in-field training)

Infrastructure: As per Appendix-1 of this document.

Examination:

At least one mandatory separate paper on Radiation Safety should be incorporated in the University final examination pattern covering the radiation safety syllabus prescribed in this document.

The paper should have same weightage as given to other clinical papers.

Passing Criteria: As prescribed by University.

Syllabus: **(60 h)**

1. Basic Radiation Physics (4 h)

Atomic structure, atomic number, mass number, bound and free electrons, binding energy, ionization, excitation, fluorescence, characteristic X-ray, stability of nucleus, isotopes, radioisotopes, types of radioactive disintegration, directly and indirectly ionizing radiations, radioactivity, X-rays and gamma rays, energy of ionizing radiation, half-life

2. Introduction to X-ray Equipment (6 h)

Components of X-ray equipment, Production of X-ray, bremsstrahlung and characteristic X-rays, X-ray spectrum, types of X-ray tubes (anode, cathode, inherent filters, focal spot), heat production in the anode and cooling mechanism, quality and quantity of X-rays (effect of kV, mA), significance of filtration in X-ray tube.

3. Interaction of Radiation with Matter (4 h)

Interaction of electrons with matter, interaction of photon with matter (photoelectric, Compton and pair production), influence of photoelectric effect and Compton effect on image quality and patient dose, absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

4. Radiation Quantities and Units (3 h)

Activity (Becquerel & Curie), energy, exposure(C/kg &Roentgen), air kerma, absorbed dose (Gray & rad), radiation weighting factors(W_R), tissue weighting factors(W_T), equivalent dose (Sievert & rem), effective dose (sievert & rem).

5. Biological Effects of Radiation (4 h)

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, tissue reactions (deterministic) and stochastic (probabilistic) effects, effects of partial and whole body exposures. Biological effects observable in diagnostic radiology practice.

6. Operational Limits (4 h)

Introduction to natural background radiation, concept of occupational risk, concept of justification, optimization and dose limitation applicable in diagnostic radiology, ALARA, AERB/ICRP recommendations dose limits to radiation workers and general public, diagnostic reference levels and their significance for patient protection, radiation safety for comforters of patients.

7. Radiation Detection and Measurement (3 h)

Principle of radiation detection, introduction to gas filled detectors (ionization chamber, and GM counter), scintillation, semiconductors detectors and Thermoluminescent Dosimeter {TLD}), radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, direct reading dosimeter (DRD).

8. Radiation Protection Aspects (8 h)

External hazard and their perspective, evaluation and control of hazard due to external radiation: individual and workplace monitoring, application of time, distance and shielding; Concept of Work Load, radiation protection survey and its assessment, shielding adequacy of radiation protection accessories, Operational safety requirements in fluoroscopy, patient protection in fluoroscopy procedures.

9. X-ray Imagining Devices and Techniques (10 h)

Fundamentals of diagnostic radiology, limitations of conventional X-ray imaging, image quality characteristics (noise, contrast, resolution) parameters affecting image quality, methods to reduce scattered radiation, Bucky grids. Descriptions of technology of x-ray imaging equipment, medical x-ray film, screen film system- H&D curve, image intensifier, Computed Radiography (CR) system, digital imaging system and flat panel detectors. Radiography and fluoroscopy, CT scanning, digital subtraction angiography (DSA), mammography, interventional radiology, bone densitometry and dental radiology.

10. Planning of Diagnostic X-ray Installation (3 h)

General principles of planning of diagnostic installations, site selection, workload, shielding requirement, openings and ventilation, illumination control, X-ray installation layout- control console, patient waiting area, warning light and placard; model layouts of various X-ray facilities.

11. Quality Assurance in Diagnostic Radiology (6 h)

Importance of QA in Diagnostic radiology, test parameters for congruence of optical and radiation fields, central beam alignment, effective focal spot size, exposure time, applied tube potential, total filtration, table top transmission, linearity of timer loading station, linearity of mA loading station, consistency of radiation output, low and high contrast resolution, table top dose rate, radiation leakage through tube housing and collimator, dark room procedures, Familiarization of QA of CT, IR & mammography and dental equipment.

12. Regulatory Aspects of Diagnostic Radiology (3 h)

Regulations for use of X-ray equipment, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO), radiologist and radiation Technologist (DR), Licensing requirements, regulatory requirements for import, procurement, installation, commissioning, operation, transfer, dismantling and decommissioning of diagnostic equipment, Radiation Protection Programme (RPP).

13. Radiation Incidents and Case Studies (2 h)

Radiation incidents during handling of X-ray equipment, excessive exposure to occupational workers, investigation of excessive exposure and case studies, prevention of excessive exposure.

Practical/Demonstration:

1. Familiarization with QA equipment and QA tools in diagnostic radiology
2. Quality Assurance of conventional X-ray equipment
3. Radiation protection survey of conventional X-ray installation
4. Effect of time, distance & shielding on radiation exposure
5. Demonstration for checking the shielding adequacy of protective accessories (lead apron/mobile portative barrier (MPB))
6. Familiarization of QA aspects of CT and IR equipment
7. Investigation of reported excessive exposure of TLD, its genuineness and estimation of actual dose received

****

ANNEXURE-2D

RADIATION SAFETY SYLLABI FOR TRAINING COURSE FOR RP-DR-2 IN DIAGNOSTIC RADIOLOGY

(Two years Training Course)

(Applicable for personnel operating all X-ray equipment, including CT &IR)

Minimum Radiation Safety Syllabus prescribed by AERB for RP-DR-2 professional course conducted by various teaching institutes/universities/paramedical boards.

Course Duration: As prescribed by University/Board, subject to fulfilling the minimum course duration and minimum entry level qualifications stipulated in this document.

The syllabus prescribed in this annexure is for two years course for RP-DR-2 program (Inclusive of 6 months in-field training)

Infrastructure: As per Appendix-1 of this document.

Examination:

At least one mandatory separate paper on Radiation Safety should be incorporated in the University final examination pattern covering the radiation safety syllabus prescribed in this document.

The paper should have same weightage as given to other clinical papers.

Passing Criteria: As prescribed by University.

Syllabus: **(80 h)**

1. Basic Radiation Physics (4 h)

Atomic structure, atomic number, mass number, bound and free electrons, binding energy, ionization, excitation, fluorescence, characteristic X-ray, stability of nucleus, isotopes, radioisotopes, types of radioactive disintegration, directly and indirectly ionizing radiations, radioactivity, X-rays and gamma rays, energy of ionizing radiation, half-life

2. Introduction to X-ray Equipment (8 h)

Components of X-ray equipment, Production of X-ray, bremsstrahlung and characteristic X-rays, X-ray spectrum, types of X-ray tubes (anode, cathode, inherent filters, focal spot), heat production in the anode and cooling mechanism, quality and quantity of X-rays (effect of kV, mA), Components of CT, IR, C-Arm, mammography.
Filters in CT.

3. Interaction of Radiation with Matter (6 h)

Interaction of electrons with matter, interaction of photon with matter (photoelectric, Compton and pair production), influence of photoelectric effect and Compton effect on image quality and patient dose, absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT), beam hardening, importance of X-ray beam filtration in diagnostic radiology

4. Radiation Quantities and Units (3 h)

Activity (Becquerel & Curie), energy, exposure(C/kg &Roentgen), air kerma, absorbed dose (Gray & rad), radiation weighting factors(W_R), tissue weighting factors(W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

5. Biological Effects of Radiation (5 h)

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, tissue reactions (deterministic) and stochastic (probabilistic) effects, effects of partial and whole body exposures. Biological effects observable in diagnostic radiology practice

6. Operational Limits (6 h)

Introduction to natural background radiation, concept of occupational risk, concept of justification, optimization and dose limitation applicable in diagnostic radiology, ALARA, AERB/ICRP recommendations for dose limits to radiation workers and general public, diagnostic reference levels and their significance for patient protection, radiation safety for comforters of patients.

7. Radiation Detection and Measurement (4 h)

Principle of radiation detection, introduction to filled gas detectors (ionization chamber, and GM counter), scintillators, semiconductors detectors Thermoluminescent Dosimeter {TLD}), radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, direct reading dosimeter (DRD).

8. Radiation Protection Aspects (5 h)

External hazard and their perspective, evaluation and control of hazard due to external radiation: individual and workplace monitoring, application of time, distance and shielding; Concept of Work Load, radiation protection survey and its assessment, shielding adequacy of radiation protection accessories, Operational safety requirements. Radiation leakage measurement, significance of filtration in X-ray tube.

9. X-ray Imagining Devices and Techniques (10 h)

Fundamentals of diagnostic radiology, limitations of conventional X-ray imaging, image quality characteristics (noise, contrast, resolution) parameters affecting image quality, methods to reduce scattered radiation, Bucky grids. Descriptions of technology of x-ray imaging equipment, medical x-ray film, screen film system- H&D curve, image intensifier, Computed Radiography (CR) system, digital imaging system and flat panel detectors. Radiography and fluoroscopy, CT scanning, digital subtraction angiography (DSA), mammography, interventional radiology, digital radiology, bone densitometry and dental radiology.

10. Planning of Diagnostic X-ray Installation (3 h)

General principles of planning of diagnostic installations, site selection, workload, shielding requirement, openings and ventilation, illumination control, X-ray installation layout- control console, patient waiting area, warning light and placard; model layouts of various X-ray facilities.

11. Quality Assurance in Diagnostic Radiology (10 h)

Importance of QA in Diagnostic radiology, test parameters and test procedures for congruence of optical and radiation fields, central beam alignment, effective focal spot size, exposure time, applied tube potential, total filtration, table top transmission, linearity of timer loading station, linearity of mA loading station, consistency of radiation output, low and high contrast resolution, table top dose rate, radiation leakage through tube housing and collimator, dark room procedures.

Quality assurance of CT (CT phantoms and measurement of CT dose index), QA of IR, QA of mammography, dental equipment and bone mineral density (BMD) analysis equipment.

12. Radiation Safety Aspects of Fluoroscopy, CT and IR (8 h)

CT Imaging Techniques, DSA, Interventional Radiology **(**IR), Patient safety considerations, operational safety requirements, comparison of doses in fluoroscopy, cine acquisition and DSA, Impact on patient and operator doses, introduction to patient dose monitoring quantities such as ESD, CTDI, DLP and DAP, and cumulative dose and its significance; Diagnostic reference levels and their significance for patient protection, radiation safety for comforters of patients, requirement of monitoring and recording of patient dose quantities in CT &IR, radiation injuries during fluoroscopy procedures.

13. Regulatory Aspects of Diagnostic Radiology (5 h)

Regulations for use of X-ray equipment, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO), radiologist and radiation Technologist(DR), Licensing requirements, regulatory requirements for import, procurement, installation, commissioning, operation, transfer, dismantling and decommissioning of diagnostic equipment, Radiation Protection Programme (RPP).

14. Radiation Incidents and Case Studies (3 h)

Radiation incidents during handling of X-ray equipment, excessive exposure to occupational workers, investigation of excessive exposure and case studies, prevention of excessive exposure, radiation injuries - causes and prevention.

Practical/Demonstration:

1. Familiarization with QA equipment and QA tools in diagnostic radiology
2. Quality Assurance of conventional X-ray equipment
3. Radiation protection survey of conventional X-ray installation
4. Quality Assurance and radiation protection survey of interventional radiology equipment
5. Quality Assurance and radiation protection survey of a CT Scan installation
6. Effect of Time, distance & shielding on radiation exposure
7. Demonstration for checking the shielding adequacy of protective accessories (lead apron/mobile protective barriers MPB))
8. Investigation of reported excessive exposure of TLD, its genuineness and estimation of actual dose received

ANNEXURE-2E

SYLLABI FOR 'BASIC RADIATION SAFETY MODULE' IN DIAGNOSTIC RADIOLOGY

The RSO of the institution should provide the basic training to the Auxiliary staff on the following Radiation Safety topics

1. Basic Radiation Physics and Introduction to X-ray Equipment

Atomic structure, atomic number, mass number, bound and free electrons, binding energy, ionization, excitation, fluorescence, characteristic X-ray, stability of nucleus, isotopes, radioisotopes, types of radioactive disintegration, directly and indirectly ionizing radiations, radioactivity, X-rays and gamma rays, energy of ionizing radiation, half-life

Interaction of electrons with matter, interaction of photon with matter (photoelectric, Compton and pair production), influence of photoelectric effect and Compton effect on image quality and patient dose, absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

Principle of radiation detection, introduction to gas detectors (ionization chamber, and GM counter) solid state detectors (scintillators, semiconductors and Thermo luminescent Dosimeter {TLD}), radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, direct reading dosimeter (DRD).

Components of X-ray equipment, Production of X-ray, bremsstrahlung and characteristic X-rays, X-ray spectrum, types of X-ray tubes (anode, cathode, inherent filters, focal spot), heat production in the anode and cooling mechanism, quality and quantity of X-rays (effect of kV, mA), significance of filtration in X-ray tube.

2. Biological Effects and Operational Units

Introduction to radiation quantities such as Activity (Becquerel & Curie), energy, exposure(C/kg &Roentgen), air kerma, absorbed dose (Gray & rad), radiation weighting factors(W_R), tissue weighting factors(W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, tissue reactions (deterministic) and stochastic (probabilistic) effects, effects of partial and whole body exposures. Biological effects observable in diagnostic radiology practice.

3. Radiation Protection and Operational Safety Aspects in DR

External hazard and their perspective, evaluation and control of hazard due to external radiation: individual and workplace monitoring, application of time, distance and shielding; Concept of Work Load, radiation protection survey and its assessment, shielding adequacy of radiation protection accessories, Operational safety requirements in fluoroscopy, patient protection in fluoroscopy procedures.

4. Introduction to Quality Assurance of X-ray Equipment

Importance of QA in Diagnostic radiology, test parameters for congruence of optical and radiation fields, central beam alignment, effective focal spot size, exposure time, applied tube potential, total filtration, table top transmission, linearity of timer loading station, linearity of mA loading station, consistency of radiation output, low and high contrast resolution, table top dose rate, radiation leakage through tube housing and collimator, dark room procedures, Familiarization of QA of CT, IR & mammography and dental equipment.

5. X-ray Imaging Devises and Techniques

Fundamentals of diagnostic radiology, limitations of conventional X-ray imaging, image quality characteristics (noise, contrast, resolution) parameters affecting image quality, methods to reduce scattered radiation, Bucky grids. Descriptions of technology of x-ray imaging equipment, medical x-ray film, screen film system- H&D curve, image intensifier, Computed Radiography (CR) system, digital imaging system and flat panel detectors. Radiography and fluoroscopy, CT scanning, digital subtraction angiography (DSA), mammography, interventional radiology, bone densitometry and dental radiology.

6. Regulatory Aspects and Planning of Diagnostic Radiology Facilities

General principles of planning of diagnostic installations, site selection, workload, shielding requirement, openings and ventilation, illumination control, X-ray installation layout-control console, patient waiting area, warning light and placard; model layouts of various X-ray facilities.

Regulations for use of X-ray equipment, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO), radiologist and radiation Technologist (DR), Licensing requirements, regulatory requirements for import, procurement, installation, commissioning, operation, transfer, dismantling and decommissioning of diagnostic equipment, Radiation Protection Programme (RPP).

7. Radiation Incidents and Case Studies

Radiation incidents during handling of X-ray equipment, excessive exposure to occupational workers, investigation of excessive exposure and case studies, prevention of excessive exposure.

****

ANNEXURE-2F

SYLLABI FOR 'ADVANCED RADIATION SAFETY MODULE' IN DIAGNOSTIC RADIOLOGY

The syllabus is applicable for renewal of RSO and Service Personnel (RP-DR-S) in Diagnostic Radiology

1. Basic Radiation Physics and Introduction to X-Ray Equipment

Atomic structure, atomic number, mass number, bound and free electrons, binding energy, ionization, excitation, fluorescence, characteristic X-ray, stability of nucleus, isotopes, radioisotopes, types of radioactive disintegration, directly and indirectly ionizing radiations, radioactivity, X-rays and gamma rays, energy of ionizing radiation, half-life.

Interaction of electrons with matter, interaction of photon with matter (photoelectric, Compton and pair production), influence of photoelectric effect and Compton effect on image quality and patient dose, absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT),

Components of X-ray equipment, Production of X-ray, bremsstrahlung and characteristic X-rays, X-ray spectrum, types of X-ray tubes (anode, cathode, inherent filters, focal spot), heat production in the anode and cooling mechanism, quality and quantity of X-rays (effect of kV, mA), significance of filtration in X-ray tube,

2. Radiation Detection, Measurement and Personnel Monitoring

Principle of radiation detection, gas detectors (ionization chamber, and GM counter) solid state detectors (scintillators, semiconductors and Thermoluminescent Dosimeter {TLD}), radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, direct reading dosimeter(DRD), calibration and response of radiation monitoring instruments.

3. Radiation Quantities and Units

Activity (Becquerel & Curie), energy, exposure(C/kg &Roentgen), air kerma, absorbed dose (Gray & rad), radiation weighting factors(W_R), tissue weighting factors(W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

4. Biological Effects

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, tissue reactions (deterministic) and stochastic (probabilistic) effects, threshold dose (partial and whole body exposures), biological effects observable in diagnostic radiology practice.

5. X-Ray Imaging Devises and Techniques

Fundamentals of diagnostic radiology, limitations of conventional X-ray imaging, image quality characteristics (noise, contrast, resolution) parameters affecting image quality,

methods to reduce scattered radiation, bucky grids, X-ray imaging devices: x-ray film, screen film system- H&D curve, image intensifier; Computed Radiography (CR) system, digital imaging system and flat panel detectors.
Radiography, fluoroscopy, Computed Tomography (CT), digital subtraction angiography (DSA), mammography, interventional radiology, bone mineral densitometry and dental radiology.

6. Radiation Protection and Operational Safety Aspects in DR

External hazard and their perspective, evaluation and control of hazard due to external radiation: individual and workplace monitoring, application of time, distance and shielding; Concept of Work Load, radiation protection survey and its assessment, shielding adequacy of radiation protection accessories, safe work practice, Diagnostic reference levels and their significance for patient protection, radiation safety for comforters of patients.

7. Radiation Safety Aspects of Fluoroscopy, CT and IR

CT Imaging Techniques, DSA, Interventional Radiology **(I**R), Patient safety considerations, operational safety requirements, comparison of doses in fluoroscopy, cine acquisition and DSA, Impact on patient and operator doses, introduction to patient dose monitoring quantities such as ESD, CTDI, DLP and DAP, and cumulative dose and its significance; requirement of monitoring and recording of patient dose quantities in CT &IR, Diagnostic reference levels and their significance for patient protection, radiation safety for comforters of patients, radiation injuries to patient during fluoroscopy procedures-identification, management and follow-up.

8. Quality Assurance of X-ray Equipment

Importance of QA in Diagnostic radiology, test parameters and test procedures for congruence of optical and radiation fields, central beam alignment, effective focal spot size, exposure time, applied tube potential, total filtration, table top transmission, linearity of timer loading station, linearity of mA loading station, consistency of radiation output, low and high contrast resolution, table top dose rate, radiation leakage through tube housing and collimator, dark room procedures.
Quality assurance of CT (CT phantoms and measurement of CT dose index), QA of IR, QA of mammography, dental equipment and bone mineral density (BMD) analysis equipment.

9. Excessive Exposure and Investigations

Workload evaluation, radiation protection survey, Investigation of excessive exposures, work practice evaluation, performance checks of protective accessories.

10. Regulatory Aspects and Planning of Diagnostic Radiology Facilities

General principles of planning of diagnostic installations, site selection, workload, shielding requirement, openings and ventilation, illumination control, X-ray installation layout-control console, patient waiting area, warning light and placard; model layouts of various X-ray facilities.

Regulations for use of X-ray equipment, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety

Officer (RSO), radiologist and radiation Technologist (DR), Licensing requirements, regulatory requirements for import, procurement, installation, commissioning, operation, transfer, dismantling and decommissioning of diagnostic equipment, Radiation Protection Programme (RPP).

11. Radiation Incidents and Case Studies

Radiation incidents during handling of X-ray equipment, excessive exposure to occupational workers, investigation of excessive exposure and case studies, prevention of excessive exposure, radiation injuries - causes and prevention.

****

ANNEXURE-3: RADIATION SAFETY CERTIFICATION FOR PERSONNEL IN NUCLEAR MEDICINE

ANNEXURE- 3A

RADIATION SAFETY SYLLABI FOR POST GRADUATE MEDICAL COURSES IN NUCLEAR MEDICINE

Course Duration: As prescribed by University.

Faculty

The faculty proposed by the university/institution for delivering lectures and conducting practical on radiation safety should have adequate experience in relevant practice i.e. RSO (NM) /RSO (Medical).

Infrastructure: As prescribed by the relevant authority of India.

Examination:

At least one mandatory separate paper on Radiation Safety should be incorporated in the University final examination pattern covering the radiation safety syllabus prescribed in this document.

The paper should have same weightage as given to other clinical papers.

Passing Criteria: As prescribed by University.

Syllabus: **(60 h)**

1. Basic Radiation Physics (4 h)

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, types of radioactive disintegrations, electron capture, characteristics of alpha, beta and gamma rays, energy of ionizing radiation, half-life (physical, biological), effective half-life, isomeric transitions, secular, transient and no-equilibrium, production of radioisotopes and X-rays (characteristic and Bremsstrahlung), neutron sources.

2. Interaction of Radiation with Matter (4 h)

Interaction of charged particles with matter, range of charged particles, interaction of photons with matter (photoelectric, Compton scatteringand pair production), annihilation, absorption, scattering and attenuation of photons, importance of these interactions in radiology and nuclear medicine, Half Value Thickness (HVT) and Tenth Value Thickness (TVT)

3. Radiation Quantities and Units (3 h)

Activity (Bq & Ci), energy, exposure(C/kg &Roentgen), linear energy transfer (LET), charged particle equilibrium (CPE), air kerma, absorbed dose (Gray& Rad), radiation weighting factors (W_R), tissue weighting factors(W_T), equivalent dose (Sievert& rem), effective dose (Sievert & rem), collective effective dose (Person Sv), Annual Limit of Intake {ALI} (Becquerel), Derived Air Concentration {DAC} (Becquerel/m^3).

4. Biological Effects of Radiation (4 h)

Interaction of radiation with cell, direct and indirect interactions, mechanism of radiation damage in living cells, radiation effect on major organs and organ systems, pre-natal effects, modifying factors, chromosomal aberration, stochastic effects and tissue reaction (deterministic effect), effect of partial body and whole body exposures, low dose exposure to ionizing radiation, threshold doses, biological dosimetry.

5. Operational Limits (2 h)

Introduction to natural background radiation, concept of occupational risk, philosophy of radiation protection, system of dose limitation, ALARA, AERB/ICRP recommendations on dose limits to radiation workers and general public, dose constraints for comforters of patients.

6. Radiation Detection &Measurement (4 h)

Principle of radiation detection, gas filled detector (ionization chamber, proportional counter and GM counter), scintillator, semiconductor detectors and Thermoluminescent Dosimeter {TLD}), isotope calibrator, radiation monitoring instruments, personnel monitoring, area monitoring, environmental monitoring, direct reading dosimeter (DRD), calibration and response of radiation monitoring instruments.

7. Radiation Hazard Evaluation and Control (6 h)

Internal and external radiation hazards and their perspective, evaluation and control of hazard due to external radiation, individual and workplace monitoring - time, distance and shielding, specific gamma ray constant, external radiation monitoring, survey meters.

Internal hazard evaluation and control, protective measures for handling unsealed sources (e.g. fume-hood), environmental control, protective clothing, contamination monitoring (direct and indirect), air contamination monitoring, personnel contamination monitoring and decontamination procedures, surface decontamination procedures.

8. Quality Assurance (QA) of Nuclear Medicine Equipment and Radio-pharmaceuticals (6 h)

Working principle of thyroid uptake probe, isotope calibrator, gamma camera, SPECT, SPECT-CT, PET, PET-CT/MRI and their QA tests as per national/international standard (eg. NEMA, IAEA), concept of QA of radio-pharmaceuticals.

9. Radiation Protection Standards (4 h)

Basic concepts of radiation protection standards, International Commission on Radiological Protection (ICRP) and its recommendations, the system of Radiological Protection, justification of practice, optimisation of protection and individual dose limits, radiation and tissue weighting factors, potential exposures, dose and dose constraints, guidance level for diagnostic administration.

10. Radionuclide Therapy- Radiation Safety Aspects (6 h)

Radionuclide administration techniques, pre-and post-therapy precautions, nursing care, patient monitoring and discharge criteria, optimization of radiation dose to non-target tissues, radiation safety consideration in treatment of Ca-thyroid, palliative bone metastases and other therapeutic procedures -such as radiation synovectomy, peptide therapy; special consideration for breast feeding mother and female patient of reproductive age.

11. Planning of Nuclear Medicine (NM) Laboratories (3 h)

General features of NM laboratories (site, typical floor plans, ventilation, surface, walls, floor and ceiling, work surfaces, containment systems, fume-hood etc.),planning of NM laboratories, such as diagnostic and high dose therapy, PET-CT, model layouts of various NM laboratories.

12. Regulatory Aspects of Nuclear Medicine Laboratories (4 h)

Regulations with respect to nuclear medicine laboratories, Regulatory Control: Licensing, Inspection and Enforcement; relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO), technologist and radioisotope supplier, incident reporting in nuclear medicine, e-licensing of radiation applications(e-LORA).

13. Security of Radioactive Sources (1 h)

Physical protection of sources, categorization of radiation sources, safety and security of sources during storage, use, transport and disposal, security measures (administrative and technical), security threat and graded approach in security provision, graded approach in security provision, physical protection system.

14. Transport of Radioactive Material (1 h)

Transportation of radioactive material, general packing requirements, type of transport package, labeling and marking of packages, regulations applicable for different modes of transport, consignor’s and carrier’s responsibilities.

15. Disposal of Radioactive Waste (3 h)

Origin and types of waste, classification of wastes and methods of disposal, disposal of short-lived solid, liquid and gaseous radioactive waste, disposal limits for ground burial and sanitary sewage system, incineration, disposal of long-lived and indispersible radioactive wastes.

16. Emergency Response Plans and Preparedness (2 h)

Normal and potential exposures, unusual occurrences involving radioisotopes, management of cadavers with radioactivity, management of clinical emergencies with patient administered with therapeutic doses, elements of emergency planning and preparedness including procedures for notification and communication, emergency

response accessories, responsibilities of employer, licensee, RSO, technologist and radioisotope/equipment supplier.

17. Radiation Accidents, Case Studies and Lessons Learned (3 h)

Radiation accidents involving radioisotopes, orphan and vulnerable sources, handling of emergency situations resulting from spillage of radiopharmaceuticals/liquid radioisotopes, misadministration of radio-pharmaceuticals and its consequences, general methods of prevention of accidents, loss of radioisotope, accident due to fire and explosions; follow up actions through emergency response plans, case studies and mitigation, lessons learned.

(Note : In addition to above syllabi, university may incorporate detailed topics related to radiation safety as required.)

****

ANNEXURE 3 B

RADIATION SAFETY SYLLABI FOR TRAINING COURSE FOR RP-NM-2 IN NUCLEAR MEDICINE

Course Duration: As prescribed by University/Board/Institution subject to fulfilling the minimum course duration and minimum desirable entry level qualifications stipulated in this document.

Infrastructure: As per Appendix-2 of this document

Examination:

At least one mandatory separate paper on Radiation Safety should be incorporated in the University final examination pattern covering the radiation safety syllabus prescribed in this document.
The paper should have same weightage as given to other clinical papers.

Passing Criteria: As prescribed by University.

Syllabus: **(116 h)**

1. Basic Radiation Physics (6 h)

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, radionuclide chart, specific activity, types of radioactive disintegrations and their characteristics (Range, penetration power etc.)., Laws of successive transformations electron capture, characteristics of alpha, beta and gamma rays; positron emission; beta particle spectrum; K shell electron capture, Auger effect, Metastable state and isomeric transition, internal conversion, energy of ionizing radiation, half-life (physical, biological), mean life, effective half-life, isomeric transitions, secular, transient and no-equilibrium, production of radioisotopes and X-rays (Characteristic and Bremsstrahlung), neutron sources.

2. Interaction of Radiation with Matter (4 h)

Interaction of charged particles with matter, range of charged particles, interaction of photons with matter (photoelectric, Compton scattering and pair production), annihilation, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT), interaction of neutrons with matter, specific ionization and linear energy transfer (LET), importance of these interactions in radiology and nuclear medicine.

3. Radiation Quantities and Units (4 h)

Activity (Becquerel & Curie), energy, exposure(C/kg & Roentgen), LET, charged particle equilibrium (CPE), linear and mass attenuation coefficients, mass stopping power, air kerma, Terma, absorbed dose (Gray & rad), radiation weighting factors (W_R), tissue weighting factors (W_T), equivalent dose (Sievert & rem), effective dose (Sievert &rem), collective Effective dose (Person Sv), Annual Limit of Intake {ALI} (Becquerel), Derived Air Concentration {DAC} (Becquerel/m^3), personnel dose equivalent, committed dose.

4. Biological Effects of Radiation (6 h)

Interaction of radiation with cell, direct and indirect interactions, mechanism of radiation damage in living cells, LET, RBE, pre-natal effects, modifying factors, chromosomal aberration, stochastic effects and tissue reaction (deterministic effect), effect of partial body and whole body exposures, low dose exposure to ionizing radiation, threshold doses, biological dosimetry.

Radiation effects on major organ systems: Hematopoietic system, digestive system, reproductive system, nervous system; Effects of ionizing radiation on the embryo and fetus (Teratogenic and delayed effects).

5. Operational Limits (2 h)

Introduction to natural background radiation, concept of occupational risk, philosophy of radiation protection, system of dose limitation, ALARA, AERB/ICRP recommendations on dose limits to radiation workers and general public, dose constraints for comforters of patients, ALI and DAC values for typical radioisotopes used in nuclear medicine.

6. Radiation Detection and Measurement (8 h)

Principle of radiation detection, gas filled detector (ionization chamber, proportional counter and GM counter), isotope calibrator, scintillator, semiconductor detectors and Thermoluminescent Dosimeter {TLD}), liquid scintillation counting systems, nuclear counting statistics, confidence level of measurement, radiation monitoring instruments, personnel monitoring, survey meters, area monitoring, environmental monitoring, direct reading dosimeter (DRD), calibration and response of radiation monitoring instruments, radiation detectors suitable for use in a medical cyclotron facility.

7. Radiation Protection Standards (4 h)

Basic concepts of radiation protection standards, International Commission on Radiological Protection (ICRP) and its recommendations, the system of Radiological Protection, justification of practice, optimisation of protection and individual dose limits, radiation and tissue weighting factors, potential exposures, dose and dose constraints, guidance level for diagnostic administration.

8. Radiation Hazard Evaluation and Control (8 h)

Internal and external radiation hazards and their perspective, evaluation and control of hazard due to external radiation, individual and workplace monitoring, application of time, distance and shielding; specific gamma ray constant, external radiation monitoring, survey meters, performance check of radiation measuring and monitoring instruments.
Internal hazard evaluation and control, protective measures for handling of unsealed sources (e.g. fume-hood), environmental control, protective clothing, contamination monitoring (direct and indirect), air contamination monitoring, personnel contamination monitoring and decontamination procedures, surface decontamination procedures.

9. Working Principle of Nuclear Medicine Equipment (10 h)

Working principle of thyroid uptake probe, isotope calibrators, gamma camera, SPECT, SPECT-CT, PET, PET-CT/MRI and Medical Cyclotron.

10. Quality Assurance (QA) of Nuclear Medicine Equipment (8 h)

QA of Nuclear Medicine equipment, test parameters as per national/international standard (eg. NEMA, IAEA), thyroid uptake probe, isotope calibrator, Gamma Camera system, SPECT, SPECT-CT, PET, PET-CT/MRI and concept of QA of radiopharmaceuticals.

11. Radiation Dosimetry (7 h)

Compartmental Model- single compartment model, two compartment model with and without back transference; in-vivo dosimetry using classical dosimetry mechanism, beta dosimetry, gamma dosimetry, geometrical factor, dosimetry of low energy electromagnetic radiation, MIRD formulation- cumulated activity, equilibrium absorbed dose constant, absorption factor, specific absorbed fraction and the dose reciprocity theorem, mean dose per cumulated activity, limitation of MIRD method; extremity dosimetry.

12. Radionuclide Therapy - Radiation Safety Aspects (6 h)

Radionuclide administration techniques, pre-and post-therapy precautions, nursing care, patient monitoring and discharge criteria, isolation of patients, optimization of radiation dose to non-target tissues, radiation safety consideration in radio iodine therapy, palliative bone metastases and other therapeutic procedures (including high dose therapy) such as radiation synovectomy, peptide therapy; special consideration for breast feeding mother and female patient of reproductive age.

13. Overview of Radionuclide Production (8 h)

Reactors and charged particle accelerators, nuclear reactions, cross section, neutron activation with thermal neutrons, nuclear fission, fission products, physics of accelerator, type of cyclotron, working principle of cyclotron, cyclotron produced radionuclides, type of radionuclide generators and different types of equilibrium.

14. Planning of Nuclear Medicine and Medical Cyclotron Facility (6 h)

General features of NM facility (site, typical floor plans, ventilation, surface, walls, floor and ceiling, work surfaces, containment systems, fume-hood etc.),planning of NM facility such as low dose and high dose therapy, imaging modalities (eg. SPECT, SPECT-CT, PET, PET-CT) and medical cyclotron (MC) facility, shielding evaluation of various NM and medical cyclotron facility, model layouts of various NM and MC facilities.

15. Operational Procedures (6 h)

Radiological safety aspects to be followed during labeling procedures, use of handling tools : L- Bench, lead bricks, syringe shield, syringe carrier, lead bricks/pot, long tongs; functional check of fume hood, decontamination procedures, decontamination agents, decontamination kit, radiological safety aspects during high dose therapy procedures, procedures for safe management of radioactive wastes and disused sources and decayed isotope generator.

16. Regulatory Aspects for Nuclear Medicine Laboratories (4 h)

Regulations with respect to nuclear medicine facilities, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO), technologist and radioisotope supplier.

Regulatory requirements for import/export, procurement, use, handling, transfer and disposal of radioisotopes; inventory control, Radiation Protection Program (RPP).

17. Security of Radioactive Sources (2 h)

Safety and security of radioactive sources during transport and storage, inventory control, categorization of sources, security functions, security measures (administrative and technical), graded approach in security provision, physical protection system.

18. Transport of Radioactive Material (3 h)

Regulatory aspects of safe transport of radioactive material, introduction, terms used (e.g. Competent Authority, A1&A2 values, transport index (TI) etc.), transport scenarios (routine, normal & accident), variety of packages covered under the transport regulations, general requirement of all packaging, requirements for transport of radioactive material in liquid form, preparation, marking, labelling of packages, preparation of transport documents (Consignor's Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general instructions.

19. Disposal of Radioactive Waste (4 h)

Origin and types of waste, classification, segregation, collection of wastes and methods of safe disposal, disposal of short-lived solid, liquid and gaseous radioactive waste; disposal limits for ground burial and sanitary sewage system, incineration, disposal of long-lived and indispersible radioactive wastes, delay tank facility, radiation exposure measurements, effluent Concentration (lodine-131, Lutetium-177, etc).

20. Emergency Response Plans and Preparedness (4 h)

Normal and potential exposures, unusual occurrences involving radioisotopes, management of medical emergencies for patient administered with radioactivity, management of cadavers with radioactivity, accidental inhalation, patient accidental exposure, leakage of radioactivity substance to environment.

Elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical procedures, emergency response accessories, responsibilities of employer, licensee, RSO, technologist and radioisotope/equipment supplier in case of emergency.

21. Radiation Accidents, Case Studies and Lessons Learned (3 h)

Radiation accidents involving radioisotopes, orphan and vulnerable sources, unusual occurrences handling of emergency situations resulting from spillage of radiopharmaceuticals/liquid radioisotopes, misadministration of radio-pharmaceuticals and its consequences, causes and prevention of excessive exposure-investigation procedures general methods of prevention of accidents, loss of radioisotope, accident due to fire, flood and explosions; follow up actions through emergency response plans, case studies and mitigation, lessons learned.

22. Introduction to Concepts of Radiological Equipment (3 h)

Physical principles of X-ray diagnosis, density, contrast, selection of kV, mAs, filtration, FSD, screens, films, grids, contrast media, basics of radiography, fluoroscopy, film/CR/DR systems, image intensifiers, optimization of patient dose, CT scanners, radiation dose, CT-PET fusion, quality control of CT, scanner design, spiral computed tomography, difference's between conventional single slice, multislice, spiral and electron beam CT; comparison of patient radiation doses and effects of slice thickness.

Mammography, bone densitometry, dental radiography, interventional radiology, digital radiology, Quality Assurance (QA) in all modalities of diagnostic radiology, workload, planning, radiation protection survey and regulatory aspects of Diagnostic radiology.

Practical:

1. To measure Half Value Layer of β and γ emitters and to measure the absorption coefficients of different materials with gamma rays and beta particles.
2. To study back scatter.
3. Radiation exposure: effect of distance, time & shielding
4. To determine the half-life of a radioactive material.
5. To study the change in activity of a sample consisting of two independently decaying radioisotopes (or a mixture of isotopes).
6. To determine the plateau of GM tube and find out the dead time/ resolving time of GM counter.
7. To determine the efficiency of GM counter and find out the activity of the given unknown radioactive source.
8. Gamma ray spectrometry of ^{137}Cs with a single channel analyzer.
9. To find out the spectrum of energies emitted by a radioisotope by using gamma ray spectrometer. (e.g. ^{131}I).
10. To study the statistics of radioisotopic measurements and observe the effect of background on the counting statistics.
11. To determine the energy resolution of spectrometer.
12. To study the energy linearity of given spectrometer.
13. To observe gamma ray spectrum of the given two radionuclide sources (A and B) and identify composition of a tube containing mixture of these two radionuclide sources by evaluating scatter fraction.
14. To identify unknown radionuclide on the basis of its principal energy by using scintillation counter.
15. Estimation of radioactivity in radioactive liquid effluents from high dose therapy facility.
16. Radiological survey – work place and personnel monitoring.
17. Decontamination of work surface.

****

ANNEXURE-4: RADIATION SAFETY CERTIFICATION FOR PERSONNEL IN RADIOTHERAPY

ANNEXURE 4 A

RADIATION SAFETY SYLLABI FOR POST GRADUATE MEDICAL COURSES (RADIOTHERAPY)/DNB (RT)

Course Duration: As prescribed by University/Institution subject to fulfilling the minimum course duration and minimum desirable entry level qualifications stipulated in this document.

Faculty

The faculty proposed by the University/institution for delivering lectures and conducting practical on radiation safety should have adequate experience in relevant practice i.e. Radiation Physics / RSO (Medical).

Infrastructure: As prescribed by relevant authority of India.

Examination:
At least one mandatory separate paper on Radiation Safety should be incorporated in the University final examination pattern covering the radiation safety syllabus prescribed in this document.

The paper should have same weightage as given to other clinical papers.

Passing Criteria: As prescribed by University.

Syllabus: **(70 h)**

PART-I: BASIC RADIATION PHYSICS, RADIATION SOURCES & RADIATION SAFETY

1.1 Basic Radiation Physics (3 h)

Radioactivity - General properties of alpha, beta and gamma rays - Laws of radioactivity – Radioactive Decay (alpha, beta, gamma, Electron capture - Internal conversion) - Half Life- Decay Constant-Radioactive equilibrium - Nuclear isomerism - Artificial radioactivity.

1.2 X-ray Production (1 h)

Discovery - Production - Properties of X-rays - Characteristics and continuous X-ray-Design of X-ray tube – HVL-Tube Filtration-Overview of medical x-ray tubes.

1.3 Interaction of Radiation with Matter (2 h)

Interaction of electromagnetic radiation with matter: Exponential attenuation-Photoelectric effect-Compton effect - Pair production - Attenuation and mass energy absorption coefficients .Interaction of charged particles with matter -Interaction of heavy charged particles through matter - Energy loss by collision - Range energy relation - Bragg curve - Specific ionization - Stopping Power. Interaction of neutrons with matter

1.4 Radiation Quantities and Units (3 h)

Radiation quantities and units - Linear and mass attenuation coefficients - Mass energy transfer and mass energy absorption coefficients - Stopping power - LET - Absorbed dose - Kerma - Exposure - Air kerma rate constant - Charged particle equilibrium (CPE) – Relationship between Kerma, absorbed dose and exposure under CPE –Equivalent Dose-Effective Dose-Collective Dose-Committed Effective Dose-ALI-DAC- Familiarisation with various units used such as Becquerel-Curie-Roentgen-Gray-Rad-Sievert etc.

1.5 Radiation Sources & its Medical Applications (2 h)

Radiation sources - Natural and artificial radioactive sources - production of isotopes - Reactor produced isotopes - Cyclotron produced isotopes - Fission products.

Characteristics of Radiation Sources (Co-60, Ir-192, Cs-137, I-125, Ru-106, Sr-90, Au-198 etc.) & its Medical Application-Telecobalt sources, Brachytherapy Sources, permanent implants, ophthalmic applicators.

1.6 Radiation Detection and Measurements (4 h)

Basic principles of radiation detection - Gas Filled detectors - Ionisation chambers - Proportional and GM Counters-Thimble Chamber-Parallel Plate Chamber-Well Type Chamber - Scintillation detectors - Semiconductor detectors - Radiographic and Radiochromic films - Thermoluminescent Dosimeters (TLD) -Radiation field analyser (RFA) -Radioisotope calibrator- Pocket Dosimeter- Gamma Zone monitors, Contamination monitors for alpha, beta and gamma radiation, Neutron Monitors.

1.7 Radiation Hazard, Evaluation and Control (2 h)

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation, individual and workplace monitoring, specific gamma ray constant, application of time, distance and shielding concepts, external radiation monitoring, survey meters.

1.8 Radiation Dosimetry (2 h)

Output calibration of ^{60}Co gamma rays, high energy x-rays and electron beams using IAEA TRS 398- AAPM TG 43 and other dosimetry protocols.

1.9 Radiation Biology (4 h)

Action of radiation on living cells - Radiolytic products of water and their interaction with biomolecule Survival curve parameters - Model for radiation action - Target theory - Modification of radiation damage - LET, RBE, dose rate, dose fractionation - Oxygen and other chemical sensitizers - Hyperthermic sensitization - Radio-protective agents.

Somatic effects of radiation - Physical factors influencing somatic effects - Dependence on dose, dose rate, type and energy of radiation, temperature, anoxia, - Acute radiation sickness - LD 50 dose - Effect of radiation on skin and blood forming organs, digestive tract - Sterility and cataract formation - Effects of chronic exposure to radiation -Radiation Carcinogenesis

1.10 Biological Basis of Radiotherapy and Time Dose Fractionation (4 h)

Physical and biological factors affecting cell survival, tumour re-growth and normal tissue response - 4R's of Radiotherapy -Non-conventional fractionation scheme and their effects, Effects of re-oxygenation, repair, redistribution in the cell cycle - High LET radiation therapy, Hyperthermia.

Time dose fractionation - Basis for dose fractionation in beam and brachytherapy - Concepts for Nominal Standard Dose (NSD), Roentgen equivalent therapy (RET) - Time dose fractionation (TDF) factors and cumulative radiation effects (CRE) - Gap correction, Linear and Linear Quadratic models (LQ model)-Biological Effective Dose (BED).

1.11 RADIATION THERAPY

1.11.1 Teletherapy (6 h)

Construction and working of telecobalt units - source design - beam collimation and penumbra - trimmers and breast cones. Working principle of medical electron linear accelerators - beam collimation - asymmetric collimator - Multileaf collimator - X Knife Gamma Knife- Tomotherapy- Cyber knife –Particle therapy accelerator.

Central axis dosimetry parameters - Tissue air ratio (TAR) Back scatter/ Peak scatter factor (BSF/PSF) - Percentage depth doses (PDD) - Tissue phantom ratio (TPR) - Tissue maximum ratio (TMR) -Build-up region and surface dose. Tissue equivalent phantoms. Radiation filed analyzer (RFA)- Description and measurement of isodose curves/charts.

Beam modifying and shaping devices - wedge filters - universal, motorized and dynamic wedges- shielding blocks and compensators. Integral dose. Arc/ rotation therapy and Clarkson technique for irregular fields - mantle and inverted Y fields. Conventional and conformal radiotherapy. Treatment time and Monitor unit calculations.

Clinical electron beams - energy specification - electron energy selection for patient treatment -depth dose characteristics (D_s, D_x, R_{100}, R_{90}, R_{50}, R_p etc.) - beam flatness and symmetry - penumbra .

1.11.2 Brachytherapy (4 h)

Definition and classification of brachytherapy techniques - surface mould, intracavitary, interstitial and intraluminal techniques- Image Based brachytherapy - Classification of brachytherapy treatment modality- Low dose rate (LDR), high dose rate (HDR) and pulsed dose rate (PDR)- . Paterson Parker and Manchester Dosage systems. ICRU 38 and 58 protocols. Specification and calibration of brachytherapy sources - RAKR and AKS.

2. Imaging modalities and networking system in Radiotherapy

2.1 Imaging modalities (4 h)

Radiography-C-Arm-Mammography-Computed Tomography (CT)-Magnetic Resonance Imaging (MRI)-Ultrasound- Single Photon Emission Tomography (SPECT), Positron Emission Tomography (PET).

2.2 Networking and communication in Radiotherapy (1 h)

Picture Archiving and communication system (PACS)-Digital Imaging and Communication in Medicine (DICOM)-other associated networking systems used in Radiotherapy.

PART-II: ADVANCED RADIATION PHYSICS, QUALITY ASSURANCE & RADIATION SAFETY

1.1 Special and Advanced Techniques of Radiotherapy (6 h)

Three Dimensional Conformal Radiation Therapy (3D-CRT)-Intensity modulated radiation therapy (IMRT) - Step and shoot and sliding window techniques - inverse treatment planning - immobilization for IMRT - Intensity Modulated Arc Therapy (IMAT e.g. Rapid Arc/VMAT/mARC). Image Guided Radiotherapy (IGRT) - kV cone beam CT (kVCT), MV cone beam CT (MVCT)- 4DCT- Particle Therapy(e.g. Proton Therapy/Carbon ion Therapy)- Total body irradiation (TBI) - Total skin electron therapy (TSET) - Electron arc treatment- Intraoperative radiotherapy(IORT)- Stereotactic radiosurgery/radiotherapy (SRS/SRT/SBRT) and current advancements in Radiotherapy.

1.2 Quality Assurance Test/Acceptance Test in Radiotherapy (3 h)

Quality assurance (QA) in Radiotherapy- Definition and practical advantages-National regulatory requirements for QA-Type approval Testing-Periodicity of QA for radiotherapy units such as telecobalt , linear accelerator, Tomotherapy, Cyber Knife, Gamma knife, HDR brachytherapy equipment's Simulator, CT-Simulator & Treatment Planning System(TPS).

1.3 Radiation Protection Standards (3 h)

Radiation dose to individuals from natural radioactivity in the environment and man-made sources. Basic concepts of radiation protection standards - Historical background - International Commission on Radiological Protection(ICRP) and its recommendations – The system of Radiological Protection – Justification of Practice, Optimisation of Protection (ALARA) and individual dose limits, – Radiation and tissue weighting factors-Potential exposures- dose and dose constraints – System of protection for intervention - Categories of exposures – Occupational, Public and Medical Exposures.

1.4 Safety in the Medical Uses of Radiation (6 h)

Evaluation of radiation hazards in medical therapeutic installations - Radiation monitoring procedures - Protective measures to reduce radiation exposure to staff and patients, Radiation hazards in brachytherapy departments and teletherapy departments - Particle accelerators Protective equipment - Handling of patients - Radiation safety during source transfer operations, Special safety features in accelerators. Brief introduction of planning of radiotherapy installations (e.g. Telecobalt, Accelerator, HDR, Simulator etc.). Radiation Protection survey of radiotherapy installations.

1.5 Legislation (3 h)

National legislation – Regulatory framework – Atomic Energy Act – Atomic Energy (Radiation Protection) Rules and other relevant rules – Applicable Safety Codes, Standards, Guides and Manuals – Regulatory Control – Licensing, Inspection and Enforcement – Responsibilities of Employers, Licensees, Radiological Safety Officers and Radiation Workers- Incident reporting in radiotherapy–e-licensing of radiation applications(e-LORA)-Overview of recommendations of international agencies (eg. IAEA/WHO/ICRP /IEC/ISO) in radiation therapy.

1.6 Security of Radioactive Sources (1 h)

Physical protection of sources – category of sources, safety and security of sources during storage, use, transport and disposal – Security provisions: administrative and technical measures as stipulated by national regulatory authority, graded approach in security provision.

1.7 Transport of Radioactive Material (1 h)

Transportation of radioactive substances - General packing requirements – Type of Transport Package- Labeling and marking of packages - Regulations applicable for different modes of transport -Consignor's and carrier's responsibilities

1.8 Radioactive Waste Disposal (1 h)

Radioactive wastes – sources of radioactive wastes - Classification of waste - Treatment techniques for solid, liquid and gaseous effluents – Permissible limits for disposal of waste -Waste disposal facilities.

1.9 Radiation Emergencies and their Medical Management (4 h)

Radiation accidents and emergencies in the use of radiation sources and equipment in industry and medicine - Loss of radiation sources and their tracing - Typical accident cases. Radiation injuries, their treatment and medical management - Case histories.

****

ANNEXURE 4 B

RADIATION SAFETY SYLLABI FOR TRAINING COURSES FOR RP-RT-2 IN RADIOTHERAPY

[This is a minimum contents which needs to be incorporated in the syllabi of the course. Number of hours are indicative only.]

Course Duration: As prescribed by University/Institution subject to fulfilling the minimum course duration and minimum desirable entry level qualifications stipulated in this document.

Infrastructure : As per Appendix -3A of this document.

Examination: As prescribed by University

Passing Criteria: As prescribed by University.

Syllabus: **(416 h Theory)**

PAPER - I: RADIATION PHYSICS & RADIATION GENERATORS (42 h)

1.1 Nuclear Physics (10 h)

Radioactivity - General properties of alpha, beta and gamma rays - Laws of radioactivity - Laws of successive transformations - Natural radioactive series - Radioactive equilibrium - Alpha ray spectra - Beta ray spectra - Theory of beta decay - Gamma emission - Electron capture - Internal conversion - Nuclear isomerism - Artificial radioactivity - Nuclear cross sections - Elementary ideas of fission and reactors - Fusion.

1.2 Particle Accelerators (10 h)

Particle accelerators for industrial, medical and research applications - The Resonant transformer - Cascade generator - Van De Graff Generator - Pelletron - Cyclotron – Betatron - Synchro-Cyclotron- Linear Accelerator - Klystron and magnetron - Travelling and Standing Wave Acceleration - Microtron - Electron Synchrotron-Proton synchrotron- Cyclotrons for medical applications - Hadron (proton/carbon ion) accelerators – self shielded cyclotrons - working principles- Beam transport systems - Beam delivery systems- Energy slits – degrader - Ridge filter - Range Shifter - Uniform and Pencil beam scanning systems-beam dump.

1.3 X-ray Generators (10 h)

Discovery - Production - Properties of X-rays - Characteristics and continuous spectra - Design of hot cathode X-ray tube - Basic requirements of medical diagnostic, therapeutic and industrial radiographic tubes - Rotating anode tubes - Hooded anode tubes - Rating of tubes –standard exposure charts, Limitations on loading Safety devices in X-ray tubes - Insulation and cooling of X-ray tubes –Design requirements for x-ray equipment, Faults detection in X-ray equipment such as pitting of anode, filament evaporation etc. - Types of x-ray units (Fixed radiography, CT, Interventional radiology, C-Arm, Mammography, Bone Mineral Densitometer, dental X-ray units etc.).

Electric Accessories for X-ray tubes - Filament and high voltage transformers - High voltage circuits - Half-wave and full-wave rectifiers - Condenser discharge apparatus - Three phase apparatus - Voltage doubling circuits - Current and voltage stabilizers - Automatic exposure control - Automatic Brightness Control- Measuring instruments for Measurement of kV and mA - timers - Control Panels - Complete X-ray circuit - Image intensifiers and flat panel detectors - Computed Radiography and Digital Radiography Systems - Modern Trends.

1.4 Interaction of Radiation with Matter (12 h)

Interaction of electromagnetic radiation with matter - Exponential attenuation - Thomson scattering - Photoelectric and Compton process and energy absorption - Pair production - Attenuation and mass energy absorption coefficients - Relative importance of various processes.

Interaction of charged particles with matter - Classical theory of inelastic collisions with atomic electrons - Energy loss per ion pair by primary and secondary ionization - Dependence of collision energy losses on the physical and chemical state of the absorber - Cerenkov radiation - Electron absorption process – Scattering, Excitation and Ionization - Radiative collision - Bremmstrahlung - Range energy relation - Continuous slowing down approximation (CSDA) - transmission and depth dependence methods for determination of particle penetration - empirical relations between range and energy - Back scattering.

Interaction of heavy charged particles with matter - Energy loss by collision - Range energy relation - Bragg curve – Spread out Bragg Peak (SOBP) - Specific ionization - Stopping Power - Bethe Bloch Formula.

Interaction of neutrons with matter – Classification of neutrons, slow and fast neutron interactions, microscopic and macroscopic interaction cross section, charged particle emission, - radiative capture and its significance in radiation dose to humans – elastic and inelastic scattering - Neutron induced nuclear reactions- neutron induced activiation –fission – Neutron attenuation.

PAPER – II: RADIOLOGICAL MATHEMATICS (38 h)

2.1 Probability, Statistics and Errors (12 h)

Probability - addition and multiplication laws of probability, conditional probability, population variates - collection, tabulation and graphical representation of data.
Basic ideas of statistical distributions, frequency distributions, and measures of central tendency (mean, median, standard deviation variance etc.)

Application to radiation detection - uncertainty calculations, error propagation, time distribution between background and sample, minimum detectable limit
Binomial distribution, Poisson distribution, Gaussian distribution, exponential distribution - additive property of normal variates, confidence limits, Bivariate distribution, Correlation and Regression, Chi-Square distribution, t-distribution, F-distribution.

2.2 Counting Statistics (6 h)

Statistics of nuclear counting - Application of Poisson's statistics - Goodness-of-fit tests - Lexie's divergence coefficients Pearson's chi-square test and its extension - Random fluctuations, - Evaluation of equipment performance - Signal-to-noise ratio Efficiency and sensitivity of

radiation detectors - Statistical aspects of gamma ray and beta ray counting - Special considerations in gas counting and counting with proportional counters - Statistical accuracy in double isotope technique.
Sampling and sampling distributions - confidence intervals. Hypothesis testing and errors. Regression analysis. : Linear regression: Examples and exercises.

2.3 Computational Techniques (20 h)

Numerical methods - accuracy and errors on calculations - round-off error, evaluation of formulae. Iterative methods- Initial Approximation and Convergence Criteria, Newton-Raphson Method. Taylor series, approximating the derivation, numerical differentiation formulas. Introduction to Trapezoidal rule, Simpson's rule, Simpson's Three-Eighth rule, Taylor's method, Euler's method, the modified Euler's method, Runge-Kutta method.

Introduction to Monte Carlo techniques: Random variables, discrete random variables, continuous random variables, Probability density functions, discrete probability density function, continuous probability distributions, cumulative distribution function, accuracy and precision, central limit theorem, random numbers and their generation, tests for randomness, inversion random sampling technique including worked examples, integration of simple 1-D integrals including worked examples. Overview of computational codes used in medical physics such as MCNP, Fluka, Geant 4, BEAMnrc etc. Introduction to MATLAB/ Mathematica etc. in data analysis and graphics.

PAPER - III: RADIATION DOSIMETRY AND STANDARDIZATION (55 h)

3.1 Radiation Quantities and Units (6 h)

Radiometric quantities: Activity, exposure, Particle flux, fluence, fluence rate – Energy flux and energy fluence – Interaction Quantities : Linear and mass attenuation coefficients - Mass energy transfer and mass energy absorption coefficients - Stopping power, Mass Stopping Power - LET - Dosimetric Quantities : Exposure, Absorbed Dose, Kerma, Terma, Charged particle equilibrium (CPE) – Relationship between Kerma, absorbed dose and exposure under CPE - Radiation chemical yield - W value.
Radiation protection quantities: Equivalent Dose, effective dose, committed equivalent dose, committed effective dose, radiation weighting factor, Tissue weighting factor, Annual Limit Intake (ALI), Derived Air Concentration (DAC),
Operational quantities: Dose equivalent - Ambient and directional dose equivalents [(H*(d) and H'(d)] –personnel dose equivalent from strongly and weekly penetrating radiation, Hp (10), Hp (0.07) &Hp (3).
Radiation Units : Becquerel & Curie, exposure units -C/kg & Roentgen, Gray & Rad, Sievert & Rem.

3.2 Radiation Sources and their Medical Applications (5 h)

Radiation sources - Natural and artificial radioactive sources - Large scale production of isotopes - Reactor produced isotopes (^{60}Co, ^{192}Ir, ^{99}Mo etc.) - Cyclotron produced isotopes (^{18}F, ^{13}N, ^{15}O, ^{11}C)- Fission products (^{137}Cs, ^{99}Mo, ^{131}I, ^{90}Sr)– Teletherapy and Brachytherapy sources – sources for permanent implants(^{198}Au - ^{125}I , ^{103}Pd etc.) - Beta ray applicators – ophthalmic applicators (^{90}Sr,^{125}I, ^{106}Ru etc.) Thermal and fast neutron sources (^{241}Am-Be, ^{252}Cf etc.).

3.3 Dosimetry and Standardization of X and Gamma Rays Beams (15 h)

Standards - Primary and Secondary Standards, Traceability, Uncertainty in measurement. Charged Particle Equilibrium (CPE), Free Air Ion Chamber (FAIC), Design of parallel plate FAIC, Measurement of Air Kerma/ Exposure. Limitations of FAIC. Bragg-Gray theory, Mathematical expression describing Bragg-Gray principle and its derivation. Burlin and Spencer Attix Cavity theories. Transient Charged Particle Equilibrium (TCPE), Concept of D_{gas}, Cavity ion chambers, Derivation of an expression for sensitivity of a cavity ion chamber. General definition of calibration factors - N_X, N_K, $N_{D,\,air}$, $N_{D,\,W}$. Various steps to arrive at the expression for absorbed dose to water –Determination of absorbed dose to water due to photon, electron and heavy charged particles (proton, carbon ion etc.) using current IAEA protocols, Calorimetric standards – Inter-comparison of standards.

Determination of absorbed dose to water due to photon, electron and heavy charged particles (proton, carbon ion etc.) using current IAEA protocols:
General definition of calibration factors - N_X, N_K, $N_{D,\,air}$, $N_{D,\,W}$. Various steps to arrive at the expression for absorbed dose to water –Determination of absorbed dose to water due to photon, electron and heavy charged particles (proton, carbon ion etc.) using current IAEA protocols ,

Measurement of D_W for External beams (photon, electron and heavy ion) Reference conditions for measurement, correction factors used Type of ion chambers, Phantom, Waterproof sleeve, Derivation of an expression for machine timer error (for telecobalt unit and brachytherapy units) , Temperature and pressure correction, Saturation correction (K_{sat}), derivation of expression for charge collection efficiency of an ion chamber. Parallel plate, cylindrical and spherical ion chambers, Two voltage method for continuous and pulsed beams, Polarity correction. Correction factors for high-energy photon/electron and heavy ion beams: Beam quality, beam quality index, beam quality correction coefficient, concept of cross calibration of dosimeters.
Quality Audit Programmes (TLD inter-comparison etc.)

Standardization of brachytherapy sources - Apparent activity - Reference Air Kerma Rate - Air Kerma Strength - Standards for HDR ^{192}Ir and ^{60}Co sources - Standardization of ^{125}I and beta sources - IAEA Protocols- room scatter correction.
Calibration of Protection Level Instruments: Calibration of protection level instruments and monitors used in radiotherapy (such as Survey Meters, gamma zone monitor, neutron survey meter, personnel monitoring dosimeters (active and passive).

3.4 Neutron Standards and Dosimetry (9 h)

Neutron classification, neutron sources, Neutron standards - primary standards, secondary standards, Neutron yield and fluence rate measurements, Manganese sulphate bath system, precision long counter, Activation method. Neutron spectrometry, threshold detectors & scintillation detectors, Neutron dosimetry, Neutron survey metersand their calibration, neutron field survey around high energy medical accelerators/cyclotrons/hadron therapy facilities.

3.5 Standardization of Radionuclides (8 h)

Methods of measurement of radioactivity - Defined solid angle and 4π counting - Beta gamma coincidence counting - Standardization of beta and gamma emitters- Ionization chamber methods - Extrapolation chamber - Scintillation counting methods for alpha, beta and gamma emitter - Reentrant ionization chamber methods - Methods using (n, γ) and (n, p) reactions - Determination of yield of neutron sources.

3.6 Radiation Chemistry and Chemical Dosimetry (12 h)

Definitions of free radicals and G-value - Kinetics of radiation chemical transformations - LET and dose-rate effects - Radiation Chemistry of water and aqueous solutions, peroxy radicals, pH effects - Radiation polymerisation, effects of radiation on polymers and their applications in dosimetry - Formation of free radicals in solids and their applications in dosimetry - Dosimetry principles: Definitions of optical density, molar absorption coefficient, Beer- Lambert's law, spectrophotometry –dose estimation techniques- - Requirements for an ideal chemical dosimeter - Fricke dosimeter - FBX dosimeter - Free radical dosimeter –Ceric-Cerous, Ceric sulphate dosimeter-ESR/EPR- Applications of chemical dosimeters in Radiotherapy.

PAPER – IV: RADIATION DETECTORS AND INSTRUMENTATION (40 h)

4.1 Medical Electronics (5 h)

Semiconductor diodes - JFET – MOSFET – Integrated Circuits - Operational amplifiers (Op-Amp) and their characteristics - Differential Amplifier - Operational amplifier systems – Op-Amp Applications -Addition, subtraction, Integration and Differentiation - Active amplifiers - Pulse Amplifiers - Decoders and Encoders - Microprocessors and associated peripherals - Power supplies - Regulated power supplies using IC's - DC-DC converter and RF power supplies- Switching mode power supplies - AC regulators.

4.2 Principles of Radiation Detection (18 h)

Principles of Radiation detection and measurement - Basic principles of radiation detection - Gas Filled detectors - Ionisation chambers, - Theory and design - Construction of condenser type chambers and thimble chambers - Gas multiplication - Proportional and GM Counters – basic detection mechanism, types of radiation detected, mode of operation, different variants of detectors (e.g. sealed, flow type, high pressure, multi-wire, position sensitive) - Types of instruments which uses gas filled detectors – radiation dosimeters, survey meters, contamination monitors - Cylindrical, plane parallel, spherical and well-type ionization chambers, Extrapolation chamber- Characteristics of organic and inorganic counters - Dead time and recovery time - Scintillation detectors - Advantages of scintillation detectors, properties of ideal scintillatior, basic electronic blocks in scintillation detector setup. Radiation detection mechanism of organic and in-organic scintillators, types of scintillators for various applications - Semiconductor detectors and its application for gamma spectrometry, Diode and MOSFET dosimeters - Chemical dosimeters - Radiographic and Radiochromic films - Thermoluminescent Dosimeters (TLD) – Optically stimulated Luminescence dosimeters (OSLD) - Radiophotoluminescent dosimeters- Neutron Detectors: - Nuclear track emulsions for fast neutrons - Solid State Nuclear track (SSNTD) detectors - Neutron detection by activation, Self powered neutron detectors (SPND), BF_3, ^3He, Bubble detectors - Calorimeters - New Developments (direct ion storage (DIS), radiochromic films, diamond detectors etc.).

4.3 Radiation Measuring & Monitoring Instruments (17 h)

Dosimeters based on condenser chambers - Pocket chambers - Dosimeters based on current measurement - Different types of electrometers – MOSFET - Diode Detectors, Semi-conductor Detectors., Vibrating condenser and Varactor bridge types - Secondary standard therapy level dosimeters - Farmer Dosimeters – Radiation field analyser (RFA) - Radioisotope calibrator - Multipurpose dosimeter (used in Diagnostic Radiology) - Water phantom dosimetry systems -

Brachytherapy dosimeters – well type chamber-Isotope calibrators - Thermoluminescent dosimeter readers for medical applications - Calibration and maintenance of dosimeters.

Instruments for personnel monitoring - TLD badge readers – Personnel Monitoring film densitometers – OSLD readers - Glass dosimeter readers – Working principle of Digital pocket dosimeters using solid state devices and GM counters – Instruments for area monitoring Portable and fixed area monitors, beta-gamma zone monitor, survey meters, Gamma area (Zone) alarm monitors –wide range survey instrument- Teletector. Contamination monitoring instruments for portable contamination monitor, alpha, beta and gamma radiation detection- Hand and Foot monitors –Whole Body counter, Portal Monitors - Scintillation monitors for X and gamma radiations - Neutron area Monitors, Tissue equivalent survey meters - Flux meter and dose equivalent monitors - neutron personnel monitors - CR-39, TLD Li-6, Bubble detector.
Instruments for counting and spectrometry - Portable counting systems for alpha and beta radiation - Gamma ray spectrometers –Single and Multichannel Analyser–HPGe- Liquid scintillation counting system (Organic/Inorganic)- RIA counters – Whole body counters - Air Monitors for radioactive particulates and gases. Details of commercially available instruments and systems.

PAPER - V: RADIATION BIOLOGY (50 h)

5.1 Cell Biology (5 h)

Cell physiology and biochemistry - Structure of the cell - Types of cells and tissue, their structures and functions - Organic constituents of cells - Carbohydrates, fats, proteins and nucleic acids - Enzymes and their functions - Functions of mitochondria, ribosomes, golgi bodies and lysosomes - Cell metabolism - DNA as concepts of gene and gene action - Mitotic and meiotic cell division - Semi conservative DNA synthesis, Genetic variation Crossing over, mutation, chromosome segregation - Heredity and its mechanisms.

5.2 Anatomy, Physiology and Pathology (10 h)

Anatomy and physiology as applied to radiodiagnosis and radiotherapy - Structure & function of organs and systems & their common diseases: Skin, Lymphatic system, Bone and muscle, Nervous, Endocrine, Cardiovascular, Respiratory, Digestive (Gastro-Intestinal), Urinary, Reproductive, Eye and ear.
Anatomy of human body, nomenclature & Surface anatomy, Radiographic Anatomy (including cross sectional anatomy - identify the different organs/ structures on plain x-rays, CT scans and other available imaging modalities. Normal anatomy & deviation for abnormalities.
Tumour pathology and carcinogenesis, common pathological features of cancers and interpretation of clinico-pathological data.

5.3 Interaction of Radiation with Cells (6 h)

Action of radiation on living cells – Radio-lytic products of water and their interaction with biomolecule - Nucleic acids, proteins, enzymes, fats - Influence of oxygen, temperature - Cellular effects of radiation - Mitotic delay, chromosome aberrations, mutations and recombinations - Giant cell formation, cell death Recovery from radiation damage - Potentially lethal damage and sublethal damage recovery - Pathways for repair of radiation damage. Law of Bergonie and Tribondeau.

Survival curve parameters - Model for radiation action - Target theory - Multihit, Multitarget - Repair misrepair hypothesis - Dual action hypothesis - Modification of radiation damage - LET,

RBE, dose rate, dose fractionation - Oxygen and other chemical sensitizers - Anoxic, hypoxic, base analogs, folic acid, and energy metabolism inhibitors - Hyperthermic sensitization - Radio-protective and radio sensitizer agents – Bystander effect.

5.4 Biological Effects of Radiation (9 h)

Somatic effects of radiation - Physical factors influencing somatic effects - Dependence on dose, dose rate, type and energy of radiation, temperature, anoxia, - Acute radiation sickness - LD 50 dose - Effect of radiation on skin and blood forming organs, digestive tract - Sterility and cataract formation - Effects of chronic exposure to radiation - Induction of leukaemia - Radiation Carcinogenesis - Risk of carcinogenesis – epidemiological data- life span studies - Animal and human data - effects of In-utero radiation exposure - Genetic effects of radiation - Factors affecting frequency of radiation induced mutations - Dose-effect relationship - first generation effects - Effects due to mutation of recessive characteristics - Genetic burden - Prevalence of hereditary diseases and defects - Spontaneous mutation rate - Concept of doubling dose and genetic risk estimate.

5.5 Basics of Radiation Oncology (10 h)

Site specific symptoms, diagnosis and management: Head and Neck, Breast, Gynaecological, Gastro-Intestinal tract, Genito-Urinary, Lung & Thorax, Lymphomas & Leukemias& Other cancers including AIDS related cancers. Benign and malignant disease, Spread of malignant disease, Staging and grading systems, Treatment intent - Curative & Palliative, Different modalities of cancer management (e.g. Radiation Therapy, Surgery, Chemotherapy), Hormone Therapy, Immunotherapy, Radionuclide therapy. Patient management on treatment - side effects related to radiation and dose - Acute & Late effects - Monitoring and common management of side effects.

5.6 Biological Basis of Radiotherapy (5 h)

Effect of radiation on cell survival, cell survival curve(s), Dose response Curve(s) for tumor and normal tissue, Physical and biological factors affecting cell survival, cell cycle - tumour re-growth and normal tissue response -4R's of Radiotherapy- Non-conventional fractionation schemes and their effect of reoxygenation, repair, repopulation and redistribution - Effects on cells due to Low and High LET radiation , Hyperthermia, Tumour Control Probability (TCP), Normal Tissue Complication Probability (NTCP),therapeutic ratio.

5.7 Time Dose Fractionation (5 h)

Time dose fractionation - Basis for dose fractionation in beam therapy - Concepts for Nominal Standard Dose (NSD), Time dose fractionation (TDF) – cumulative radiation effects (CRE) - Gap correction, Linear and Linear Quadratic models (LQ model), Biological Effective Dose (BED. Biological optimization, Tolerance Doses and Volumes, Quantitative Analysis of Normal Tissue Effects in the Clinic (QUANTEC).

PAPER – VI: MEDICAL IMAGING (65 h)

6.1 Medical Imaging Fundamentals (10 h)

Production of X-rays, Interactions of X-rays with human body, differential transmission of x-ray beam, spatial image formation, formation of radiological (latent) image and its visualization , limitations of projection imaging technique Viz. superimposition of overlying structures and scatter, application of contrast media and projections at different angles to overcome superimposition of overlying structures

Digital Imaging systems: Tomographic Reconstruction Techniques (Filtered Back Projection, Iterative reconstruction), Linear Systems, Acquisition, formation, processing and display of medical images, Evaluation of Image Quality.

Physics of Imaging Detectors: Physics of generic photon detectors, Quantum efficiency, Direct and Indirect conversion detectors, Charge generation and charge collection, Photomultiplier Tube (PMT), Charge coupled device, Flat panel detector, CR-DR imaging plates, image intensifier.
Noise considerations, Signal –to- noise ratio, Concept of spatial frequency depending on detector quantum efficiency.

6.2 Principles of X-ray Diagnosis & Conventional Imaging (10 h)

Physical Principle of Diagnostic Radiology

Radiography techniques: Prime factors (kVp, mAs and SID/SFD), influence of prime factors on image quality, selection criteria of prime factors for different types of imaging, different type of projection and slices selected for imaging, objectives of radio-diagnosis, patient dose versus image quality

X-ray beam Filters: inherent and added filters, purpose of added filters, filters used for shaping X-ray spectrum (K-edge filters: holmium, gadolinium, molybdenum), minimum filtration requirements for X-ray beam

Scatter reduction: Factors influencing scatter radiation, objectives of scatter reduction, contrast reduction factor, scatter reduction methods; beam restrictors (diaphragms, cones/cylinders & collimators), grids (grid function, different types of stationary grids, grid performance evaluation parameters, moving grids, artifacts caused by grids, grid selection criteria), air gap technique
Intensifying screens: Principles and function of intensifying screens, screen function evaluation parameters, emission spectra and screen film matching, conventional screens Vs rare earth screens
Radiographic Film: Components of radiographic film, principle of image formation on film, double and single emulsion film, sensitometeric parameters of film (density, speed, latitude etc.), QA of film developer
Image quality: Image quality parameters; sources of un-sharpness, reduction of un-sharpness, factors influencing radiographic contrast, resolution, evaluation of resolution (point spread function (PSF), line spread function (LSF), edge spread function (ESF), modulation transfer function (MTF), focal spot size evaluation, Phantoms used for determination of image resolution
QA of conventional diagnostic X-ray equipment: Purpose of QA, QA protocols and procedures, QA test methods for performance evaluation of x-ray diagnostic equipment
Planning and shielding calculations of diagnostic radiology facilities. Regulatory requirements for diagnostic radiology facilities.

6.3 Digital X-Ray Imaging and Computed Tomography (10 h)

Xero-radiography, mammography, Interventional radiology, digital radiography (CR and DR systems), digital subtraction techniques, orthopan tomography (OPG), Cone Beam CT (DBCT), Computed Tomography (CT).

Digital detectors: computed radiography- CT, Dual Energy CT (DECT), Tomosynthesis; detectors based on direct and indirect conversion methods, QA of CT equipment, Interventional Radiology , QA of interventional radiology equipment, Dual energy imaging and absorptiometry (DEXA), Patient dose optimization techniques, Dual and Multi-modality Imaging techniques.

6.4 Other Associated Medical Imaging Techniques (4 h)

Physics of Magnetic Resonance and ultrasound imaging and their applications in radiotherapy for treatment planning.

6.5 Nuclear Medicine & Internal Dosimetry (25 h)

(i) Physics of Nuclear Medicine (11 h)

Introduction to Nuclear Medicine, Unsealed Sources, Production of Radionuclide used in Nuclear Medicine; Reactor and accelerator based Radionuclides, Photonuclear activation, Equations for Radionuclide Production, Radionuclide Generators and their operation principles. Preparation and Various usages of Radiopharmaceuticals.

In-vivo Non-imaging procedures; Thyroid Uptake Measurements, Renogram, Life Span of RBC, Blood Volume studies etc.

Radionuclide Imaging: General concept of Radionuclide Imaging and Historical developments. The Rectilinear Scanner and its operational principle, Basic Principles and Design of the Gamma Camera / Scintillation Camera, System components, Detector System and Electronics, Different types of Collimators, Design and Performance Characteristics of the Converging, Diverging and Pin hole Collimator, Image Display and Recording Systems, Digital Image Processing Systems, Scanning Camera, Limitation of the Detector System and Electronics.

Different Imaging Techniques: Basic Principles, Two dimensional Imaging Techniques, Three Dimensional Imaging Techniques - Basic Principles and Problem, Focal Plane Tomography, Emission Computed Tomography, Single Photon Emission Computed Tomography (SPECT), Positron Emission Tomography (PET), Fusion imaging PET-CT, PET-MRI. Various Image Reconstruction Techniques during Image formation such as Back Projection and Fourier based Techniques, Iterative Reconstruction method and their drawbacks. Attenuation Correction, Scatter Correction, Resolution Correction, Other requirements or Sources of Error.

Image Quality Parameters: Spatial Resolution, Factor affecting Spatial Resolution, Methods of Evaluation of Spatial Resolution, Contrast, Noise. National and International protocol followed for Quality Assurance / Quality Control of Imaging equipment (SPECT, PET-CT and SPECT-CT) such as IEC/NEMA Protocols.

In-vitro Technique: RIA/IRMA techniques and its principles.

Physics of Imaging system (PET/SPECT) : Principles of PET/SPECT, PET Instrumentations, Annihilation Coincidence Detection, PET Detector ad Scanner Design, Data Acquisition for PET, Data corrections and Quantitative Aspect of PET.

(ii) Radionuclide Therapy (6 h)

Treatment of Thyrotoxicosis, Thyroid cancer with I-131, use of P-32 and Y-90 for palliative treatment, Radiation Synovectomy and the isotopes used. Concept of Delay Tank and various Waste Disposal Methods used in Nuclear Medicine.

Planning and Shielding Calculations during the installation of SPECT, PET/CT, High Dose Therapy in the Nuclear Medicine Department as per National/International methods.

Performance check of radiation measuring and monitoring instruments, work place and environmental (stack) monitoring, Permissible radiation limits for controlled and supervised area, Contamination limits, Radiation protection survey and contamination checks, Air-borne contamination, estimation of gases effluent discharge, dose apportionment and dose budgeting.

Radiological safety aspects during servicing and maintenance.

Unusual occurrences and its handling procedures: Failure of cooling system, target foil ruptured, spillage, power failure, excessive exposure, personnel contamination; Protective and Emergency equipment requirements in medical cyclotron facility.

(iii) Internal Dosimetry (8 h)

Internal Radiation Dosimetry: Different Compartmental Model; Single Compartmental Model, Two Compartmental Model with Back Transference, Two Compartmental Model without Back Transference. Classical Methods of Dose Evaluation; Beta particle Dosimetry; Equilibrium Dose Rate Equation, Beta Dose Calculation Specific Gamma Ray Constant, Gamma Ray Dosimetry, Geometrical Factor Calculation, Dosimetry of Low Energy Electromagnetic Radiation.

MIRD Technique for Dose calculations; Basic procedure and some practical problems, Cumulative Activity, Equilibrium Dose Constant, Absorbed Fraction, Specific Absorbed Fraction, Dose Reciprocity Theorem, Mean Dose per unit Cumulative Activity and Problems related to the Dose Calculations. Limitation of MIRD Technique.

6.6 Principle of Cyclotron Operation (6 h)

Principle of Cyclotron and charged particle accelerators, Applications of cyclotrons in medicine, Types of Cyclotrons: self-shielded and unshielded (in-bunker) and locally shielded.

Auxiliary equipment and their safety significance: vacuum pumps, RF-power, magnet power supply; cooling system, control software and programs used for medical cyclotron operation.

PAPER – VII: RADIATION THERAPY (66 h)

7.1 Beam Therapy (30 h)

Type of External beam therapy (EBRT) equipment: Working principles of Telecobalt, Gammaknife, Linear Accelerator, Cyber Knife, Tomotherapy, Intra Operative Radiotherapy & Proton/carbon ion Therapy. Components of beam delivery mechanism such as target, flattening filter, scattering foil, bending magnet, monitor chamber, Collimator jaws, MLC, micro MLC and other systems specific to various types of equipment. Safety interlocks in beam delivery process. Source design and classification- beam collimation and penumbra - trimmers and breast cones used in telecobalt unit. Output calibration of ^{60}Co gamma rays, high energy x-rays and electron beams using (IAEA/AAPM protocols etc.) and other dosimetry protocols. Relative merits and demerits of gamma rays, MV x-rays and electron beams. Radiotherapy simulator and its applications, CT simulation and virtual simulations.

Central axis dosimetry parameters - Tissue air ratio (TAR) Back scatter/ Peak scatter factor (BSF/PSF) - Percentage depth doses (PDD) - Tissue phantom ratio (TPR) - Tissue maximum ratio (TMR) - Collimator, phantom and total scatter factors. Relation between TAR and PDD and its applications - Relation between TMR and PDD and its applications. SAR, SMR, Off axis ratio and Field factor. Build-up region and surface dose. Description and measurement of isodose curves/charts, Dosimetry data resources.

Clinical electron beams - energy specification - electron energy selection for patient treatment - depth dose characteristics (D_s, D_x, R_{100}, R_{90}, R_{50}, R_p etc.) - beam flatness and symmetry - penumbra -isodose plots - monitor unit calculations - output factor formalisms - effect of air gap on beam dosimetry - effective SSD.
Particulate beam therapy - Relative merits of electron, neutron, x-ray and gamma ray beams - Neutron capture therapy - Heavy ion therapy.

Measuring tools/phantoms: Water phantom and Tissue equivalent/solid water phantoms for dosimetry Radiation filed analyzer (RFA), Array detectors for beam analysis, phantom for beam energy check etc.

Beam modifying and shaping devices - wedge filters - universal, motorized and dynamic wedges- shielding blocks and compensators, multi leaf collimators (MLC) and micro MLC.

Treatment planning in teletherapy - target volume definition and dose prescription criteria as per ICRU protocols - SSD and SAD set ups - two and three dimensional localization techniques - contouring - simulation of treatment techniques - field arrangements - single, parallel opposed and multiple fields - corrections for tissue inhomogeneity, contour shapes and beam obliquity - integral dose.

Treatment Techniques: Conventional and conformal radiotherapy, Treatment time and Monitor unit calculations , Arc/ rotation therapy - mantle and inverted Y fields.

Quality assurance in radiation therapy - precision and accuracy in clinical dosimetry - quality assurance protocols for telecobalt, medical linear accelerator and radiotherapy simulators - IEC requirements - acceptance, commissioning and. quality control of telecobalt, medical linear accelerator and radiotherapy simulators. Portal and in-vivo dosimetry. Electronic portal imaging devices. Patient Specific quality assurance in radiotherapy, Quality assurance of On Board Imager system (OBI)/EPID. QA of ARC Therapy. QA of MLC. Overview of QA & acceptance test

proforma of AERB for Telegamma, Simulators and Medical Electron Accelerators and FFF beam.

7.2 Brachytherapy (12 h)

Definition and classification of brachytherapy techniques - surface mould, intracavitary, interstitial and intraluminal techniques. Requirement for brachytherapy sources - Description of radium and radium substitutes - ^{137}Cs, ^{60}Co, ^{192}Ir, ^{125}I and other commonly used brachytherapy sources. Dose rate considerations and classification of brachytherapy techniques - Low dose rate (LDR), high dose rate (HDR) and pulsed dose rate (PDR). Paterson Parker and Manchester Dosage systems. ICRU 38 and 58 protocols. Specification and calibration of brachytherapy sources - RAKR and AKS - IAEA TECDOC 1274 and ICRU 72 recommendations. Point and line source dosimetry formalisms - Sievert Integral - AAPM TG-43/43U1 and other dosimetry formalisms.

After loading techniques - Advantages and disadvantages of manual and remote after loading techniques. AAPM and IEC requirements for remote after loading brachytherapy equipment. Acceptance, commissioning and quality assurance of remote after loading brachytherapy equipment. ISO requirements and QA of brachytherapy sources. Integrated brachytherapy unit. Brachytherapy treatment planning - CT/MR based brachytherapy planning - forward and inverse planning - DICOM image import / export from OT - Record & verification. Brachytherapy treatment for Prostate cancer. Ocular brachytherapy using photon and beta sources. Intravascular brachytherapy - classification - sources - dosimetry procedures - AAPM TG 60 protocol. Electronic brachytherapy (Axxent, Mammosite, etc.).

Planning and shielding calculations of brachytherapy facilities. Regulatory requirements for brachytherapy facilities.

Overview of QA & acceptance test proforma of AERB for Brachytherapy units.

Proton/Hadron Therapy : Proton therapy- Principle, applications of proton therapy in radiation oncology, commissioning of proton/hadron accelerator, proton therapy treatment planning and delivery, beam modifiers, QA protocols, TRS 398 and other dosimetry procedures for heavy charged particle therapy, Prescribing, Recording and Reporting Proton Beam Therapy (ICRU Report 78); National/International/ IEC requirements for hadron therapy equipment, safety interlocks for gamma and neutron radiations, induced activity and its minimization.

Siting, layout planning and shielding calculations for hadron therapy facilities; neutron yield and aspects for neutron shielding

7.3 Computers in Treatment Planning (12 h)

Scope of computers in radiation treatment planning - Review of algorithms used for treatment planning computations - Pencil beam, double pencil beam, Clarkson method, convolution superposition, lung interface algorithm, fast Fourier transform, Inverse planning algorithm, Monte Carlo based algorithms. Treatment planning calculations for photon beam, electron beam, hadron beam (proton/heavy ion) beam and brachytherapy - Factors to be incorporated in computational algorithms. Plan optimization - direct aperture optimization - beamlet optimization - simulated annealing - dose volume histograms - Indices used for plan comparisons - Hardware and software requirements - beam & source library generation. Networking, DICOM and PACS. Acceptance, commissioning and quality assurance of radiotherapy treatment planning systems using IAEA TRS 430 and other protocols. Dose calculation algorithms , ICRU Report 38, AAPM TG 43 formalism , HDR/LDR, Equipment, Treatment Planning , Inverse Planning, optimization, IMRT, VMAT, FFF & Proton Therapy dose computational algorithms.

7.4 Special and Advanced Techniques of Radiotherapy (12 h)

Special techniques in radiation therapy - Total body irradiation (TBI) - large field dosimetry - total skin electron therapy (TSET) - electron arc treatment and dosimetry - intraoperative radiotherapy.

Stereotactic radiosurgery/radiotherapy (SRS/SRT) - cone and mMLC based X-Knife - Gamma Knife - immobilization devices for SRS/SRT - dosimetry and planning procedures - Evaluation of SRS/SRT treatment plans - QA protocols and procedures for X- and Gamma Knife units - Patient specific QA. Physical, planning, clinical aspects and quality assurance of stereotactic body radiotherapy (SBRT) and Cyber Knife based therapy.

Intensity modulated radiation therapy (IMRT) - principles - MLC based IMRT - step and shoot and sliding window techniques - Compensator based IMRT – Tomotherapy based IMRT, planning process - inverse treatment planning - immobilization for IMRT - dose verification phantoms, dosimeters, protocols and procedures - machine and patient specific QA. Volumetric Modulated Arc Therapy (VMAT).

Image Guided Radiotherapy (IGRT) - concept, imaging modality, kV cone beam CT (kVCT), MV cone beam CT (MVCT), image registration, plan adaptation, QA protocol and procedures - special phantom, 4DCT. Tomotherapy - principle - commissioning - imaging - planning and dosimetry - delivery - adaptive radiotherapy - QA protocols and procedures.

Proton therapy- Principle, applications of proton therapy in radiation oncology, commissioning of proton/hadron accelerator, treatment planning and delivery, QA protocols and procedures, safety interlocks for gamma and neutron radiations, induced activity.

Small field dosimetry - fundamental aspects, protocols), small-field radiotherapy equipment and techniques.
Image guidance and verification in radiotherapy (Cone beam CT, ultrasound, Portal imaging, in-vivo dosimetry, image registration), Radiation therapy information systems.

Information Technology for Medical Physics - International standards (IEC, DICOM, IHE), General concepts and architecture of HIS/RIS/PACS, Radiotherapy record and verify (R&V) systems , DICOM objects for patient dosimetry.

PAPER – VIII: RADIATION SAFETY (60 h)

8.1 Radiation Protection Standards (7 h)

Radiation dose to individuals from natural radioactivity in the environment and man-made sources. Basic concepts of radiation protection standards - Historical background - International Commission on Radiological Protection and its recommendations – The system of Radiological Protection – Justification of Practice, Optimisation of Protection and individual dose limits – Radiation and tissue weighting factors, equivalent dose, effective dose, committed equivalent dose, committed effective dose – Concepts of collective dose- Potential exposures, dose and dose constraints – System of protection for intervention - Categories of exposures – Occupational, Public and Medical Exposures - Permissible levels for neutron flux - Factors governing internal exposure - Radionuclide concentrations in air and water - ALI, DAC and contamination levels.

8.2 Principles of Monitoring and Protection (6 h)

Evaluation of external radiation hazards - Effects of distance, time and shielding - Shielding calculations - Personnel and area monitoring - Internal radiation hazards – Radio toxicity of different radionuclides and the classification of laboratories – Control of contamination – Bioassay and air monitoring – chemical protection – Radiation accidents – disaster monitoring.

8.3 Planning of Medical Radiation Installations (15 h)

Planning of medical radiation installations - General considerations - Design of diagnostic, X-ray, Radiotherapy (telegamma, accelerator, tomothreapy, cyberknife and brachytherapy) installations, Nuclear Medicine facilities and research laboratories using radioisotopes.

8.4 Radiation Hazard Evaluation in Medical Radiation Installations (8 h)

Evaluation of radiation hazards in medical diagnostic and therapeutic equipment and installations - Radiation monitoring procedures – measurement of leakage radiation through the treatment head / X-ray tube housing. Radiation survey and evaluation of radiation levels around RT, NM and DR installation. Protective measures to reduce radiation exposure to staff and patients - Radiation hazards in brachytherapy departments and teletherapy departments and radioisotope laboratories - Particle accelerators - Protective equipment - Handling of patients - Waste disposal facilities - Radiation safety during source transfer operations - Special safety features in accelerators.

8.5 Radioactive Waste Disposal (4 h)

Radioactive wastes – sources of radioactive wastes - Classification of waste - Treatment techniques for solid, liquid and gaseous effluents – Permissible limits for disposal of waste - Sampling techniques for air, water and solids – Geological, hydrological and meteorological parameters – Ecological considerations.

Disposal of radioactive wastes - General methods of disposal - Management of radioactive waste in medical, industrial, agricultural and research establishments.

8.6 Transport of Radioactive Material (4 h)

Transportation of radioactive substances - Historical background - General packing requirements - Transport documents - Labeling and marking of packages - Regulations applicable for different modes of transport - Transport by post - Transport emergencies - Special requirements for transport of large radioactive sources and fissile materials - Exemptions from regulations – Shipment approval – Shipment under exclusive use – Transport under special arrangement – Consignor's and carrier's responsibilities.

8.7 Legislation (11 h)

Physical protection of sources - Safety and security of sources during storage, use, transport and disposal – Security provisions: administrative and technical – Security threat and graded approach in security provision

National legislation – Regulatory framework – Atomic Energy Act – Atomic Energy (Radiation Protection) Rules – Applicable Safety Codes, Standards, Guides and Manuals – Regulatory Control – Licensing, Inspection and Enforcement – Responsibilities of Employers, Licensees, Radiological Safety Officers and Radiation Workers – National inventories of radiation sources –

Import, Export procedures guidelines, requirement and procedures for setting up medical radiation facilities, Cyclotron facilities, Emergency preparedness in medical radiation/cyclotron facilities.

8.8 Radiation Emergencies and their Medical Management (5 h)

Normal and potential exposure, potential accident situations involving radioisotopes, elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical procedures, responsibilities of employer, licensee, RSO, Service Engineer and source/equipment supplier in case of emergency, probable emergency situations and accidents in medical applications of radiation (failure of pneumatic system, improper functioning of timer, software mix-up in accelerator etc.), - probable accidents during Loading and unloading of sources - Loss of radiation sources and their tracing - Typical accident cases in radiotherapy with Case histories Radiation injuries in Radiotherapy and Interventional Radiology procedures, mis-administration of radio isotopes in NM, treatment and medical management of affected patients– Personal (external and internal) and environmental dosimetry in accidental exposures- Investigation of accidental exposure to patients or excessive exposure to occupational radiation workers, Emergency preparedness plan, Radiation protection programme - design, implementation and management.

Practical:

1. Production and attenuation of bremsstrahlung, HVT/TVT measurement.
2. Range of beta particles by Feather analysis.
3. Backscattering of beta particles and its applications.
4. Statistics of radioactive counting.
5. Study of voltage and current characteristics of an ionization chamber.
6. Calibration of survey instruments and pocket dosimeters.
7. Calibration of a therapy level dosimeter.
8. Calibration of TL phosphor & TLD reader and its use in dose distribution measurements.
9. Determination of plateau and resolving time of a G.M. counter
10. Calibration of a TLD personnel monitoring badge and dose evaluation.
11. Calibration of Gamma ray spectrometer [NaI(Tl), HPGe] and identification of unknown sources using single/multichannel analyser.
12. Preparation and standardization of unsealed sources.
13. Quality assurance of diagnostic x-ray equipment
14. Evaluation of characteristics of a radiographic image.
15. Study and calibration of thyroid uptake measurement unit.
16. Dose output measurement of photon (^{60}Co gamma rays and high energy x-rays) beams used in radiotherapy treatment.
17. Dose output measurement and beam characterization of photon & electron beams used in radiotherapy treatment.
18. Integrity check and calibration of low activity brachytherapy sources.

19. AKS/ RAKR measurement of HDR brachytherapy sources using well type and cylindrical ionisation chambers.
20. Familiarisation with treatment planning procedure using a computerised radiotherapy treatment planning system for various treatment techniques (IMRT, IGRT, SRS/SRT, SBRT, 3D CRT, VMAT etc).
21. Survey of a radioisotope laboratory and study of surface and air contamination.
22. Radiation protection survey of teletherapy/ NM and diagnostic radiology installations.
23. Commissioning and acceptance testing of Medical Accelerator, Telecobalt and HDR brachytherapy equipment using AERB acceptance protocol.
24. Commissioning and acceptance testing of CT, CT-Simulator/conventional Simulators unit using AERB protocol (including measurement of CTDI).
25. Quality assurance of Treatment Planning System using TRS-430 protocol.
26. Familiarisation with patient specific QA of VMAT/Rapid Arc Therapy.
27. Familarisation with Simulation, virtual simulation, DRR's, image registration, patient setup, including positioning and immobilization and image guidance verification (Cone beam CT/ultrasound/Portal Imaging)

******

ANNEXURE-4 C

RADIATION SAFETY SYLLABI FOR TRAINING COURSES FOR RP-RT-3 IN RADIOTHERAPY

Course Duration: As prescribed by University/Institution subject to fulfilling the minimum course duration and minimum desirable entry level qualifications stipulated in this document.

Infrastructure: As per Appendix-3B of this document

Examination:

At least one mandatory separate paper on Radiation safety should be incorporated in the University final examination pattern covering the radiation safety syllabus prescribed in this document.

The paper should have same weightage as given to other clinical papers.

Passing Criteria: As prescribed by University.

Syllabus: **(85 h)**

1. **Basic Radiation Physics (4 h)**

Radioactivity, general properties of alpha, beta and gamma rays, laws of radioactivity, radioactive Decay (alpha, beta, gamma, Electron capture - Internal conversion), half-life, decay constant, radioactive equilibrium, nuclear isomerism, artificial radioactivity.

2. **Basic of X-ray and Its Production (8 h)**

Discovery, production, properties of x-rays, characteristics and continuous spectra, basic requirements of medical diagnostic and therapeutic x-ray tubes, rotating anode tubes, hooded anode tubes, rating of tubes, standard exposure charts, limitations on loading safety devices in x-ray tubes, insulation and cooling of x-ray tubes, types of x-ray units (Fixed radiography, Computed Tomography, Interventional Radiology, C-Arm, Mammography, Dental X-ray units etc.)

Filament and high voltage transformers, high voltage circuits, half-wave and full-wave rectifiers, three phase apparatus, automatic exposure control, automatic brightness control, measuring instruments for measurement of kV and mA, timers, control panels, image intensifiers and flat panel detectors, modern trends.

3. **Interaction of Radiation with Matter (6 h)**

Interaction of electromagnetic radiation with matter: Photoelectric effect, Compton effect, Pair production; attenuation and mass energy absorption coefficients, interaction of charged particles including electrons with matter, interaction of heavy charged particles with matter, energy loss by collision, bragg curve, spread out Bragg peak (SOBP), interaction of neutrons with matter, elastic scattering, inelastic scattering, capture, neutron induced nuclear reactions.

4. **Radiation Quantities and Units (5 h)**

Radiation quantities and units –Fluence, fluence rate, energy fluence, Linear and mass attenuation coefficients - Mass energy transfer and mass energy absorption coefficients - Stopping power - LET - Absorbed dose - Kerma - Exposure - Air kerma rate constant - Charged particle equilibrium (CPE) – Relationship between Kerma, absorbed dose and exposure under CPE –Equivalent Dose-Effective Dose-Collective Dose-Committed Effective Dose-ALI-DAC-Familiarization with various units used such as Becquerel-Curie-Roentgen-Gray-Rad-Sievert etc.

5. Radiation Detection and Measurements (6 h)

Basic principles of radiation detection - Gas Filled detectors - Ionisation chambers - Proportional and GM Counters-Thimble Chamber-Parallel Plate Chamber-Well Type Chamber - Scintillation detectors - Semiconductor detectors - Radiographic and Radiochromic films - Thermoluminescent Dosimeters (TLD) , Optically stimulated luminescence (OSL) dosimeter-Radiation field analyser (RFA) - Pocket Dosimeter- Gamma Zone monitors, Contamination monitors, Gamma/X-Ray survey meter and neutron survey meter.

6. Radiation Hazard, Evaluation and Control (4 h)

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation, specific gamma ray constant, application of time, distance and shielding concepts, individual and workplace monitoring, external radiation monitoring.

7. Radiation Biology (4 h)

Interaction of radiation on living cells and subsequent physical, chemical and biological changes – Radiolysis of water, formation of free radicals-Survival curve parameters -Modification of radiation damage – Linear Energy transfer (LET), Radiobiological effectiveness (RBE), effect of dose rate, Oxygen and chemical sensitizers on radiosensitivity- Effect of radiation on skin and blood forming organs, digestive tract - Sterility and cataract formation - Effects of chronic exposure to radiation -Radiation Carcinogenesis.

8. Biological Basis of Radiotherapy and Time Dose Fractionation (5 h)

Effect of ionising radiation on Cell, Chromosomal aberration and its application for the biological dosimetry, Somatic effects and hereditary effects, stochastic and deterministic effects, Acute exposure and Chronic exposure, $LD_{50/60}$. Biological basis of radiotherapy, L-Q model, radio-sensitivity, radio-resistivity, 4R's of Radiotherapy – Time dose fractionation, Effects of re-oxygenation, repair, redistribution in the cell cycle - High LET radiation therapy, Hyperthermia.

9. Radiation Protection Standards (4 h)

Basic concepts of radiation protection standards - Historical background - International Commission on Radiological Protection(ICRP) and its recommendations – The system of Radiological Protection – Justification of Practice, Optimization of Protection (ALARA) and individual dose limits, – Radiation and tissue weighting factors-Potential exposures- dose and dose constraints – System of protection for intervention - Categories of exposures – Occupational, Public and Medical Exposures.

10. Radiation Sources & its Medical Applications (3 h)

Radiation sources – Natural and artificial radioactive sources – production of isotopes – Reactor produced isotopes – Cyclotron produced isotopes – Fission products. Characteristics of Radiation

Sources (Co-60, Ir-192, Cs-137, I-125, Ru-106, Sr-90, Au-198, Cf-252 etc.) & its Medical Application.

11. Teletherapy (6 h)

Construction and working of telecobalt unit - source design - beam collimation and penumbra - trimmers and breast cones. Working principle of medical electron linear accelerators - beam collimation - asymmetric collimator - Multileaf collimator. Central axis dosimetry parameters - Tissue air ratio (TAR) Back scatter/ Peak scatter factor (BSF/PSF) - Percentage depth doses (PDD) - Tissue phantom ratio (TPR) - Tissue maximum ratio (TMR) -Build-up region and surface dose. Tissue equivalent phantoms. Radiation filed analyzer (RFA).Beam modifying and shaping devices - wedge filters - universal, motorized and dynamic wedges- shielding blocks and compensators. Treatment techniques-Conventional and conformal radiotherapy (3D-CRT, IMRT,IGRT, VMAT). Treatment time and Monitor unit calculations. Clinical electron beams - energy specification - electron energy selection for patient treatment -depth dose characteristics beam flatness and symmetry - penumbra .ICRU reports for external beam therapy.

12. Brachytherapy (4 h)

Definition and classification of brachytherapy techniques - surface mould, intracavitary, interstitial and intraluminal techniques- Image Based brachytherapy - Classification of brachytherapy treatment modality- Low dose rate (LDR), high dose rate (HDR) and pulsed dose rate (PDR). Paterson Parker and Manchester Dosage systems. ICRU report for Brachytherapy. Specification and calibration of brachytherapy sources - RAKR and AKS.

13. Imaging Modalities and Networking System in Radiotherapy (4 h)

Radiography-C-Arm-Mammography-Computed Tomography (CT) - Single Photon Emission Tomography (SPECT), Positron Emission Tomography (PET), Medical Resonance Imaging (MRI).

Picture Archiving and communication system (PACS)-Digital Imaging and Communication in Medicine (DICOM) - other associated networking systems used in Radiotherapy.

14. Current Advancement in Radiotherapy (4 h)

Introduction of Tomotherapy, Cyber knife & Particle Therapy (e.g. Proton Therapy/Carbon ion Therapy) - units. Image Guided Radiotherapy (IGRT) - kV cone beam CT (kVCT), MV cone beam CT (MVCT)- 4DCT- Total body irradiation (TBI) - Total skin electron therapy (TSET) - Electron arc treatment- Intraoperative radiotherapy(IORT)- Stereotactic radiosurgery/radiotherapy (SRS/SRT/SBRT).

15. Treatment Planning in Radiotherapy (7 h)

Overview of Mould Room-Thermoplastic Masks- Styrofoam Cutter Machine-Bolus-Compensator- Electron cut out- Shielding Blocks- Customized –Field shaping.
Overview of treatment planning in external radiation therapy and brachytherapy.
Overview of Portal Imaging/KVCT/MVCT.

16. Quality Assurance Test/Acceptance test in Radiotherapy (5 h)

Quality assurance (QA) in Radiotherapy- Periodic QA (Daily-Monthly-Weekly –Annual) of radiotherapy equipment's (Telecobalt-Medical Accelerator-HDR Brachytherapy-Imaging System/Simulator/CT-Simulator units) as per AERB requirements.

17. Regulatory Aspects for Radiation Therapy (2 h)

National Regulatory Body- Role & Responsibilities, Overview of applicable Act, Rules, Standards, Codes and Guides, Responsibilities of employer, licensee, registrants and RSO.

18. Security of Radioactive Sources (1h)

Physical protection of sources - Safety and security of sources during storage, use, transport and disposal – Security provisions: administrative and technical measures as stipulated by Atomic Energy Regulatory Board (AERB).

19. Transport of Radioactive Material (1h)

Transportation of radioactive substances, general packing requirements, type of transport package, labeling and marking of packages, regulations applicable for different modes of transport, consignor's and carrier's responsibilities.

20. Radioactive Waste Disposal (2 h)

Radioactive wastes, sources of radioactive wastes, classification of waste, treatment techniques for solid, liquid and gaseous effluents, permissible limits for disposal of waste, waste disposal facilities.

Practical:

1. Time, Distance and Shielding, measurement of HVT & TVT.
2. Familiarization with various radiation survey meters used in radiotherapy.
3. Radiological Protection Survey of Radiotherapy installations (Telecobalt, Medical Accelerator, Brachytherapy, Simulator/ CT Simulator etc.).
4. Output measurement of photon (^{60}Co gamma rays & high energy x-rays) beams and electron beam used in radiotherapy treatment.
5. Familiarization with reference air kerma rate (RAKR) and activity measurement of HDR brachytherapy sources using well type ionisation chambers.
6. Familiarization with quality assurance (QA) tests of Telecobalt unit using AERB QA protocol.
7. Familiarization with quality assurance tests of Medical Accelerator unit using AERB QA protocol.
8. Familiarization with quality assurance tests of HDR brachytherapy unit using AERB QA protocol.
9. Familiarization with quality assurance tests of Simulator/CT-Simulator unit using AERB QA protocol.
10. Familiarization with patient treatment simulation procedure followed in radiotherapy using Simulator/CT-Simulator.
11. An overview of computerized Radiotherapy Treatment Planning System used for external beam & brachytherapy Treatment.
12. An overview of electronic portal imaging, kV /MV imaging used in radiotherapy.

****

ANNEXURE-4 D

RADIATION SAFETY CERTIFICATION FOR SERVICE ENGINEERS OF RADIOTHERAPY EQUIPMENT (RP-RT-S)

Duration: 6 (Six) working days

Examination:

The examination should consist of

(i) A written paper of 80 marks (60 marks Objective + 20 marks Descriptive)

(ii) Viva-voce of 20 marks

Passing Criteria:

(i) Not less than 50% each in written and viva-voce examinations

(ii) Not less than 60% in aggregate.

Course Content:

A.	**Lectures (20 h)**	**Duration**
1.	Basic Radiation Physics	1 h
2.	Interaction of Radiation with Matter	1 h
3.	Radiation Quantities and Units	1 h
4.	Biological Effects of Radiation	1 h
5.	Operational Limits	1 h
6.	Radiation Detection and Measurement	1 h
7.	Radiation Hazard Evaluation and Control	2 h
8.	Planning of Radiotherapy Facilities	2 h
9.	Quality Assurance (QA) of Radiotherapy Equipment	4 h
10.	Transport of Radioactive Material	1 h
11.	Radiation Safety during Source Transfer Operation	1 h
12.	Regulatory Aspects for Radiotherapy Facility	1 h
13.	Security of Radioactive Sources	1 h
14.	Radiation Accidents, Case Studies and Lessons Learned	1 h
15.	Emergency Response Plans and Preparedness	1 h

B. Discussion: (2 h)

C. Practical: (8 h)

1. Radiation absorption characteristics & HVT, TVT measurements (2 h)
2. Familiarization with therapy and protection level equipments and radiation protection survey of a Radiotherapy Facility (2 h)
3. Quality Assurance of radiotherapy equipment(s) (4 h)

Syllabus:

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, types of radioactive disintegrations, electron capture, characteristics of alpha, beta and gamma rays; energy of ionizing radiation, half-life, effective half-life, production of radioisotopes and X-rays (Characteristic and Bremsstrahlung), neutron sources.

2. Interaction of Radiation with Matter

Interaction of charged particles with matter, bremsstrahlung, range of charged particles, interaction of photon with matter (photoelectric, Compton and pair production), absorption, scattering and attenuation of photons, shielding material, Half Value Thickness (HVT) and Tenth Value Thickness (TVT), interaction of neutrons with matter.

3. Radiation Quantities and Units

Activity (Becquerel & Curie), energy, exposure(C/kg & Roentgen), charge particle equilibrium, air kerma, absorbed dose (Gray & rad), radiation weighting factors(W_R), tissue weighting factors(W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

4. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cell, chromosomal aberration, somatic and genetic effects, deterministic and stochastic (Probabilistic) effects, partial body and whole body exposures.

5. Operational Limits

Introduction to natural background radiation, concept of occupational risk, philosophy of radiation protection, system of dose limitation, ALARA, dose limits to radiation workers and general public, AERB/ICRP recommendations.

6. Radiation Detection and Measurement

Principle of radiation detection, gas detectors (ionization chamber, proportional counter and GM counter), solid state detectors (scintillators, semiconductors and Thermoluminescent Dosimeter {TLD}), radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, direct reading dosimeters, calibration and response of radiation monitoring instruments.

7. Radiation Hazard Evaluation and Control

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation: individual and workplace monitoring; application of time, distance and shielding; specific gamma ray constant, external radiation monitoring, radiation survey meters.

8. Planning of Radiotherapy Facilities

General principles of planning of Radiotherapy facilities, site selection, area requirement, shielding material, shielding calculation {workload (W), use factor (U) and occupancy factor (T)}; model layouts of Telecobalt, Medical Linear Accelerator and Remote Afterloading Brachytherapy facilities.

9. Quality Assurance (QA) of Radiotherapy Equipment

Need and necessity of QA in radiotherapy, QA test parameters of Telecobalt, Medical Linear Accelerator and Remote Afterloading Brachytherapy, evaluation of transit dose, integrity test of Brachytherapy sources, leakage and contamination, uniformity of activity, source strength verification, LDR and HDR sources, radiation protection survey.

10. Transport of Radioactive Material

Regulatory aspects of transport of radioactive material, introduction, terms used (e.g. Competent Authority, A1&A2 values, transport index etc.), transport scenarios (routine, normal & accident), variety of packages covered under the transport regulations, general requirement of all packaging, preparation, marking, labelling of packages, preparation of transport documents (Consignors Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general instructions.

11. Radiation Safety during Source Transfer Operation

General precautions to be taken in source transfer operation in Telecobalt and Remote Afterloading Brachytherapy units, source transfer using source flask and source container, procedure for handling source stuck condition in Telecobalt and Remote AfterloadingBrachyrherapyequipments, role of service engineers.

12. Regulatory Aspects for Radiotherapy Facility

Regulations with respect to radiotherapy facilities, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO), Service Engineers, and radiotherapy source/equipment supplier; regulatory requirements for import/export, procurement, use, handling, transfer and safe disposal of radioactive material/equipment, inventory control.

13. **Security of Radioactive Sources**

Categorization of radiation sources, safety and security of radioactive sources during transport and storage, security provisions: administrative and technical measures, graded approach in security provision

14. **Radiation Accidents, Case Studies and Lessons Learned**

Radiation accidents involving radioisotopes, orphan and vulnerable sources, handling of emergency situations resulting during source transfer, line of command of actions,

accessories for handling accidents/incidents, loss of radioisotope, fire accidents and explosions, follow-up actions, case studies and lessons learned.

15. Emergency Response Plans and Preparedness

Normal and potential exposure, potential accident situations involving radioisotopes, elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical procedures, responsibilities of employer, licensee, RSO, Service Engineer and source/equipment supplier in case of emergency, probable emergency situations (failure of pneumatic system, improper functioning of timer, software mix-up in accelerator etc.).

****

ANNEXURE-4 E

RADIATION SAFETY CERTIFICATION FOR RSO IN OCULAR BRACHYTHERAPY FACILITY

Course Duration: 5 (Five) working days

Examination:
The examination should consist of;

(i) A written paper of 80 marks (60 marks Objective + 20 marks Descriptive)

(ii) Viva-voce of 20 marks.

Passing Criteria:

(i) Not less than 50% each in written and viva-voce examinations

(ii) Not less than 60% in aggregate.

Course Content:

A.	**Lectures (16 h)**	**Duration**
1.	Basic Radiation Physics	2 h
2.	Interaction of Radiation with Matter	1 h
3.	Radiation Quantities and Units	1 h
4.	Biological Effects of Radiation	1 h
5.	Operational Limits	1 h
6.	Radiation Detection and Familiarization with Survey Instruments	2 h
7.	Radiation Hazard Evaluation and Control	1 h
8.	Ocular Brachytherapy Sources	1 h
9.	Eye plaque Dosimetry and Source Strength Measurement	1 h
10.	Operational Safety Aspects of Ocular Brachytherapy	1 h
11.	Regulatory Aspects of Ocular Brachytherapy	1 h
12.	Security of Radioactive Sources	1 h
13.	Transport of Radioactive Material	1 h
14.	Emergency Response Plans and Preparedness	1 h

B. Demonstration : 4 h (1 h each)

1. Radiation absorption characteristics and HVT/ TVT measurements, performance check of radiation survey instruments

2. Radiation survey of ocular brachytherapy installation

3. Preparation and testing of $^{125}I/^{106}Ru/^{90}Sr$ seed sources for Ocular Bracthytherapy Applications.

4. Brachytherapy source strength measurement.

Syllabus:

1. Basic Radiation Physics

Radioisotopes, radioactivity, specific activity, types of radioactive decay, half-life, effective half-life, production of radioisotopes and X-rays (Characteristic and Bremsstrahlung).

2. Interaction of Radiation with Matter

Interaction of photon with matter (photoelectric, Compton and pair production), absorption, scattering and attenuation of photons, shielding material, Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

3. Radiation Quantities and Units

Activity (Becquerel & Curie), fluence, fluence rate, energy fluence energy, exposure(C/kg & Roentgen), charge particle equilibrium, air kerma, absorbed dose (Gray & rad), radiation weighting factors(W_R), tissue weighting factors(W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

4. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, free radicals, effect of radiation on living cell, chromosomal aberration, somatic and genetic effects, and stochastic effects and tissue reaction (deterministic effect)

5. Operational Limits

Introduction to natural background radiation, concept of occupational risk, philosophy of radiation protection (Justification, ALARA, dose limits), ICRP recommendations on dose limits to radiation workers and members of public, AERB/ICRP recommendations on dose limits for radiation workers and members of public, concept of radiation weighting factors (W_R), tissue weighting factors (W_T), equivalent dose & effective dose and its relevance in radiation protection.

6. Radiation Detection and Familiarization with Survey Instruments

Principle of radiation detection, overview of gas filled detectors (ionization chamber, proportional counter and GM counter), scintillators, semiconductors detectors, Thermoluminescent Dosimeter {TLD}), radiation monitoring instruments and its performance check, personnel monitoring, survey meters, direct reading dosimeter (DRD).

7. Radiation Hazard Evaluation and Control

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation: individual and workplace monitoring; application of time, distance and shielding; specific gamma ray constant, external radiation monitoring, radiation protection survey.

8. Ocular Brachytherapy Sources

Radiation sources used in ocular brachytherapy and its production, classification of sealed sources as per AERB requirement, integrity test of brachytherapy sources, leakage and contamination, swipe test, uniformity of activity, source strength verification.

9. Eye plaque Dosimetry and Source Strength Measurement

Procedures for standardization of brachytherapy sources, apparent activity, reference Air Kerma Rate (RAKR), Air Kerma strength, standardization of $^{125}I/^{106}Ru/^{90}Sr$, room scatter correction, source strength measurement protocols and techniques.

10. Operational Safety Aspects of Ocular Brachytherapy

Safety during preparation of ocular sources, handling of the sources, verification of sources prior and after treatment, patient isolation, patient monitoring, local transportation and storage.

11. Regulatory Aspects of Ocular Brachytherapy

Regulations with respect to eye plaque brachytherapy, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO); regulatory requirements for import/export, procurement, use, handling, transfer and safe disposal of radioactive material/equipment, inventory control.

12. Security of Radioactive Sources

Physical protection of sources, safety and security of radiation sources during storage, use, transport and disposal, security culture, security functions, categorization of radiation sources, security levels and security objectives, security provisions (administrative and technical), graded approach in security provision.

13. Transport of Radioactive Material

Regulatory aspects of transport of radioactive material, variety of packages covered under the transport regulations, general requirement of all packaging, preparation, marking, labelling of packages, preparation of transport documents (Consignors Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general instructions.

11. Emergency Response Plans and Preparedness

Normal and potential exposure, potential accident situations involving radioisotopes (including wrong dose delivery, wrong patient, loss of sources), handling of patients complication during treatment, elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical procedures, responsibilities of employer, licensee, RSO in case of emergency.

ANNEXURE-5: RADIATION SAFETY CERTIFICATION FOR PERSONNEL IN MEDICAL CYCLOTRON FACILITY

ANNEXURE-5 A

RADIATION SAFETY CERTIFICATION OF RSO IN MEDICAL CYCLOTRON FACILITY

The syllabi is applicable for specialized training for a personnel to become eligible for RSO Medical Cyclotron facility.

Duration: **4 weeks**
Lectures (Total 34 h) + Field training.

Syllabus

1. Basic Nuclear Physics (3 h)

Radioactive decay processes and emission of different types of Radiations (α, β, positron, γ, n) and their characteristics (Range, penetration power etc.). Interactions of radiations with matter. Radiation detectors suitable for use in a medical cyclotron facility.

2. Principle of Cyclotron Operation (6 h)

Principle of Cyclotron and charged particle accelerators, Applications of cyclotrons in medicine, Types of Cyclotrons: self-shielded and unshielded (in-bunker) and locally shielded.

Auxiliary equipment and their safety significance: vacuum pumps, RF-power, magnet power supply; cooling system, control software and programs used for medical cyclotron operation.

3. Planning for Medical Cyclotron Facility (6 h)

General features of Self-shielded, unshielded (bunker-design) and locally shielded cyclotron installations (site, typical floor plans, ventilation, etc.), shielding evaluation and shielding material; negative pressure gradient for control of spread of radioactivity, safety interlocks and emergency stop switches, interlocks for gamma and neutron radiations; steps to minimize neutron activation of various components, model layouts of various cyclotron facility.
Planning of associated facilities: Radio synthesis laboratory, labelling, dispensing, QC lab., packaging and dispatch area, storage of radioactive waste.

4. Production and Distribution of Radiopharmaceutical (4 h)

Targets used in medical cyclotrons (solid, liquid and gas); radioisotope produced and their characteristics, synthesis of some commonly used F-18, C-11, N-13 and O-15 labelled radiopharmaceuticals; Radiation safety considerations during synthesis, dispensing and QC; Use of Reference Standards, dose calibrators, Industry Standards for quality assurance, Maintenance.

Production of short-lived radioisotopes, transfer of radioactivity to radio-chemistry lab, storage of radioactive material.
Requirements for transport of radioactive material in liquid form**:** preparation, marking, labelling of packages, preparation of transport documents (Consignor's Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general safety instructions.

5. Operational Safety and Emergency Handling (6 h)

Performance check of radiation measuring and monitoring instruments, work place and environmental (stack) monitoring, Permissible radiation limits for controlled and supervised area, Contamination limits, Radiation protection survey and contamination checks, Air-borne contamination, estimation of gases effluent discharge, dose apportionment and dose budgeting.
Radiological safety aspects during maintenance
Unusual occurrences and its handling procedures: Failure of cooling system, target foil ruptured, spillage, power failure, excessive exposure, personnel contamination; Protective and Emergency equipment requirements in medical cyclotron facility.

6. Regulatory Aspects for Cyclotron Facility (4 h)

Regulatory requirement for setting up medical Cyclotron facility, personnel requirement, Responsibilities of employer, licensee, RSO, operator, radio-pharmacist, radio nuclide supplier.
Familiarization with regulatory requirements for end user: Procurement, transport, use and storage of radiopharmaceutical and disposal.

7. Radioactive Waste Generation and its Management (3 h)

Nature and composition of radioactive waste generated: Solid, Liquid & Gaseous (waste gas compression system), management of minor & major spills/contamination; management of ruptured target (haver) foil, neutron activated products.
Radioactive waste management; Good practices of waste minimization, segregation, collection, storage & disposal.

8. Decommissioning of Medical Cyclotron Facility (2 h)

Concept of decommissioning, procedures – planning & execution, radioactive wastes arising during decommissioning and procedures of its safe management, role of supplier/manufacturer in decommissioning of the MCF, regulatory requirements.

****

ANNEXURE- 5B

SYLLABUS FOR 'BASIC RADIATION SAFETY COURSE FOR RP-MC-2 AND RP-MC-3 OF MEDICAL CYCLOTRON FACILITY

The RSO of medical cyclotron facility should give training to operator and Radio-pharmacist on following topics

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, bound and free electrons, binding energy, ionization, excitation, stability of nucleus, isotopes, radioisotopes, types of radioactive disintegration, directly and indirectly ionizing radiations, radioactivity, X-rays and gamma rays, energy of ionizing radiation, half-life

Interaction of Radiation with matter (photoelectric, Compton and pair production), Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

Principle of radiation detection, introduction to gas detectors (ionization chamber, and GM counter) solid state detectors (scintillators, semiconductors and Thermo luminescent Dosimeter {TLD}), radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, direct reading dosimeter (DRD).

2. Biological Effects and Operational Units

Introduction to radiation quantities such as Activity (Becquerel & Curie), energy, exposure(C/kg &Roentgen), air kerma, absorbed dose (Gray & rad), radiation weighting factors(W_R), tissue weighting factors(W_T), equivalent dose (Sievert & rem), effective dose (sievert & rem).

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, tissue reactions (deterministic) and stochastic (probabilistic) effects, effects of partial and whole body exposures.

3. Radiation Protection and Operational Safety Aspects in Medical Cyclotron

External hazard and their perspective, evaluation and control of hazard due to external radiation: individual and workplace monitoring, application of time, distance and shielding; Permissible radiation limits for controlled and supervised area, Contamination limits, Radiation protection survey and contamination checks, Air-borne contamination, estimation of gases effluent discharge ,Unusual occurrences and its handling procedures: Failure of cooling system, target foil rupture, spillage, power failure, excessive exposure, personnel contamination; Protective and Emergency equipment requirements in medical cyclotron facility.

4. Production and Distribution of Radiopharmaceutical

Targets used in medical cyclotrons (solid, liquid and gas); radioisotope produced and their characteristics, synthesis of some commonly used F-18, C-11, N-13 and O-15 labelled radiopharmaceuticals; Radiation safety considerations during synthesis, dispensing and QC;

Production of short-lived radioisotopes, transfer of radioactivity to radio-chemistry lab, storage of radioactive material.

Requirements for transport of radioactive material in liquid form**:** preparation, marking, labelling of packages, preparation of transport documents (Consignor's Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general safety instructions.

5. Radioactive Waste Generation and its Management

Nature and composition of radioactive waste generated: Solid, Liquid & Gaseous (waste gas compression system), management of minor & major spills/contamination; management of ruptured target foil, neutron activated products.
Radioactive waste management; Good practices of waste minimization, segregation, collection, storage & disposal.

****

ANNEXURE- 6: RADIATION SAFETY CERTIFICATION FOR PERSONNEL IN RADIATION PROCESSING FACILITIES

ANNEXURE- 6A

RADIATION SAFETY CERTIFICATION FOR RSO IN RADIATION PROCESSING FACILITY (GAMMA AND ELECTRON BEAM)

Duration: **12 weeks**
{150 h Theory and Practical + 75 h Field Training}

Examination:

The examination should consist of;

(i) Three written paper of 100 marks each (Three papers of total 300 marks), (80 marks descriptive including short answers + 20 marks objective)
(ii) Practical of 50 marks
(iii) Viva-voce of 50 marks

Passing Criteria:

(i) Not less than 50% each in written, practical and viva-voce examinations
(ii) Not less than 60% in aggregate.

Course Content:

Paper 1: Radiation Physics, Radiobiology and Radiation Measurement (38 h)

A.1	Lectures	Duration
1.1	Basic Radiation Physics	4 h
1.2	Interaction of Radiation with Matter	4 h
1.3	Radiation Quantities and Units	2 h
1.4	Radiation Biology and Biological Effects	8 h
1.5	Operational Limits	2 h
1.6	Radiation Detection and Measurement	6 h
1.7	Radiation Hazard Evaluation and Control	6 h
1.8	Radiation Protection Standards	2 h
1.9	Radiation Sources/Generators and their Properties	4 h

Paper 2: Design Features, Radiation Safety and Regulatory Aspects of Radiation Processing Facility (34 h)

A.2	Lectures	Duration
2.1	Overview of Industrial Applications of Radiation	3 h
2.2	Design Details of Irradiator Sources	1 h
2.3	Overview of Radiation Processing Facilities	1 h
2.4	Design Safety Features of Gamma Irradiators	5 h
2.5	Design Safety Features of Electron Beam Facilities	3 h
2.6	Planning of Radiation Processing Facilities	3 h
2.7	Regulatory Aspects of Radiation Processing Facilities	3 h
2.8	Security of Radioactive Sources	2 h

2.9	Transport of Radioactive Material	2 h
2.10	Disposal of Radioactive Waste	2 h
2.11	Quality, Health, Safety and Environment (QHSE)	1 h
2.12	Management of Radiation Processing Facility	2 h
2.13	Radiation Accidents, Case Studies and Lessons Learned	3 h
2.14	Emergency Response Plans and Preparedness	2 h
2.15	Medical Management of Radiation Accidents	1 h

Paper 3: Radiation Dosimetry, Process Control and Radiation Processing Technology **(24 h)**

A.3 Lectures **Duration**

3.1	Radiation Dosimetry	**8 h**
	3.1.1 Radiation Dosimetry - An overview	(2 h)
	3.1.2 Film Dosimeters	(2 h)
	3.1.3 Chemical Dosimeters	(2 h)
	3.1.4 Dose Inter-comparison and Validation	(2 h)
3.2	Radiation Processing Technology	**5 h**
	3.2.1 Radiation Processing of Food –An Overview	(2 h)
	3.2.2 QA in Food Processing for Extension of Shelf-life :Food Quality Parameters	(3 h)
3.3	Radiation Processing of Food Products	**4 h**
	3.3.1 Bulbs & tubers, Fruits and Vegetables	
	3.3.2 Cereals and Legumes	
	3.3.3 Radiation Processing of Fleshy Foods (Fish, Meat and Chicken)	
3.4	Detection of Radiation Processed Food	**1 h**
3.5	QA Programme in Commercial Irradiation Facility (Personnel and Products Safety)	**1 h**
3.6	Other Applications of Radiation Processing Technology	**3 h**
3.7	Food Irradiation Regulations (Codes, Standards, Guides)	**2 h**

B. Discussions : (10 h)

C. Practical : 36 h (3h each)

1. Introduction to radiation monitoring instruments– Area & Personnel
2. Characteristics of GM counter
3. Inverse square law & attenuation of gamma rays
4. Absorption and back scattering of gamma rays-Determination of HVT & TVT
5. Statistics of counting and activity measurement
6. Gamma ray spectrometry with germanium detector using multi-channel analyzer
7. Output measurement in a gamma irradiation chamber using Fricke dosimeter
8. Calibration of survey instruments and pocket dosimeter
9. Calibration of gamma ray spectrometer and identification of unknown sources
10. Survey and evaluation of a radiation processing facility
11. Dose distribution measurement in the product box(s)
12. Biological dosimetry.

D. Technical visit to associated facilities: (20 h)

Technical visits to Gamma and Electron beam radiation processing facilities.

E. FIELD TRAINING: (75 h)

Familiarization with radiation processing facility, design and operational aspects, control consol, source hoist mechanism, types of conveyor system and its design principle, familiarization of safety components and interlock systems, loading/unloading procedures of radiation sources, familiarization with handling tools for source transfer, radiation protection survey and evaluation of irradiator facility, DM Plant, contamination checking of water pool type and dry storage irradiators; pH, conductivity and temperature measurements, requirement of ventilation systems, ozone measurement, dosimetry of irradiated products, process control, understanding the emergency situation and its handling, Good Manufacturing Practices (GMP) and Good Irradiation Practices (GIP), Operation & Maintenance of radiation processing facility.

Syllabus:

Paper 1: Radiation Physics, Radiobiology and Radiation Measurement

1.1 Basic Radiation Physics

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, electron capture, characteristics and properties of alpha, beta and gamma radiations; laws of radioactivity & successive transformations, natural and artificial radioactivity, radioactive equilibrium, radioactive decay, decay constant, decay chain of radioisotopes, half-life, mean life, nuclear cross section, X-rays (Characteristic and Bremsstrahlung), neutron sources.

1.2 Interaction of Radiation with Matter

Interaction of charge particles with matter (alpha and beta), Range-Energy relationship, mechanism of energy loss, ionization and excitation, bremsstrahlung and Cerenkov radiation, interaction of uncharged particles, (Gamma and X-ray) interaction mechanism (photoelectric effect, Compton scattering, pair production), absorption and scattering coefficients, exponential absorption, interaction of neutron with matter, neutron activation, nuclear cross sections.

1.3 Radiation Quantities and Units

Particle flux and fluence, energy flux and fluence, cross section, linear and mass absorption coefficient, stopping power and LET, w-value, charge particle equilibrium (CPE), electronic equilibrium, activity, energy, exposure, rate constant, air kerma, absorbed dose, relative biological effectiveness (RBE), radiation weighting factors (W_R), tissue weighting factors (W_T), equivalent dose, effective dose, ambient and directional dose equivalent and their relevance to dosimetry, personnel dose equivalent, tissue equivalence, commitment doe and collective effective dose.

1.4 Radiation Biology and Biological Effects

Organization of cell structure and functions, indirect interactions, tissues, organs, systems and organization of human body, hematopoietic, digestive, respiratory, skeletal, nervous, endocrine and urinary systems; sensory perception.

Mechanism of cellular level damages by radiation, cell killing and mutation induction, target theory and linear quadratic models of cell survival, modifying factors of radiation damage, classification of radiation damage, radiation carcinogenesis, genetic effects,

dose and dose rate effect (DDREF), radiation damage and classification, cell division, basic genetics, direct and indirect interactions.

Stochastic effects: radiation carcinogenesis- latent period, sensitivity variation among different organs and tissues, age and sex, genetic effects of radiation, doubling dose, risk factor.

Deterministic effects, tissue reaction, acute radiation syndrome, damage to individual organs, LD 50/60, prenatal effects, management of tissue reaction, management of acute radiation injury, biological dosimetry.

1.5 Operational Limits

Introduction to natural background radiation, concept of occupational risk, philosophy of radiation protection, system of dose limitation, ALARA, dose limits to radiation workers and general public, AERB/ICRP recommendations.

1.6 Radiation Detection and Measurement

Principles of measurement of radiation and radioactivity, Gas filled detectors (ionization chambers, proportional counters, GM counters), solid state detector {scintillation detectors, TLD}, chemical detectors, photochromic emulsion (films), characteristics of organic and inorganic gas counters, dead time, resolving time, semiconductor devices and BF_3 counters for neutron detection, spectrometers, pulse height analysis of spectra.

Radiation monitoring instruments, personnel monitoring, pocket dosimeters using solid state devices, teletector, portable survey meter, gamma area/zone monitors, contamination monitors for alpha-beta and gamma radiation, scintillation monitors for X-and gamma radiation, neutron monitors, tissue equivalent survey meters-flux meters and dose equivalent monitors, calibration and maintenance of radiation monitors.

Thermoluminescent dosimetry (TLD): Process and properties, glow curves and dose response, photon energy dependence, fading, material form, Residual-TL and annealing procedure for reuse, repeated readouts of TLDs, TL instrumentation, personnel monitoring.

1.7 Radiation Hazard Evaluation and Control

Radiation hazard perception, internal and external hazard and their perspective, evaluation and control of hazard due to external radiation-Individual and workplace monitoring; application of time, distance and shielding, specific gamma ray constant, shielding calculations for beta, gamma and neutron radiation, choice of materials, primary and secondary radiations, source geometry and shielding requirements for industrial and research installations including accelerator installations, operational safety and radiation protection survey.

1.8 Radiation Protection Standards

Analysis of A-bomb survivor data- dose response for carcinogenesis, risk projection models- additive vs multiplicative models, evaluation of cancer risks. Radiobiological basis of ICRP recommendations, evolution of radiation standards, basis of dose limits, AERB's radiation protection standards.

1.9 Radiation Sources/Generators and their Properties

Production of beta and gamma sources by neutron and charge particle bombardment, nuclear cross section, growth of activity, specific activity, neutron sources, fission products, basic features of nuclear reactors used in isotope production, X-ray machines and electron linear accelerators.

Paper 2: Design Features, Radiation Safety and Regulatory Aspects of Radiation Processing Facility

2.1 Overview of Industrial Applications of Radiation

Application of ionizing radiations in industry, principles of industrial radiography with X-ray and Gamma ray; radiography exposure devices, radiation hazard potential in industrial radiography, principles of nucleonic gauges, application of nucleonic gauges: level, density, thickness, composition gauges, well logging, XRF gauges; radiation hazard potential in nucleonic gauge applications, principles of operation of consumer products using radiation sources: smoke detectors, baggage inspection systems, static charge eliminators, luminous dial paints and gas mantles.

2.2 Design Details of Irradiator Sources

Details of source assembly, national/international sealed source design standards, types of encapsulation, method of preparation of sources, prototype type tests, acceptance criteria, leak test methods, sealed source classification.

2.3 Overview of Radiation Processing Facilities

Radionuclide sources and machine sources, applications of irradiation, gamma irradiators: Self-contained and panoramic irradiator; throughput, dose uniformity ratio (DUR), dose control parameters, mode of operation of irradiator: batch mode, continuous mode, pallet irradiator; optimization of throughput and DUR, source overlap and product overlap geometry, split source and mobile shield design, electron beam accelerators, types of accelerators: low, medium and high energy.

2.4 Design Safety Features of Gamma Irradiators

Type of irradiation facilities, Category of irradiators (Dry and wet storage irradiators), radiological safety objectives and safety philosophy in design i.e. concept of defence-in-depth applied to the design process; national/international design standards, design features and requirements; source storage (dry/wet) and source frame, radiation cell shielding, integrity of dry shielding, designing of water pool, access to radiation source and interlock, personnel access door, integrity test, source hoist mechanism, product handling system, transport, loading and unloading of sources; source guard, removable shielding plugs, individual and work place monitoring, DM plant, water level and contamination monitoring; pH and conductivity and temperature monitoring, , noxious gas production, ventilation system, periodic servicing and maintenance of safety systems/components; maintenance of safety records.

2.5 Design Safety Features of Electron Beam Facilities

Classification of EB accelerators, categories of EB accelerators, depth dose, principle of electron beam and photon accelerator and types of accelerators, philosophy of radiation protection and safety, safety interlocks, operational procedures, safety consideration in the design of electron beam accelerators: national/international design standards, shielding, operating parameters, accelerator hazards: electrical safety, magnetic safety, RF and microwave safety, SF6 gas safety; ventilation requirement, preventive maintenance, product conveyor system for EB accelerator, accelerators for application in industrial processing, merits and demerits of machine source applications.

2.6 Planning of Radiation Processing Facilities

Planning of gamma irradiator and electron beam irradiation facilities, site selection, area requirement, shielding calculation parameters- workload (W), primary and secondary protective barriers, use factor (U), occupancy factor (T); effects of scattering, albedo, skyshine, noxious gas production, ventilation requirements, shielding requirements for transport and storage containers for high activity sources.

Safety consideration in the planning of electron/X-ray accelerator facilities, shielding, production of bremsstrahuling radiation and neutron production, non- radiation hazards and control, safety and security measures.

2.7 Regulatory Aspects of Radiation Processing Facilities

National regulations, regulatory framework, regulatory aspects of new and operating radiation processing plants, relevant regulatory documents such as Act, Rules, Codes, standards, Guides, Food Irradiation Rules, licensing requirements, approval of Radiation Generating devices, consenting process: siting, design, construction, commissioning, operation and decommissioning of radiation processing facilities and disposal of radiation sources, regulatory requirements for import/export, procurement, use, handling, transfer and disposal of radioisotopes, inventory control, responsibilities of operating organization and certified personnel, transport regulations, waste disposal rules, Radiation Protection Programme (RPP).

2.8 Security of Radioactive Sources

Physical protection of sources, safety and security of sources during storage, use, transport and disposal, security principles, security culture, security functions, categorization of radiation sources, security levels and security objectives, security threat and vulnerability assessment, security provisions: administrative and technical measures, graded approach in security provision, physical protection system.

2.9 Transport of Radioactive Material

Regulatory aspects of transport of radioactive material, introduction, terms used {e.g. Competent Authority, A1&A2 values, unilateral & multilateral approval, special form radioactive material, special arrangement, transport index (TI) etc.}, transport scenarios (routine, normal & accident), variety of packages covered under the transport regulations, general requirement of all packaging, requirements for transport by air mode, test requirements, preparation, marking, labelling of packages, preparation of transport documents (Consignors Declaration, TREM Card, Instructions to the Carrier

& Emergency in Writing), general instructions and response to off-normal situations during transport.

2.10 Disposal of Radioactive Waste

Regulatory aspects of Radioactive waste disposal, sources of radioactive waste, classification of waste, treatment techniques for solid, liquid and gaseous effluents, permissible limits for disposal of waste, sampling techniques for air, water and solid media; geological, hydrological, meteorological and ecological considerations for waste disposal. Disposal of radioactive wastes, general methods of disposal, management of radioactive waste in industrial, agricultural and research facilities.

2.11 Quality, Health, Safety and Environment (QHSE)

Familiarization with Quality, Health, Safety and Environment (QHSE) policies including organizational responsibility, safety culture, setting safe working environment, quality management system (QMS), awareness, training, implementation, compliance, inspections & audits, corrective actions.

2.12 Management of Radiation Processing Facility

Introduction, good manufacturing practices (GMP), {Primary production and/or harvesting}, good irradiation practices (GIP) packaging, handling, storage and transport, operational management (Manpower management and training, standard operating procedures, preventive maintenance and scheduling, plant and personnel safety, liaison with licensing authorities, customer relation and feedback, health of workers, recordkeeping and emergency preparedness.

2.13 Radiation Accidents, Case Studies and Lessons Learned

Accidents with fatal consequences and severe radiation injuries, major causes of accidents, fire, explosion, prevention and remedial measures, abnormal events, overexposure cases, case studies and lessons learned from abnormal events & accidents in industrial irradiators.

2.14 Emergency Response Plans and Preparedness

Basis for emergency response planning, normal and potential exposure, orphan and vulnerable sources, accident situations involving radioisotopes, elements of emergency planning and preparedness including procedures for notification and line of communication, administrative and technical procedures, emergency response accessories, emergency handling, graded approach, radiation hazard assessment due to different emergencies, emergency scenarios and potential exposures, remedial actions, written emergency procedures, identification and list of authorities to be contacted, communication links and incident reporting system, responsibilities of employer, licensee, RSO, operators and manufacturer and designer of facility, source supplier in case of emergency.

2.15 Medical Management of Radiation Accidents

Radiation injuries in high intensity irradiators (Dose vs. Symptoms), healing of wounds and post care of radiation injuries, grafting etc., case studies and lessons learned. Radiation injuries and their medical management.

Paper 3: Radiation Dosimetry, Process Control and Radiation Processing Technology

3.1 Radiation Dosimetry

3.1.1 Radiation Dosimetry - An overview

Importance of dosimetry in radiation processing, types of dosimeters: physical and chemical dosimeters, measurement of exposure and absorbed dose, Bragg-Gray principle and ionization, X- and gamma ray dosimetry, electron beam dosimetry, dose distribution in process load- its measurement and significance.

3.1.2 Film Dosimeters

Types of film dosimeters, principles, dose range, readout systems, mechanism,

ASTM practice number (if any)

3.1.3 Chemical Dosimeters

Types of chemical dosimeters, principles, dose range, readout systems, mechanism, ASTM practice number (if any)

3.1.4 Dose Inter-comparison and Validation

Intercomparison procedures with standards laboratory with respect to irradiation conditions, process geometry, number of passes to achieve desirable absorbed dose, D_{max}, D_{min} and DUR.

For electron beam irradiation- verification of operating parameters, e.g. electron energy, beam current, conveyor speed, scan width, etc.

3.2 Radiation Processing Technology

3.2.1 Radiation Processing of Food –An Overview

Current status, marketing, economics, regulations and consumer issues

3.2.2 QA in Food Processing for Extension of Shelf-Life: Food Quality Parameters

(i) Microbiological Quality

Source of contamination, factors affecting quality of food, effect of ionizing radiation on microorganism, radiation sensitivity of microorganisms (intrinsic and extrinsic factor), radurization, radicidation, radappertiazation (sterilization by radiation), good manufacturing practice (GMP), good irradiation practice (GIP).

(ii) Nutritional Aspects of Radiation Processed Food

Effect on macronutrients like carbohydrates, proteins and lipids, effects on

micronutrients like vitamins.

(iii) Safety, Security and Wholesomeness of Radiation Processed Food
Microbiological safety, safety of chemical changes, nutritional adequacy, animal feeding studies, human trials, technological benefits and advantages of radiation processing, absence of residual activity.

(iv) Labelling, Packaging and Transport of Irradiated Food
Types of packages, labelling of radiation processed products (radura), environmental conditions of transport and storage.

3.3 Radiation Processing of Food Products

3.3.1 Bulbs & tubers, Fruits and Vegetables

Purpose of irradiation, general properties of fruits and vegetables, chemical composition, shelf- life parameters and deterioration, ripening of climacteric and non-climacteric fruits, delayed ripening, sprout inhibition, disinfestations for quarantine purpose, radiation processing of minimally processed fruits and vegetables, effect of radiation on sensory and nutritional quality of fruits.

3.3.2 Cereals and Legumes

Factors affecting quality of cereals and legumes, different methods of control of insects, effect of radiation on insect, extension of shelf life of cereals and legumes.

3.3.3 Radiation Processing of Fleshy Foods (Fish, Meat and Chicken)

Factors affecting the quality of fleshy food (fish, meat and chicken), current conventional practices for processing and preservation of fleshy food (e.g. low temperature, drying), purpose of radiation processing of fleshy food for preservation, extension of shelf life, elimination of pathogens and parasites, radiation processing methods for extension of shelf life/preservation of fish and fishery products like radurization, radicidation, radiation disinfestations, radiation processing of meat for preparation of shelf stable products, hygienisation of fresh meat and meat products and intermediate moisture meat products.

3.4 Detection of Radiation Processed Food

Requirement of the method for the detection of irradiated and processed food, criteria to evolve a standard technique, present status, physical methods (ESR, Luminescence (TL/OSL/PSL), chemical methods {induced hydrocarbons, detection of 2-Alkyl cyclobutanones}, biological method based on microbial load, mechanism of detection methods, applicability of detection methods to different food products.

3.5 QA Programme in Commercial Irradiation Facility (Personnel and Product Safety)

Assessment of the probabilistic hazards in the normal operation of irradiation facility, Quality assurance (QA) programme, personnel safety, parameters under consideration, codes and protocols on: irradiation cell integrity, QA programme for safety interlocks,

storage of pool water, radiation monitoring instruments and mechanical, electrical, pneumatic and hydraulic system.

QA programme for product safety: Plant commissioning dosimetry, calibration and traceability studies, dose mapping and absorbed dose in the product.

3.6 Other Applications of Radiation Processing Technology

Principle and applications of radiation processing, radiation processing for sterilization of medical products, non-food items (herbal and other medicinal products), rubber vulcanization, wood polymerization, cross linking, treatment of sewage sludge (waste water), dose limits for these applications, dosimeters used and quality assurance of end products.

3.7 Food Irradiation Regulations (Codes, Standards, Guides)

Current regulatory practices in food irradiators, food irradiation rules, licensing and national/ international food irradiation standards, codex standard, dosimetry studies, acceptance criteria, Competent Authority for food irradiation, certificate of approval, licence for radiation processing of food.

****

ANNEXURE- 6B

RADIATION SAFETY CERTIFICATION FOR RP-RPF-1 IN RADIATION PROCESSING FACILITY

(Gamma and Electron)

Duration: Six Weeks
{Theory and Practical (100 h) + Field Training (50 h)}

Examination: The examination should consist of

(i) Three written paper of 100 marks each (Three papers of total 300 marks), (80 marks objective+ 20 marks descriptive including short answers)
(ii) Practical of 50 marks
(iii) Viva-voce of 50 marks.

Passing Criteria:

(i) Not less than 50% each in written, practical and viva-voce examinations
(ii) Not less than 60% in aggregate.

Course Content:

Paper 1: Radiation Physics, Radiobiology and Radiation Measurement (16 h)

A.1	Lectures:	Duration
1.1	Basic Radiation Physics	2 h
1.2	Interaction of Radiation with Matter	2 h
1.3	Radiation Quantities and Units	1 h
1.4	Radiation Biology and Biological Effects	2 h
1.5	Operational Limits	1 h
1.6	Radiation Detection and Measurement	2 h
1.7	Radiation Hazard Evaluation and Control	4 h
1.8	Radiation Sources/Generators and their Properties	2 h

Paper 2: Design Features, Radiation Safety and Regulatory Aspects of Radiation Processing Facility (18 h)

A.2	Lectures:	Duration
2.1	Overview of Radiation Processing Facilities	1 h
2.2	Design Details of Irradiator Sources	1 h
2.3	Design Safety Features of Radiation Processing Facilities	4 h
2.4	Design Safety Features of Electron Beam Facilities	2 h
2.5	Radiation Processing Facilities Planning of Radiation Processing Facilities	1 h
2.6	Regulatory Aspects for Radiation Processing Facilities	2 h
2.7	Security of Radioactive Sources	1 h
2.8	Transport of Radioactive Material and Disposal of Radioactive Waste	1 h
2.9	Management of Radiation Processing Facility	1 h
2.10	Radiation Accidents, Case Studies and Lessons Learned	2 h
2.11	Emergency Response Plans and Preparedness	1 h
2.12	Medical Management of Radiation Accidents	1 h

Paper 3: **Radiation Dosimetry, Process Control and Radiation Processing Technology** **(24 h)**

A.3	**Lectures:**		**Duration**
3.1	Radiation Dosimetry		**8 h**
	3.1.1 Radiation Dosimetry - An overview	(2 h)	
	3.1.2 Film Dosimeters	(2 h)	
	3.1.3 Chemical Dosimeters	(3 h)	
	3.1.4 Dose Inter-comparison and Validation	(1 h)	
3.2	Radiation Processing Technology		**5 h**
	3.2.1 Radiation Processing of Food –An Overview	(2 h)	
	3.2.1 QA in Food Processing for Extension of Shelf-life : Food Quality Parameters	(3 h)	
3.3	Radiation Processing of Food Products		**4 h**
	3.3.1 Bulbs & tubers, Fruits and Vegetables		
	3.3.2 Cereals and Legumes		
	3.3.3 Radiation Processing of Fleshy Foods (Fish, Meat and Chicken)		
3.4	Detection of Radiation Processed Food		**1 h**
3.5	QA Programme in Commercial Irradiation Facility (Personnel and Product Safety)		**1 h**
3.6	Other Applications of Radiation Processing Technology		**3 h**
3.7	Food Irradiation Regulations (Codes, Standards, Guides)		**2 h**

B. Discussions: 10 hours

C: Practical: 18 h (3 h each)

1. Absorption of gamma rays in matter and demonstration of inverse square law
2. Calibration of survey instruments and pocket dosimeters
3. Calibration of dosimeters
4. Quality Control (Microbiology, Chemistry and Sensory)
5. Chemical dosimetry and processing control
6. Dose distribution measurement in the product box(s)

D. Technical visit to Associated Plant(s): (9 h)

Technical visit to a gamma and electron beam radiation processing facility.

E. FIELD TRAINING: (50 h)

Familiarization with radiation processing facility, design and operational aspects, control consol, source hoist mechanism, types of conveyor system and its design principle, familiarization of safety components and interlock systems, loading/unloading procedures of radiation sources, familiarization with handling tools for source transfer, radiation protection survey and evaluation of irradiator facility, DM Plant, contamination checking of water pool type and dry storage irradiators, pH, conductivity and temperature measurements, requirement of ventilation systems and ozone measurement, dosimetry of irradiated products, process control, understanding the emergency situation and its handling, Good Manufacturing Practices (GMP) and Good Irradiation Practices (GIP), Operation & Maintenance of radiation processing facility.

Syllabus:

Paper 1: Radiation Physics, Radiobiology and Radiation Measurement

1.1 Basic Radiation Physics

Atomic structure, atomic number, mass number, radioisotopes, radioactivity, natural and artificial radioactivity, specific activity, electron capture, radioactive decay, decay constant, half-life, general properties of gamma radiation; gamma emission, X-rays (Characteristic and Bremsstrahlung), neutron sources.

1.2 Interaction of Radiation with Matter

Interaction of charge particles with matter, ionization and excitation, bremsstrahlung and Cerenkov radiation, interaction of uncharged particles, (Gamma and X-ray) interaction mechanism (photoelectric effect, Compton scattering, pair production), absorption and scattering coefficients, exponential absorption, neutron activation.

1.3 Radiation Quantities and Units

Activity, energy, exposure, linear and mass absorption coefficient, stopping power and LET, W-value, charge particle equilibrium (CPE), air kerma, absorbed dose, relative biological effectiveness (RBE), radiation weighting factors (W_R), tissue weighting factors (W_T), equivalent dose, effective dose, ambient and directional dose equivalent and their relevance to dosimetry.

1.4 Radiation Biology and Biological Effects

Organization of cell structure and functions, effect of radiation on living cells, induction of mutation, carcinogenesis, genetic effects, dose and dose rate effect (DDREF), Stochastic effects: radiation carcinogenesis- latent period, sensitivity variation among different organs and tissues, age and sex, genetic effects of radiation.

Tissue reaction (Deterministic effects), acute radiation syndrome, damage to individual organs, $LD_{50/60}$, prenatal effects, biological dosimetry.

1.5 Operational Limits

Introduction to natural background radiation, concept of occupational risk, philosophy of radiation protection, system of dose limitation, ALARA, dose limits to radiation workers and general public, AERB/ICRP recommendations.

1.6 Radiation Detection and Measurement

Principle of radiation detection, gas filled detectors (ionization chamber, GM detector, proportional counter), solid state and scintillators, semiconductors detectors, thermoluminescent Dosimeter {TLD}), chemical detectors, photochromic emulsion (films), BF_3 counters for neutron detection, workplace monitoring, individual monitoring, type of workplace monitoring (survey meters, zone monitors, teletector, contamination monitors etc.), personnel monitoring, direct reading dosimeter(DRD), TLD badges, calibration and response of radiation monitoring instruments.

1.7 Radiation Hazard Evaluation and Control

Radiation hazard perception, internal and external hazard and their perspective, evaluation and control of hazard due to external radiation-Individual and workplace monitoring; application of time, distance and shielding; specific gamma ray constant, , primary and secondary radiations, shielding requirements for industrial and research installations including accelerator installations, shielding material, operational safety and radiation protection survey.

1.8 Radiation Sources/Generators and their Properties

Production of beta and gamma sources by neutron and charge particle bombardment, nuclear cross section, growth of activity, specific activity, neutron sources, fission products, basic features of nuclear reactors used in isotope production, X-ray machines and electron linear accelerators.

Paper 2: Design Features, Radiation Safety and Regulatory Aspects of Radiation Processing Facility

2.1 Overview of Radiation Processing Facilities

Radionuclide sources and machine sources, applications of irradiation, gamma irradiators: Self -contained and panoramic irradiator; throughput, dose uniformity ratio (DUR), dose control parameters, mode of operation of irradiator: batch mode, continuous mode, pallet irradiator; optimization of throughput and DUR, source overlap and product overlap geometry, split source and mobile shield design, electron beam accelerators, types of accelerators: low, medium and high energy.

2.2 Design Details of Irradiator Sources

Details of source assembly, national/international sealed source design standards, sealed source classification, types of encapsulation, method of preparation of sources, prototype type tests, acceptance criteria, leak test methods.

2.3 Design Safety Features of Radiation Processing Facilities

Type of irradiation facilities, Category of irradiators (Dry and wet storage irradiators), radiological safety objectives and safety philosophy in design i.e. concept of defence-in-depth applied to the design process; national/international design standards, design features and requirements; source storage (dry/wet) and source frame, radiation cell shielding, integrity of dry shielding, designing of water pool, access to radiation source and interlock, personnel access door, integrity test, source hoist mechanism, product handling system, transport, loading and unloading of sources; source guard, removable shielding plugs, individual and work place monitoring, DM plant, water level and contamination monitoring; pH and conductivity and temperature monitoring, noxious gas production, ventilation system, periodic servicing and maintenance of safety systems/components; maintenance of safety records.

2.4 Design Safety Features of Electron Beam Facilities

Classification of EB accelerators, categories of EB accelerators, depth dose, principle of electron beam and photon accelerator and types of accelerators, accelerator hazards: electrical safety, magnetic safety, RF and microwave safety, SF6 gas safety; ventilation requirement, preventive maintenance, product conveyor system for EB accelerator, accelerators for application in industrial processing, merits and demerits of machine source applications.

2.5 Planning of Radiation Processing Facilities

Planning of gamma irradiator and electron beam irradiation facilities, site selection, area requirement, familiarizations with workload (W), primary and secondary protective barriers, use factor (U), occupancy factor (T); effects of scattering, noxious gas production, ventilation requirements.

Safety consideration in the planning of electron/X-ray accelerator facilities, shielding material, production of bremsstrahuling radiation and neutron production, non-radiation hazards and control.

2.6 Regulatory Aspects for Radiation Processing Facilities

National regulations, regulatory framework, regulatory aspects of new and operating radiation processing facilities, relevant safety documents such as Act, Rules, Codes, standards, Guides, licensing requirements, approval of Radiation Generating devices, consenting process of radiation processing facilities, responsibilities of certified personnel, Radiation Protection Programme (RPP).

2.7 Security of Radioactive Sources

Physical protection of sources, safety and security of sources during storage, use, transport and disposal, security functions, categorization of radiation sources, security threat, security measures (administrative and technical), graded approach in security provision, physical protection system.

2.8 Transport of Radioactive Material and Disposal of Radioactive Waste

Regulatory aspects of transport of radioactive material, introduction, terms used {e.g. Competent Authority, A1 & A2 values, unilateral & multilateral approval, special form radioactive material, special arrangement, transport index (TI) etc.}, transport scenarios (routine, normal & accident), variety of packages covered under the transport regulations, general requirement of all packaging, preparation, marking, labelling of packages, preparation of transport documents (Consignors Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing).

2.9 Management of Radiation Processing Facility

Introduction, good manufacturing practices (GMP), (Primary production and/or harvesting), Good irradiation practice (GIP), packaging, handling, storage and transport, operational management (Manpower management and training, standard operating procedures, preventive maintenance and scheduling, plant and personnel safety, liaison with licensing authorities, customer relation and feedback, health of workers, recordkeeping and emergency preparedness.

2.10 Radiation Accidents, Case Studies and Lessons Learned

Accidents with fatal consequences and severe radiation injuries, major causes of accidents, fire, explosion, prevention and remedial measures, abnormal events, overexposure cases, case studies and lessons learned from abnormal events & accidents in industrial irradiators.

2.11 Emergency Response Plans and Preparedness

Basis for emergency response planning, normal and potential exposure, orphan and vulnerable sources, accident situations involving radioisotopes, elements of emergency planning and preparedness including procedures for notification and line of communication, emergency response accessories, graded approach, emergency scenarios and potential exposures, written emergency procedures, responsibilities of operators in case of emergency.

2.12 Medical Management of Radiation Accidents

Radiation injuries in high intensity irradiators (Dose vs. Symptoms), healing of wounds and post care of radiation injuries, grafting etc., case studies and lessons learned. Radiation injuries and their medical management

Paper 3: Radiation Dosimetry, Process Control and Radiation Processing Technology

3.1 Radiation Dosimetry

3.1.1 Radiation Dosimetry - An overview

Importance of dosimetry in radiation processing, types of dosimeters: physical and chemical dosimeters, measurement of exposure and absorbed dose, Bragg-Gray principle and ionization, X- and gamma ray dosimetry, electron beam dosimetry, dose distribution in process load- its measurement and significance.

3.1.2 Film Dosimeters

Types of film dosimeters, principles, dose range, readout systems, mechanism, ASTM practice number

3.1.3 Chemical Dosimeters

Types of chemical dosimeters, principles, dose range, readout systems, mechanism, ASTM practice number

3.1.4 Dose Inter-comparison and Validation

Intercomparison procedures with standards laboratory with respect to irradiation conditions, process geometry, number of passes to achieve desirable absorbed dose, Dmax, Dmin and DUR.

For electron beam irradiation- verification of operating parameters, e.g. electron energy, beam current, conveyor speed, scan width etc.

3.2 Radiation Processing Technology

3.2.1 Radiation Processing of Food –An Overview

Current status, marketing, economics, regulations and consumer issues

3.2.2 QA in Food Processing for Extension of Shelf Life - Food Quality Parameters

(i) Microbiological Quality
Source of contamination, factors affecting quality of food, effect of ionzing radiation on microorganism, radiation sensitivity of microorganisms (intrinsic and extrinsic factors), radurization, radicidation, radappertization (sterilization by radiation), good manufacturing practices (GMP), good irradiation practices (GIP).

(ii) Nutritional Aspects of Radiation Processed Food

Effect on macro nutrients like carbohydrates, proteins and lipids, effects on micronutrients like vitamins.

(iii) Safety, Security and Wholesomeness of Radiation Processed Food

Microbiological safety, safety of chemical changes, nutritional adequacy, animal feeding studies, human trials, technological benefits and advantages of radiation processing, absence of residual activity.

(iv) Labelling, Packaging and transport of irradiated food

Types of packages, labelling of radiation processed products (radura), environmental conditions of transport and storage

3.3 Radiation Processing of Food Products

3.3.1 Bulbs & tubers, Fruits and Vegetables, Cereals and Legumes,

Factors affecting quality of cereals and legumes, different methods of control of insects, effect of radiation on insect, extension of shelf life of cereals and legumes.

3.3.3 Radiation Processing of Fleshy Foods (Fish, Meat and Chicken)

Factors affecting the quality of fleshy food (fish, meat and chicken), current conventional practices for processing and preservation of fleshy food (e.g. low temperature, drying), purpose of radiation processing of fleshy food for preservation, extension of shelf life, elimination of pathogens and parasites, radiation processing methods for extension of shelf life/preservation of fish and fishery products like radurization, radicidation, radiation disinfestations, radiation processing of meat for preparation of shelf stable products, hygienisation of fresh meat and meat products and intermediate moisture meat products.

3.4 Detection of Radiation Processed Food

Requirement of the method for the detection of radiation processed food, criteria to evolve a standard technique, present status, physical methods {ESR, Luminescence (TL/OSL/PSL)}, chemical methods {induced hydrocarbons, detection of 2-Alkyl cyclobutanones}, biological method based on microbial load, mechanism of detection methods, applicability of detection methods to different food products.

3.5 QA Programme in Commercial Irradiation Facility (Personnel and Product Safety)

Assessment of the probabilistic hazards in the normal operation of irradiation facility, Quality assurance (QA) programme, personnel safety, parameters under consideration, codes and protocols on: irradiation cell integrity, QA programme for safety interlocks, storage of pool water, radiation monitoring instruments and mechanical, electrical, pneumatic and hydraulic system.

QA programme for product safety: Plant commissioning dosimetry, calibration and traceability studies, dose mapping and absorbed dose in the product.

3.6 Other Applications of Radiation Processing Technology

Principle and applications of radiation processing, radiation processing for sterilization of medical products, non-food items (herbal and other medicinal products), rubber vulcanization, wood polymerization, cross linking, treatment of sewage sludge (waste water), dose limits for these applications, dosimeters used and quality assurance of end products.

3.7 Food Irradiation Regulations (Codes, Standards, Guide)

Current regulatory practices in food irradiators, food irradiation rules, licensing and national/international food irradiation standards, codex standard, dosimetry studies, acceptance criteria, competent authority for food irradiation, certificate of approval, licence for radiation processing of food.

****

ANNEXURE-7: RADIATION SAFETY CERTIFICATION FOR PERSONNEL IN INDUSTRIAL RADIOGRAPHY

ANNEXURE- 7A

RADIATION SAFETY SYLLABI FOR TRAINING COURSE FOR RP-IR-1 IN INDUSTRIAL RADIOGRAPHY

This course is divided in two parts consist of Radiation safety and Radiography techniques. This document is covering only radiation safety part. The training institutes are required to incorporate the radiation safety syllabus in the training module. The syllabus and Examination on Radiography Technique should be in accordance with applicable national / international standard in the course curriculum (ISO 9712, IS-13805 or equivalent). Unsuccessful candidate(s) may re-appear in subsequent course / examination.

Course Duration: 15 (Fifteen) working days

Examination:

The examination on Radiation Safety should consist of;

(i) Written paper on Radiation Safety (100 marks)
(ii) Practical Examination Radiation Safety including vive-voce (50 marks)

Passing Criteria:

(i) Not less than 50% in written and practical examinations
(ii) Not less than 60% in aggregate Or as per ISO 9712, IS-13805 or equivalent, as applicable

Course Content:

A.	**Lectures: (21 h)**	**Duration**
1.	Basic Radiation Physics	1 h
2.	Interaction of Radiation with Matter	1 h
3.	Radiation Quantities and Units	1 h
4.	Biological Effects of Radiation	2 h
5.	Operational Limits	1 h
6.	Radiation Detection and Measurement	1 h
7.	Radiation Hazard Evaluation and Control	5 h
8.	Design Safety Aspects of Radiography Device/Equipment	2 h
9.	Operational Safety Aspects in Radiography Practice	1 h
10.	Transport of Radioactive Material	1 h
11.	Radiation Accidents, Case Studies and Lessons Learned	2 h

12. Regulatory Aspects of Industrial Radiography 1 h
13. Security of Radioactive Sources 1 h
14. Emergency Response Plans and Preparedness 1 h

B. Practical / Demonstration: (12 h)

1. Verification of inverse square Law, determination of the activity of a given source and performance check of radiation survey meter (2 h)
2. Evaluation of HVT/TVT of the gamma radiation source (2 h)
3. Assessment of the shielding adequacy of a radiography device (2 h)
4. Functional performance test for industrial radiography devices (2 h)
5. Demonstration on Radiological safety aspects in operation of radiography exposure device (2 h)
6. Demonstration on handling of radiological emergency (1 h)
7. Demonstration on Radiation safety aspects in open field radiography (1 h)

Syllabus:

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, types of radioactive disintegrations, electron capture, characteristics of alpha, beta and gamma rays; energy of ionizing radiation, half-life, production of radioisotopes and X-rays (Characteristic and Bremsstrahlung), accelerators, neutron sources.

2. Interaction of Radiation with Matter

Interaction of charged particles with matter, bremsstrahlung, range of charged particles, interaction of photon with matter (photoelectric effect, Compton scattering and pair production), absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

3. Radiation Quantities and Units

Activity (Becquerel & Curie), energy, exposure (C/kg & Roentgen), air kerma, absorbed dose (Gray & rad), radiation weighting factors (W_R), tissue weighting factors (W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

4. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effects of radiation on living cells, chromosomal aberration, somatic and genetic effects, stochastic (probabilistic) effects, tissue reactions (deterministic effects), effects of partial body and whole body exposures, threshold doses, biological dosimetry, medical management of radiation injury.

5. Operational Limits

Introduction to natural background radiation, concept of risk, philosophy of radiation protection, system of dose limitation, ALARA, AERB/ ICRP recommendation on dose limits to radiation workers and general public.

6. Radiation Detection and Measurement

Principle of radiation detection, gas filled detectors (ionization chamber, proportional counter and GM counter), scintillators, semiconductors and Thermoluminescent dosimeter (TLD)}, radiation monitoring instruments- personnel monitoring, survey meters, area/zone monitoring, direct reading dosimeter (DRD); calibration and response of radiation monitoring instruments with radiation level.

7. Radiation Hazard Evaluation and Control

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation: individual and workplace monitoring; application of time, distance and shielding; shielding material, exposure rate constant, types of radiography installations: enclosed, open top, open field; planning of radiography enclosures, controlled areas and supervised areas, concept of shielding for enclosed installations {primary protective barrier, secondary protective barrier}, work load (w), use factor (U), occupancy factor (T), scattering, Albedo, sky shine, safety in radiography installations: enclosed radiography, field radiography, calculation of cordon-off distance, search of lost source, source storage facilities, safe work practices, safety aspects of x-ray and high energy accelerators, radiation protection survey of radiography installation.

8. Design Safety Aspects of Radiography Device/ Equipment

Design objective, national/international design standards for sealed sources and radiography exposure devices, standard specifications for design and construction of exposure devices, performance classification of radiography equipment / exposure devices as per ISO 3999, quality assurance, safety interlocks, periodic maintenance procedures, marking, labeling and identification.

9. Operational Safety Aspects in Radiography Practice

Appropriate use of TLD, survey meter and DRD, temporary shielding, emergency handling accessories (CV tong, lead pot, cordoning rope, warning lights), radiation protection survey of radiography device, safe retrieval of sources.

10. Transport of Radioactive Material

Regulatory aspects of safe transport of radioactive material, introduction, terms used {e.g. Competent Authority, A1& A2 values, transport index (TI) etc.}, transport scenarios (routine, normal & accident), variety of packages covered under the transport regulations, general requirement of all packaging, preparation, marking, labelling of packages, preparation of transport documents (Consignor's Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general instructions.

11. Radiation Accidents, Case Studies and Lessons Learned

Radiation accidents involving industrial radiography exposure devices (IRED), orphan & vulnerable sources, causes of radiation accidents (stuck up and detachment of source pigtail, loss/theft of source/device, damage to source capsule/source housing, transport incident, accident due to fire and explosives, fall from height etc.), precautions to be taken

for avoiding accidents unsafe disposal of disused source, guidelines to handle radiation emergency situations, case studies and lessons learned.

12. Regulatory Aspects of Industrial Radiography

Regulations with respect to handling of industrial radiography exposure devices (IREDs), relevant regulatory documents such as Act, Rules, Codes, Standards and Guides, responsibilities of employer, licensee, RSO, radiation worker (radiographer); regulatory requirements for use, handling, transfer of IRED and safe disposal radioisotopes/radioactive material, inventory control.

13. Security Radioactive Sources

Physical protection of sources, safety and security of radiation sources during storage, use, transport and disposal, security culture, security functions, categorization of radiation sources, security levels and security objectives, security threat and vulnerability, security measures (administrative and technical).

14. Emergency Response Plans and Preparedness

Normal and potential exposure, potential accident situations involving IRED, emergency handling procedures including immediate actions for mitigation in case of various scenarios (loss, theft, damage, stuck-up, detachment etc.) accidental exposure, procedures for notification and communication, responsibilities of radiographer in case of emergency.

****

ANNEXURE- 7B

RADIATION SAFETY SYLLABI FOR CERTIFICATION OF RP-IR-2 IN INDUSTRIAL RADIOGRAPHY

This course is divided in two parts consist of Radiation safety and Radiography techniques. This document is covering only radiation safety part. The training institutes are required to incorporate the radiation safety syllabus in the training module. The syllabus and Examination on Radiography Technique should be in accordance with applicable national / international standard in the course curriculum (ISO 9712, IS-13805 or equivalent). Unsuccessful candidate(s) may re-appear in subsequent course / examination.

Course Duration: 22 (Twenty two) working days

Examination:

The examination on Radiation Safety should consist of;

(i) Written paper on Radiation Safety (100 marks)
(ii) Practical Examination on Radiation Safety including vive-voce (50 marks)

Passing Criteria:

(i) Not less than 70% in written and practical examinations

(ii) Not less than 80% in aggregate

Course Content:

A. Lectures: (23 h)	**Duration**
1. Basic Radiation Physics	1 h
2. Interaction of Radiation with Matter	1 h
3. Radiation Quantities and Units	1 h
4. Biological Effects of Radiation	3 h
5. Operational Limits	1 h
6. Radiation Detection and Measurement	1 h
7. Radiation Hazard Evaluation and Control	5 h
8. Design Safety Aspects of Radiography Device/Equipment	2 h
9. Operational Safety Aspects in Radiography Practice	2 h
10. Transport of Radioactive Material	1 h
11. Regulatory Aspects of Industrial Radiography	1 h
12. Security of Radioactive Sources	1 h
13. Radiation Accidents, Case Studies and Lessons Learned	2 h
14. Emergency Response Plans and Preparedness	1 h

B. Practical / Demonstration: (14 h)

1. Verification of inverse square Law, determination of the activity of a given source and performance check of radiation survey meter (2 h)

2. Evaluation of HVT/TVT of the gamma radiation source (2 h)
3. Assessment of the shielding adequacy of a radiography device (2 h)
4. Functional performance test for industrial radiography devices (2 h)
5. Demonstration on radiological safety aspects in operation of radiography exposure device (2 h)
6. Demonstration on radiation safety aspects in open field radiography (1 h)
7. Preparation of transport package of radiography exposure device (2 h)
8. Demonstration on handling of radiological emergency (1 h)

Syllabus:

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, types of radioactive disintegrations, electron capture, characteristics of alpha, beta and gamma rays; energy of ionizing radiation, half-life, production of radioisotopes and X-rays (Characteristic and Bremsstrahlung), accelerators, neutron sources.

2. Interaction of Radiation with Matter

Interaction of charged particles with matter, bremsstrahlung, range of charged particles, interaction of photon with matter (photoelectric effect, Compton scattering and pair production), absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT), interaction of neutrons with matter.

3. Radiation Quantities and Units

Activity (Becquerel & Curie), energy, exposure (C/kg & Roentgen), air kerma, absorbed dose (Gray & rad), radiation weighting factors (W_R), tissue weighting factors (W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

4. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effects of radiation on living cells, chromosomal aberration, somatic and genetic effects, stochastic (probabilistic) effects, tissue reactions (deterministic effects), effects of partial body and whole body exposures, threshold doses, biological dosimetry, medical management of radiation injury

5. Operational Limits

Introduction to natural background radiation, concept of risk, philosophy of radiation protection, system of dose limitation, ALARA, AERB/ ICRP recommendation on dose limits to radiation workers and general public.

6. Radiation Detection and Measurement

Principle of radiation detection, gas filled detectors (ionization chamber, proportional counter and GM counter), scintillators, semiconductors and Thermoluminescent dosimeter (TLD)}, radiation monitoring instruments, personnel monitoring, survey meters, area/zone monitoring, direct reading dosimeter (DRD); calibration and response of radiation monitoring instruments with radiation level.

7. Radiation Hazard Evaluation and Control

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation: individual and workplace monitoring; application of time, distance and shielding; shielding material, exposure rate constant, types of radiography installations: enclosed, open top, open field; planning of radiography enclosures, controlled areas and supervised areas, shielding calculation for enclosed installations {primary protective barrier, secondary protective barrier}, work load (w), use factor (U), occupancy factor (T), scattering, Albedo, sky shine, safety in radiography installations: enclosed radiography, field radiography, calculation of cordon-off distance, search of lost source, source storage facilities, safe work practices, safety aspects of x-ray and high energy accelerators, safety aspects of neutron radiography sources, radiation protection survey of radiography installation.

8. Design Safety Aspects of Radiography Device/ Equipment

Design objective, national/international design standards for sealed sources and radiography exposure devices, standard specifications for design and construction of exposure devices, acceptance criteria, performance classification of radiography equipment / exposure devices as per ISO 3999, leakage radiation measurement, prototype tests, safety interlocks, auxiliary shielding, periodic servicing/maintenance procedures, marking, labeling and identification, test requirements, administrative controls, quality assurance.

9. Operational Safety Aspects in Radiography Practice

Appropriate use of TLD, survey meter and DRD, temporary shielding, emergency handling accessories (CV tong, lead pot, cordoning rope, warning lights), radiation protection survey of radiography device, safe retrieval of sources.

10. Transport of Radioactive Material

Regulatory aspects of safe transport of radioactive material, introduction, terms used {e.g. Competent Authority, A1&A2 values, transport index (TI) etc.}, transport scenarios (routine, normal & accident), variety of packages covered under the transport regulations, general requirement of all packaging, preparation, marking, labelling of packages, preparation of transport documents (Consignor's Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general instructions.

11. Regulatory Aspects of Industrial Radiography

Regulations with respect to handling of industrial radiography exposure devices (IREDs), relevant regulatory documents such as Act, Rules, Codes, Standards and Guides, responsibilities of employer, licensee, RSO, radiation worker(radiographer) and manufacturer/ supplier of industrial radiography exposure devices (IREDs); regulatory requirements for import/export, procurement, use, handling, transfer IRED and safe disposal radioisotopes/radioactive material, inventory control, Radiation Protection Programme (RPP).

12. Security Radioactive Sources

Physical protection of sources, safety and security of radiation sources during storage, use, transport and disposal, security culture, security functions, categorization of radiation sources, security levels and security objectives, security threat and vulnerability assessment, security measures (administrative and technical), graded approach in security provision, guidelines for preparation of security plan, physical protection system.

13. Radiation Accidents, Case Studies and Lessons Learned

Radiation accidents involving industrial radiography exposure devices (IRED), orphan & vulnerable sources, causes of radiation accidents (stuck up and detachment of source pigtail, loss/theft of source/device, locating the lost sources, damage to source capsule/ source housing, transport incident, accident due to fire and explosives, fall from height etc.), precautions to be taken for avoiding accidents, unsafe disposal of disused source, guidelines to handle radiation emergency situations, case studies and lessons learned.

14. Emergency Response Plans and Preparedness

Normal and potential exposure, potential accident situations involving IRED, emergency handling procedures including immediate actions for mitigation in case of various scenarios (loss, theft, damage, stuck-up, detachment etc.), accidental exposure, procedures for notification and communication, administrative and technical procedures, responsibilities of employer, licensee, RSO, radiographer and manufacturer /supplier of IRED/sources in case of emergency.

****

ANNEXURE- 8: RADIATION SAFETY CERTIFICATION FOR RSO IN GAMMA/ X-RAY IRRADIATION CHAMBER

Course Duration: 7 (Seven) working days

Examination:

The examination should consist of;

(i) A written paper of 80 marks (60 marks Objective + 20 marks Descriptive)

(ii) Viva-voce of 20 marks.

Passing Criteria:

(i) Not less than 50% each in written and viva-voce examinations

(ii) Not less than 60% in aggregate.

Course Content:

A.	**Lectures (21 h)**	**Duration**
	Section I: Basic Radiation Safety	
1.	Basic Radiation Physics	1h
2.	Interaction of Radiation with Matter	1 h
3.	Radiation Quantities and Units	1 h
4.	Biological Effects of Radiation	1 h
5.	Operational Limits	1 h
6.	Radiation Detection and Measurement	2 h
7.	Radiation Hazard Evaluation and Control	2 h
	Section II: Practice Specific Radiation Safety and Regulatory Aspects	
8.	Design, Principle and Applications ofGamma/X-ray Irradiation Chamber	3 h
9.	Dosimetry and Calibration of Gamma/X-ray Irradiation Chamber	2 h
10.	Planning of Irradiation Chamber Installation	1 h
11.	Quality Assurance (QA) of Gamma/X-ray Irradiation Chamber	1 h
12.	Transport of Radioactive Material	1 h
13.	Regulatory Aspects of Gamma/X-ray Irradiation Chamber Facility	2 h
14.	Security of Radioactive Material	1 h
15.	Radiation Accidents, Emergency Response Plans & Preparedness	1h

B. Discussions & Revision: (1 h)

C. Demonstration: 6 h (2 h each)

1. Dose rate measurement in Gamma Irradiation Chamber
2. Radiation protection survey of Gamma Irradiation Chamber Facility
3. Familiarization with the safety features and related regulatory requirements of Irradiation Chamber Facility

D. Visit to GIC/XIC Facility: (6 h)

Syllabus:

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, types of radio-disintegrations, characteristics of alpha, beta and gamma rays, half-life, production of radioisotopes and X-rays (Characteristic and Bremstrahlung), neutron sources.

2. Interaction of Radiation with Matter

Interaction of charge particle with matter, bremstrahlung, range of charge particle, interaction of photons with matter (photoelectric, Compton scattering and pair production), absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT), shielding materials.

3. Radiation Quantities and Units

Activity (Becquerel and curie), energy, exposure (C/kg and Roentgen), air kerma, absorbed dose (Gray & rad), radiation weighting factors(W_R), tissue weighting factors (W_T), equivalent dose (Sievert & rem), effective dose(Sievert & rem).

4. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cell, chromosomal aberration, somatic and genetic effects, stochastic (probabilistic) and Tissue reactions (deterministic effects), effects of partial body and whole body exposures, threshold doses, biological dosimetry

5. Operational Limits

Introduction to natural background radiation, concept of risk, philosophy of radiation protection, system of dose limitation, ALARA, AERB/ ICRP recommendation on dose limits to radiation workers and general public.

6. Radiation Detection and Measurement

Principle of radiation detection, gas detectors (ionization chamber, GM detector), solid state detectors {scintillators, semiconductors and Thermoluminescent dosimeter (TLD)}, radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, direct reading dosimeter, calibration and response of radiation monitoring instruments.

7. Radiation Hazard Evaluation and Control

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation-Individual and workplace monitoring; application of time, distance and shielding; specific gamma ray constant, operational safety and radiation protection survey.

8. Design, Principle and Applications of Gamma/X-ray Irradiation Chamber

Design objective, types of irradiator and its principles of operation, national/international design safety standards for irradiation chamber (category-I irradiator/x-ray) and sealed source, acceptance criteria, prototype tests, leak and contamination testing, interlocks, shielding, servicing/maintenance procedures, administrative controls, quality assurance, applications in the field of medicine, industry, agriculture and research.

9. Dosimetry and Calibration of Gamma/ X-ray Irradiation Chamber

Importance of dosimetry, types and working principles of dosimeters-film, chemical, TLD and soild state dosimeters used for calibration and dosimetry, measurement of dose and dose rate at reference point, estimation of transit dose, dose mapping and dose profile measurement (central, radial and axial dose profile) of the sample compartment.

10. Planning of Irradiation Chamber Installation

General principles of planning of installation, site selection, area requirement, position of windows, openings and ventilation, shielding material, model layouts of installations.

11. Quality Assurance (QA) of Gamma/X-ray Irradiation Chamber

Need and necessity of QA, test parameters, procedures and frequency, transit dose, dose uniformity, radial and axial dose profiles, integrity test of radiation source (leakage and contamination).

12. Transport of Radioactive Material

Regulatory aspects of transport of radioactive material, introduction, terms used {e.g. Competent Authority, A1&A2 values, transport index (TI) etc.}, transport scenarios (routine, normal & accident), variety of packages covered under the transport regulations, (specific to Type B package), general requirement of all packaging, preparation, marking, labelling of packages, preparation of transport documents (Consignors Declaration, TREM Card, Instructions to the Carrier & Emergency handling procedures) and general instructions.

13. Regulatory Aspects of Gamma/X-ray Irradiation Chamber Facility

Regulations with respect to handling of GIC/X-ray, relevant regulatory documents such as Act, Rules, Codes, Standards and Guides, responsibilities of employer, licensee, radiation worker and Radiological Safety Officer (RSO), radioactive source/equipment supplier; regulatory requirements for import/export, procurement, use, handling, transfer, safe disposal of disused radioactive sources and inventory control, Radiation Protection Programme (RPP).

14. Security of Radioactive Material

Physical protection of sources, safety and security of radiation facility, security of radioactive sources during storage, use, transport and disposal, security principles, security culture, security functions, categorization of radiation sources, security levels and security objectives, security threat and vulnerability assessment, security provisions: administrative and technical measures, graded approach in security provision, physical protection system.

15. Radiation Accidents, Emergency Response Plans and Preparedness

Radiation accidents involving unit, orphan and vulnerable sources, handling of emergency situations resulting from damage to the source housing, stuck of sample drawer, breaking of wire rope, fire accidents and explosions, case studies and lessons learned.

Normal and potential exposure, elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical measures, responsibilities of employer, licensee, RSO, manufacturer /supplier in case of emergency.

ANNEXURE-9: RADIATION SAFETY CERTIFICATION FOR PERSONNEL IN NUCLEONIC GAUGES AND WELL-LOGGING

ANNEXURE -9A

Radiation Safety Certification for RSO in Nucleonic Gauges and Well-Logging

Course Duration: 6(Six) working days

Examination:
The examination on Radiation Safety should consist of;

(i) Written paper of 80 marks (60 marks objective + 20 marks descriptive)
(ii) Vive-voce of 20 marks

Passing Criteria:

(i) Not less than 50% in written and practical examinations
(ii) Not less than 60% in aggregate

Course Content:

A.	**Lectures (21 h)**	**Duration**
	Section I: Radiation Safety	
1.	Basic Radiation Physics	1 h
2.	Interaction of Radiation with Matter	1 h
3.	Radiation Quantities and Units	1 h
4.	Biological Effects of Radiation	1 h
5.	Operational Limits	1 h
6.	Radiation Detection and Measurement	3 h
7.	Radiation Hazard Evaluation and Control	3 h
	Section II: Practice Specific	
8.	Principle and Applications of IRGDs /NGs	3 h
9.	Principle and Applications of Well-logging	1 h
9.	Design Safety Standards of IRGDs/NGs and Well-logging Sources	1 h
10.	Transport of Radioactive Material	1 h
11.	Radiation Accidents, Case Studies and Lessons Learned	1 h
12.	Regulatory Aspects of IRGDs/NGs & Well-logging	1 h
13.	Security of Radiative Sources	1 h
14.	Emergency Response Plans and Preparedness	1 h

B. **Discussions :** (3 h)

C. **Practical / Demonstration:** (6 h)

1. Radiation absorption characteristics and HVT/ TVT measurements, performance check of radiation survey instruments — 2h
2. Radiation protection survey of IRGDs /NGs installations — 2 h

3. Familiarization with regulatory requirements of IRGD/NGs and radiation protection program (RPP) 2 h

Syllabus:

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, types of radioactive disintegrations, electron capture, characteristics of alpha, beta and gamma rays; energy of ionizing radiation, half-life, effective half-life, production of radioisotopes and X-rays (Characteristic and Bremsstrahlung),neutron sources.

2. Interaction of Radiation with Matter

Interaction of charged particles with matter, bremsstrahlung, range of charged particles, interaction of photon with matter (photoelectric, Compton scattering and pair production), absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT), interaction of neutrons with matter.

3. Radiation Quantities and Units

Activity (Becquerel & Curie), energy, exposure (C/kg & Roentgen), air kerma, absorbed dose (Gray & rad), radiation weighting factors (W_R), tissue weighting factors (W_T), equivalent dose (Sievert & rem) effective dose (Sievert & rem), concept of ambient and directional dose.

4. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effects of radiation on living cells, chromosomal aberration, somatic and genetic effects, stochastic (probabilistic) effects, tissue reactions (deterministic effects), effects of partial body and whole body exposures, threshold doses, biological dosimetry, medical management of radiation injury.

5. Operational Limits

Introduction to natural background radiation, concept of risk, philosophy of radiation protection, system of dose limitation, ALARA, AERB/ ICRP recommendation on dose limits to radiation workers and general public.

6. Radiation Detection and Measurement

Principle of radiation detection, gas filled detectors (ionization chamber, proportional counter and GM counter), scintillators and semiconductors, Thermoluminescent dosimeter (TLD), radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, direct reading dosimeter(DRD); calibration and response of radiation monitoring instruments with radiation level.

7. Radiation Hazard Evaluation and Control

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation, individual and workplace monitoring; application of time, distance and

shielding; shielding materials, design of source housing, operational safety aspects in handling of radioisotopes (including neutron source) and x-ray gauge and neutron generator, storage facility for sources, search of lost source/device, safe work practices, radiation protection survey of radiation installations.

8. Principle and Applications of IRGDs /NGs

Principles of ionising radiation gauging devices, criteria for sources and detectors selection, sensitivity and accuracy, radioisotope and X-ray gauges, principle of measurement: transmission and backscattering; α-gauges, beta gauges, bremsstrahlung gauges and gamma gauges and their applications: level, thickness, density, elemental composition etc; X-ray fluorescence (XRF) techniques, neutron scattering gauges.

9. Principle and Applications of Well-logging

Applications of radiation sources in well logging, measurement concept, principle of well logging, types of well logging sources, neutron generators, calibration of logging sources, source storage requirement, logging types. (nn, ng, logging)

9. Design Safety Standards of IRGDs /NGs and Well-logging Sources

Design objective, national/international design standard of IRGDs/NGs and sealed sources used in IRGDs/NGs and well-logging, performance classification of IRGDs/NGs and sealed sources, prototype tests, acceptance criteria, leakage radiation measurement, leak testing of sources, contamination checks, , marking, labeling and identification, consideration of ambient environmental conditions, safety interlocks, auxiliary shielding, periodic servicing/maintenance procedures, administrative controls, quality assurance.

10. Transport of Radioactive Material

Regulatory aspects of safe transport of radioactive material, introduction, terms used {e.g. Competent Authority, A1&A2 values, transport index (TI) etc.}, transport scenarios (routine, normal & accident), variety of packages covered under the transport regulations, general requirement of all packaging, preparation, marking, labelling of packages, preparation of transport documents (Consignor's Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general instructions.

11. Radiation Accidents, Case Studies and Lessons Learned

Radiation accidents involving IRGDs/NGs and well-logging sources, orphan and vulnerable sources, causes of radiation accidents (damage to the source housing, fall from height, missing/theft of IRGDs, unsafe disposal, accident due to fire and explosions) transport accident, case studies and lessons learned.

12. Regulatory Aspects of IRGDs /NGs and Well-logging

Regulations with respect to handling of IRGDs/NGs and well-logging, relevant regulatory documents such as Act, Rules, Code, Standard and Guides, responsibilities of employer, licensee, radiological Safety Officer (RSO) and manufacturer/supplier of IRGDs/NGs and well-logging sources; regulatory requirements for import/export, procurement, use, handling, transfer and safe disposal of IRGDs/NGs and well-logging sources, identification of disused gauges/sources, inventory control, Radiation Protection Program (RPP).

13. Security of Radioactive Sources

Physical protection of sources, safety and security of radiation sources during storage, use, transport and disposal, security culture, security functions, categorization of radiation sources, security levels and security objectives, security threat and vulnerability, security measures (administrative and technical), security plan, graded approach in security provision, physical protection system.

14. Emergency Response Plans and Preparedness

Normal and potential exposure, accident situations involving IRGDs/NGs and well-logging, emergency handling procedures including immediate actions for mitigation in case of various scenarios (loss, theft, damage, fire, stuck-up of logging sources etc.), accidental exposure, procedures for notification and communication, administrative and technical procedures, responsibilities of employer, licensee, RSO, radiation worker, and manufacturer /supplier in case of emergency.

****

ANNEXURE -9 B

SYLLABI FOR 'BASIC RADIATION SAFETY COURSE' FOR OPERATORS IN WELL LOGGING

RSO should train the operator on following basic radiation safety topics

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, characteristics of gamma rays and neutron; energy of ionizing radiation, half-life.

2. Interaction of Radiation with Matter

Interaction of gamma and neutron with matter, absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

3. Radiation Quantities and Units

Activity (Becquerel & Curie), energy, exposure (C/kg & Roentgen), absorbed dose (Gray & rad), radiation weighting factors (W_R), tissue weighting factors (W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

4. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effects of radiation on living cells, chromosomal aberration, somatic and genetic effects, stochastic (probabilistic), tissue reaction (deterministic effects) effects of , partial body and whole body exposures.

5. Operational Limits

Introduction to natural background radiation, concept of occupational risk, system of dose limitation, ALARA, AERB/ICRP recommendations dose limits to radiation workers and general public.

6. Radiation Detection and Measurement, Hazard Evaluation and Control

Radiation detection and measurement, TLD, radiation monitoring instruments, personnel monitoring, neutron monitoring, area monitoring, survey meters, direct reading dosimeter (DRD).

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation, application of time, distance and shielding; shielding materials for gamma and neutron, demonstration of safe work practice and radiation survey, storage facility for source.

7. Principle and Applications of Well-logging

Principles of well-logging, applications of sources in well logging, safety while handling well-logging sources in tool, storage requirement, design Safety Standards of well-logging sources.

8. Transport of Radioactive Material

Regulatory aspects of safe transport of radioactive material, transport index (TI), transport scenarios (routine, normal & accident), type of packages (Type A), general requirement of packaging, preparation, marking, labelling of packages, TREM Card, Emergency in Writing and general instructions.

9. Regulatory Aspects of Well-logging

Regulations with respect to handling well-logging sources, relevant regulatory documents such as Act, Rules etc., responsibilities of operator, regulatory requirements for handling of sources, transfer and safe disposal of well-logging sources, inventory control.

10. Security of Radioactive Sources

Physical protection of sources, categorization of sources, safety and security of radiation sources during storage, use, transport and disposal, security measures, graded approach to security, physical protection system.

11. Radiation Accidents, Emergency Response Plans and Preparedness

Radiation accidents involving well-logging sources, causes of incidents (missing/theft, unsafe disposal, fire accidents and explosions), case studies and lessons learned.

Emergency plan and preparedness including procedures for notification and communication, responsibilities of operator in case of emergency.

****

ANNEXURE-10: RADIATION SAFETY CERTIFICATION FOR PERSONNEL IN UNIVERSITY/ACADEMIC/RESEARCH INSTITUTION

ANNEXURE 10 A
RADIATION SAFETY CERTIFICATION FOR RSO FOR UNIVERSITY/ACADEMIC/RESEARCH INSTITUTION

Duration: 7 (Seven) working days

Examination:

The examination should consist of,

(i) A written paper of 80 marks (60 marks Objective + 20 marks Descriptive)

(ii) Viva-voce of 20 marks.

Passing Criteria:

(i) Not less than 50% each in written and viva-voce examinations

(ii) Not less than 60% in aggregate.

Course Content:

A.	**Lectures: (17 h)**	**Duration**
1.	Basic Radiation Physics	1 h
2.	Interaction of Radiation with Matter	1 h
3.	Radiation Quantities and Units	1 h
4.	Biological Effects of Radiation	1 h
5.	Operational Limits	1 h
6.	Radiation Detection and Measurement	1 h
7.	Radiation Hazard Evaluation and Control	2 h
8.	Application of Ionizing Radiation in Research and Academic Institution	2 h
9.	Planning of Radioisotope Laboratories	1 h
10.	Production of Radioisotopes and Labeled Compounds	1 h
11.	Radiation Safety Aspects for Radioisotope Laboratories	1 h
12.	Regulatory Aspects for handling of Radioisotopes	1 h
13.	Security of Radioactive Sources	1 h
14.	Transport and Disposal of Radioactive Material	1 h
15.	Emergency Response Plans and Preparedness	1 h
B.	**Practical/Demonstration**: (4 h)	
1.	Radiation absorption characteristics and HVL/TVL measurement, functional performance check of radiation survey instruments	2 h
2.	Contamination measurement & decontamination procedures	1 h
3.	Demonstration on radiation protection survey	1 h
C.	**Technical Visit to Radioisotope Laboratory:**	6 h
1.	Safety aspects during preparation of radio-labeled compounds	
2.	Radiation protection survey of radioisotope laboratory	

Syllabus:

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, types of radioactive disintegrations, electron capture, characteristics of alpha, beta and gamma rays; energy of ionizing radiation, half-life (physical, biological), effective half-life, isomeric transitions, secular, transient and no-equilibrium, production of radioisotopes and X-rays (Characteristic and Bremsstrahlung), neutron sources.

2. Interaction of Radiation with Matter

Interaction of charged particles with matter, bremsstrahlung, range of charged particles, interaction of photon with matter (photoelectric, Compton scattering and pair production), absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT), interaction of neutrons with matter.

3. Radiation Quantities and Units

Activity(Becquerel & Curie), energy, exposure (C/kg & Roentgen), Linear energy transfer (LET), air kerma, absorbed dose (Gray & rad), radiation weighting factors (W_R), tissue weighting factors(W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem), collective effective dose (Person Sv), Annual Limit of Intake{ALI} (Bq) and Derived Air Concentration {DAC} (Bq/m^3).

4. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, and stochastic (probabilistic) effects and tissue reaction (deterministic effects), effect of partial body and whole body exposures, threshold doses, biological dosimetry.

5. Operational Limits

Introduction to natural background radiation, concept of occupational risk, philosophy of radiation protection, system of dose limitation, ALARA, AERB/ICRP recommendations on dose limits to radiation workers and general public.

6. Radiation Detection and Measurement

Principle of radiation detection, gas detectors (ionization chamber, proportional counter and GM counter), scintillators, semiconductors and TLD, liquid scintillation counting systems, nuclear counting statics, radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, contamination monitor, direct reading dosimeter (DRD), calibration and response of radiation monitoring instruments with radiation level.

7. Radiation Hazard Evaluation and Control

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation, individual and workplace monitoring; application of time, distance and shielding; shielding materials, specific gamma ray constant, external radiation monitoring, survey meters.

Internal hazard evaluation and control, Annual limit of intake (ALI), derived air concentration (DAC), control of open source (e.g. fumehood, glove box etc.), environmental control, protective clothing, contamination monitoring (direct and indirect), air contamination monitoring, personnel contamination monitoring and decontamination procedures, external and internal decontamination, surface decontamination.

8. Application of Ionizing Radiation in Research and Academic Institution

Sealed and unsealed sources, sealed source classification, source selection for specific application, shielding requirements for sources, beam collimation, applications of sealed and unsealed sources in medicine, agricultural, industry research and academic institutions.

9. Planning of Radioisotope Laboratories

Classification of radioisotope laboratories, demarcation of areas for radioisotope laboratories, criteria for grading laboratories (radio-toxicity and activity), general features of radioisotope laboratories (site selection, ventilation, walls, floor and ceiling, work surfaces), containment systems(fume-hood, glove box etc.), shielding evaluation, model layout plans of various radioisotope laboratories.

10. Production of Radioisotopes and Labeled Compounds

Production of radioisotopes (Reactor-Accelerator-Generator based), separation of isotopes (chemical processing), radio-labelling of compounds, storage of radio-labeled compounds, quality and purity of radio-labeled compounds.

11. Radiation Safety Aspects for Radioisotope Laboratories

Procedures for handling unsealed radioisotopes, use of handling accessories – pro-pipettes, tongs, Perspex shields for beta emitting radioisotopes, fumehood features (face velocity, filters), procedures for management of radioactive wastes – solid and liquid, management of animals injected with radioisotopes, procedures for decommissioning of radioisotope facility.

12. Regulatory Aspects for handling of Radioisotopes

Regulations for radioisotopes, relevant regulatory documents such as Act, Rules, Code, Standard and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO) and radiation worker, regulatory requirements for import/export, procurement, use, handling, transfer and safe disposal/discharge of radioisotopes; inventory control, Radiation Protection Program (RPP).

13. Security of Radioactive Sources

Physical protection of sources, categorization of sources, safety and security of radiation sources during storage, use, transport and disposal, security measures (administrative and technical), graded approach in security provision, physical protection system.

14. Transport and Disposal of Radioactive Material

Regulatory aspects of safe transport of radioactive material, introduction, terms used {e.g. Competent Authority, A1&A2 values, transport index (TI) etc.}, variety of packages and general requirement of all packaging, preparation, marking, labelling of packages, preparation of transport documents (Consignor's Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general instructions.

Disposal of short-lived solid, liquid and gaseous radioactive waste; disposal of animal carcasses, disposal limits for sanitary sewage system, incineration, disposal of long lived and indispersible radioactive wastes, management of disused sealed sources.

15. Emergency Response Plans and Preparedness

Unusual occurrences, orphan and vulnerable sources, handling of emergency situations resulting from loss/theft/missing of radioisotope, spillage of liquid radioisotope solution, elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical procedures, responsibilities of employer, licensee, RSO and radioisotope supplier in case of emergency.

****

ANNEXURE-10 B

SYLLABI FOR RSO CERTIFICATION FOR UNIVERSITY/ACADEMIC INSTITUTION POSSESSING REFERENCE
(Based on online module of 'Basic Radiation Safety Certification')

The employer/licensee should ensure that the suitable person is designated as Radiological Safety Officer of the department of University/Academic Institution possessing check/reference sources for laboratory experiments. The person should acquire knowledge on radiation safety from the online training modules on following topics available on AERB website or its authorized agency.

1. **Basic Radiation Physics**

   Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, characteristics of alpha, beta, gamma and neutron; energy of ionizing radiation, half-life.

2. **Interaction of Radiation with Matter**

   Interaction of charge particles, interaction of gamma and neutron with matter, absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

3. **Radiation Quantities and Units**

   Activity (Becquerel & Curie), energy, exposure (C/kg & Roentgen), absorbed dose (Gray & rad), radiation weighting factors (W_R), tissue weighting factors (W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

4. **Biological Effects of Radiation**

   Interaction of radiation with cell, direct and indirect interactions, effects of radiation on living cells, chromosomal aberration, somatic and genetic effects, stochastic (probabilistic), tissue reaction (deterministic effects) effects of , partial body and whole body exposures.

5. **Operational Limits**

   Introduction to natural background radiation, concept of occupational risk, system of dose limitation, ALARA, AERB/ICRP recommendations dose limits to radiation workers and general public.

6. **Radiation Detection and Measurement,**
   Radiation detection and measurement, TLD, radiation monitoring instruments, personnel monitoring, neutron monitoring, area monitoring, survey meters, direct reading dosimeter (DRD).

7. **Hazard Evaluation and Control**

   Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation, application of time, distance and shielding; shielding materials for gamma

and neutron, demonstration of safe work practice and radiation survey, storage facility for source.

8. Application of Ionizing radiation in Medicine, Industry, Research and Training

Types of radioisotopes and radiation generators, production of radioisotopes, applications of ionizing radiation in medicine, industry, research, education and training.

9. Transport of Radioactive Material

Regulatory aspects of safe transport of radioactive material, transport index (TI), transport scenarios (routine, normal & accident), type of packages (Type A), general requirement of packaging, preparation, marking, labelling of packages, TREM Card, Emergency in writing and general instructions.

10. Regulatory Aspects

Regulations with respect to handling sources, relevant regulatory documents such as Act, Rules etc., responsibilities of employer, licensee, RSO and radiation workers, regulatory requirements for handling of sources, inventory control, transfer and safe disposal.

11. Security of Radioactive Sources

Physical protection of sources, categorization of sources, safety and security of radiation sources during storage, use, transport and disposal, security measures, graded approach to security of sources, physical protection system.

12. Emergency Response Plans and Preparedness

Unusual occurrences (missing/theft, unsafe disposal), emergency plan and preparedness including procedures for notification and communication, responsibilities of employer, licensee, RSO and workers in case of emergency.

****

ANNEXURE-11: RADIATION SAFETY CERTIFICATION FOR RSO IN RADIOLOGICAL CALIBRATION LABORATORIES (RSO-RCL)

(Radiation Monitoring Instruments and Personnel Monitoring Badges)

The person trained in this course is eligible as RSO for these laboratories from radiological safety stand point. However the calibration laboratory should comply with requirements of recognizing agency about the eligibility of personnel authorized to issue the calibration certificates.

Course Duration: 10 (Ten) working days

Examination:

The examination on Radiation Safety should consist of;

(i) Written paper of 80 marks (60 objective+20 descriptive)
(ii) Vive-voce of 20 marks

Passing Criteria:

(i) Not less than 50% in written and practical examinations
(ii) Not less than 60% in aggregate

Course Content:

A. Lectures (27 h)	**Duration**
Section I: Radiation Physics	
1. Basic Radiation Physics	1 h
2. Interaction of Radiation with Matter	1 h
3. Radiation Quantities and Units	1 h
4. Radiation Dosimetry	1 h
5. Biological Effects of Radiation	1 h
6. Operational Limits	1 h
Section II: Practice Specific	
7. Radiation Detection and Measurement including Personnel Monitoring Devices	3 h
8. Radiation Hazard Evaluation and Control	2 h
9. Design and Operation of Calibration Exposure Devices (CED)	1 h
10. Planning and Safety Requirements of Radiological Calibration Laboratories	2 h
11. Calibration Methods and Procedures	8 h
12. Quality Assurance	1 h
13. Transport of Radioactive Material and Disposal	1 h
14. Regulatory Aspects of Radiological Calibration Laboratories	1 h
15. Security of radioactive Sources	1 h
16. Radiation Accidents, Emergency Response Plans and Preparedness	1 h

B. Discussions : (2 h)

C. Practical / Demonstration: (15 h)

1.Radiation absorption characteristics, HVT & TVT measurement	3 h
2. Standardization of reference radiation field	3 h
3. Calibration of radiation monitoring instruments	3 h
4. Operational Aspects of calibration exposure devices (CED)	3 h
5. Calibration of personnel monitoring instruments and badges	3 h

D. Technical Visit to Radiological Calibration Laboratory: (6 h)

Syllabus

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, types of radio-disintegrations, electron capture, characteristics of alpha, beta and gamma rays; energy of ionizing radiation, half- life, effective half-life production of radioisotopes and X-rays (Characteristic and Bremsstrahlung), neutron sources.

2. Interaction of Radiation with Matter

Interaction of charge particle with matter, Bremsstrahlung, range of charge particle, Interaction of photons with matter (photoelectric effect, Compton scattering and pair production), absorption, scattering and attenuation of photons, broad beam & narrow beam geometry, Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

3. Radiation Quantities and Units

Activity (Becquerel & curie), energy, exposure (C/kg and Roentgen), air kerma, absorbed dose (Gray and rad), Charged particle equilibrium (CPE), radiation weighting factors(W_R), tissue weighting factors (W_T), equivalent dose (Sievert and rem), effective dose (Sievert and rem), concept of ambient and directional dose.

4. Radiation Dosimetry

Relation between air kerma, exposure and absorbed dose to air; determination of exposure and air kerma, standardization of calibration beam using ionization chamber and electrometer.

5. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cell, chromosomal aberration, somatic and genetic effects, stochastic (probabilistic) and tissue reaction (deterministic effects), effect of partial body and whole body exposures, threshold doses, biological dosimetry.

6. Operational Limits

Introduction to natural background radiation, concept of risk, philosophy of radiation protection, system of dose limitation, ALARA, AERB/ICRP recommendations on dose limits to radiation workers and general public.

7. Radiation Detection and Measurement including Personnel Monitoring Devices

Principle of radiation detection & measurement, Gas filled detectors: Ionization Chambers, Proportional and GM Counters; Dead time and recovery time, Scintillation detectors, Semiconductor detectors, principles of thermoluminescent dosimeter (TLD) and optically stimulated luminescent dosimeter (OSLD), overview of TLD/OSLD badges, Radiation monitoring instruments, personnel monitoring badge, area/zone monitors, survey instruments, direct reading dosimeter (DRD), calibration and response of radiation monitoring instruments with radiation level, personnel monitoring badges.

8. Radiation Hazard Evaluation and Control

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation, individual and workplace monitoring, application of time, distance and shielding; specific gamma ray constant, storage facility for source housings, survey of radiation installations, operational safety and radiation protection survey.

9. Design and Operation of Calibration Exposure Devices (CED)

Types of exposure devices, design principles, national/international design standards for sealed sources and CED, standard specifications for design and construction of CED, source housing, built in safety features, safety interlocks, attenuators, operational aspects, periodic maintenance procedures, performance standards, quality assurance of CED, marking, labeling and identification.

10. Planning and Safety Requirements of Radiological Calibration Laboratories

10.1 Calibration Laboratory for Protection Level Instrument

General principles of planning of calibration laboratories, site selection, area requirement, demarcation of areas, shielding material, control room, model layouts of calibration laboratory, reference standard equipment and source(s), reference measuring equipment, positioning system, distance measuring devices, alignment devices, ISO phantoms.

10.2 Calibration Laboratory for Personnel Monitoring Badges

Planning of PM laboratory, site selection, area requirement, demarcation of areas, model layouts, standard source(s), PM badge reading facility.

11. Calibration Methods and Procedures

Purpose of calibration, terminology, reference source, primary standard, secondary standard, tertiary standard, national standard, reference standard, measuring instruments, calibration factor, instrument response, conventional true value, response time, reference point of measuring instrument, calibration and tests, Type testing- linearity, energy response, angular response, overload response; routine calibrations, records and certificates, traceability

Calibration of photon measuring instruments- source selection, energy requirements, source strength, source output characteristics, source geometry, panoramic, collimated or enclosed fields, characterization of radiation field, selection and use of transfer-standard instruments, field uniformity over detector volume, spectral quality, effects of scatter, incidental and spurious radiations, instrument response considerations, mixed radiation fields, pulsed radiation fields, time constant, accuracy and acceptance criteria, uncertainty of measurement, frequency of calibration.

12. Quality Assurance

Routine quality assurance, maintenance of equipment, periodic quality assurance test of exposure devices, survey instruments and personnel monitoring systems.

13. Transport of Radioactive Material and Disposal

Regulatory aspects of safe transport of radioactive material, terms used {e.g. Competent Authority, A1 & A2 values}, Types of packages, category of packages, procedure for marking, labeling and transport index (TI), transport documents (Consignor's Declaration, TREM card, instruction to the Carrier & Emergency in Writing) and general instructions, Disposal of disused sources.

14. Regulatory Aspects of Radiological Calibration Laboratory

Regulations relevant to calibration laboratories, relevant regulatory documents such as Rules, Code, Standard and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO) and isotope supplier; requirements for accreditation/reorganization of radiological calibration laboratory (RCL), regulatory requirements for import/export, procurement, use, handling, transfer and disposal of radioisotopes, inventory control, Radiation Protection Program (RPP).

15. Security of Radioactive Sources

Physical protection of sources, safety and security of radiation sources during storage, use, transport and disposal, categorization of sources, security measure (administrative and technical), graded approach in security provision, security plan, physical protection system.

16. Radiation Accidents, Emergency Response Plans and Preparedness

Possible radiation accident scenario, orphan and vulnerable sources, handling of emergency situations resulting from damage to the source housing, loss/theft of radioisotope/device, accident due to fire and explosions, normal and potential exposure, elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical procedures, responsibilities of employer, licensee, RSO and source supplier in case of emergency.

****

ANNEXURE-12: RADIATION SAFETY CERTIFICATION FOR RSO IN SCANNING FACILITIES

Duration: 6 (Six) working days

Examination:

The examination should consist of;

(i) A written paper of 80 marks (60 marks objective + 20 marks descriptive)

(ii) Viva-voce of 20marks

Passing Criteria:

(i) Not less than 50% each in written and viva-voce examinations

(ii) Not less than 60% in aggregate.

Course Content:

A.	**Lectures (20 h)**	**Duration**
1.	Basic Radiation Physics	1 h
2.	Production of X-rays and Radioisotopes	1 h
3.	Interaction of Radiation with Matter	1 h
4.	Radiation Quantities and Units	1 h
5.	Biological Effects of Radiation	1 h
6.	Operational Limits	1 h
7.	Radiation Detection and Measurement	2 h
8.	Radiation Hazard Evaluation and Control	2 h
9.	Principles of X-ray and Gamma-ray Scanning	1 h
10.	Overview of X-ray Scanning Systems/Devices	3 h
11.	Operational Safety for Container/Vehicle Scanners	1 h
12.	Planning of High Energy X-ray Scanning Facilities	1 h
13.	Regulatory Aspects of Scanning Systems/Facilities	1 h
14.	Quality Assurance of Scanning Systems	2 h
15.	Radiation Incidents and Case Studies	1 h

B. Discussions : (2 h)

C. Demonstration : 3 h (1 h each)

(i) Radiation absorption characteristics (Inverse square law/HVT & TVT)

(ii) Radiation output measurement for X-ray based scanning system

(iii) Radiation protection survey of scanning facility

Syllabus:

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, bound and free electrons, binding energy, ionization, excitation, fluorescence, characteristic X-ray, continuous X-ray (bremmstrahlung), stability of nucleus, isotopes, radioisotopes, types of radioactive disintegration, directly and indirectly ionizing radiations, X-rays and gamma rays, energy of ionizing radiation, half-life, effective half- life.

2. Production of X-rays and Radioisotopes

Components of X-ray equipment, Interaction of accelerated electrons with target atoms, conversion of kinetic energy of electrons into X-rays, bremsstrahlung and characteristic X-rays, X-ray spectrum, types of X-ray tubes (anode, cathode, inherent filters, focal spot), heat production in the anode and cooling mechanism, quality and quantity of X-rays (effect of kV, mA and filters), production of radioisotopes.

3. Interaction of Radiation with Matter

Interaction of electrons with matter, interaction of photon with matter (photoelectric, Compton and pair production), influence of photoelectric effect and Compton effect on image quality, absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT), beam hardening.

4. Radiation Quantities and Units

Activity (Becquerel & Curie), energy, exposure(C/kg &Roentgen), air kerma, absorbed dose (Gray & rad), radiation weighting factors(WR), tissue weighting factors(WT), equivalent dose (Sievert & rem), effective dose (Sievert & rem).

5. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, stochastic (probabilistic) effect and tissue reaction (deterministic effects), effects of partial and whole body exposures, threshold doses, biological dosimetry.

6. Operational Limits

Introduction to natural background radiation, concept of occupational risk, philosophy of radiation protection, system of dose limitation, ALARA, AERB/ICRP recommendations for dose limits to radiation workers and general public,

7. Radiation Detection and Measurement

Principle of radiation detection, gas filled detectors (ionization chamber, proportional counter and GM counter), scintillators, semiconductors and Thermoluminescent Dosimeter {TLD}), selection of radiation detectors for specific application, radiation monitoring instruments, personnel monitoring, area/zone monitoring, survey meters, direct reading dosimeter (DRD), calibration of radiation monitoring instruments,

requirement of personnel monitoring for different stakeholders.

8. Radiation Hazard Evaluation and Control

External hazard and their perspective, evaluation and control of hazard due to external radiation: individual and workplace monitoring, rationale for individual monitoring, application of time, distance and shielding; leakage radiation, radiation protection in scanning facilities.

9. Principles of X-ray and Gamma-ray Scanning

Fundamentals of X-ray and Gamma ray scanning, principle of image formation, overview of detectors used in scanning facilities, image resolution, methods to reduce scattered radiation, colour coding of the images, routine quality control measures for scanners.

10. Overview of X-ray Scanning Systems/Devices

Working principle of x-ray scanning systems, X-ray baggage inspection systems, CT based X-ray baggage scanning facility, Food Inspection systems, PCB Analysers, XRD/XRF Systems, portable X-ray scanning systems, Operational safety requirements for fixed, portable and mobile scanning systems, design safety requirements for scanning systems.

11. Operational Safety for Container/Vehicle Scanners

Introduction to container/vehicle scanners, linear accelerators, betatrons, accelerator based scanning systems, mobile scanners, drive through and drive by modality of scanning, radioisotope based scanning system, operational safety in drive through system, operational safety requirements for high X-ray scanning devices, design safety requirements for high energy scanning systems.

12. Planning of High Energy X-ray Scanning Facilities

General principles of planning of radiation installation, site selection, area requirement, concept of workload, shielding requirement, shielding calculation for various installation, controlled and supervised area, control console, interlocks, pull cord, access control, warning light, placard and public announcement (PA) system, model layouts of various X-ray facilities.

13. Regulatory Aspects of Scanning Systems/Facilities

Regulations with respect to scanning systems and facilities, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of suppliers, manufacturer, licensee, Radiological Safety Officer (RSO) and operator; regulatory requirements for import, procurement, supply, installation, commissioning, operation, transfer, dismantling and decommissioning of scanning systems; type approval of the devices/systems, Radiation Protection Programme (RPP).

14. Quality Assurance of Scanning Systems

Importance of QA in scanning systems, test parameters and test procedures, central

beam alignment, effective focal spot size, exposure time, applied tube potential, linearity of timer loading station, linearity of mA loading station, consistency of radiation output, radiation leakage through tube housing and collimator, verification of interlocks and emergency switches, requirements of lead protective drapes for the systems with product transport mechanism, requirements of door interlocks for the systems which do not have product transport mechanism, output and leakage radiation level measurements, shielding requirements for self-shielded systems, use of tools for image quality verification (eg. combined test piece (CTP)).

15. Radiation Incidents and Case Studies

Radiation incidents during handling of X-ray equipment, excessive exposure to occupational workers, investigation of excessive exposure and case studies, prevention of excessive exposure, radiation injuries - causes and prevention.

****

ANNEXURE-13: RADIATION SAFETY CERTIFICATION FOR RSO OF SUPPLIER OF CONSUMER PRODUCTS AND SOURCES (LOW ACTIVITY)

Duration: 5 (Five) working days

Examination:

The examination should consist of,

(i) A written paper of 80 marks (60 marks Objective + 20 marks Descriptive)
(ii) Viva-voce of 20 marks.

Passing Criteria:

(i) Not less than 50% each in written and viva-voce examinations
(ii) Not less than 60% in aggregate.

Course Content:

A.	**Lectures (16 h)**	**Duration**
1.	Basic Radiation Physics	1 h
2.	Interaction of Radiation with Matter	1 h
3.	Radiation Quantities and Units	1 h
4.	Biological Effects of Radiation	2 h
5.	Operational Limits	1 h
6.	Radiation Detection and Measurement	1 h
7.	Radiation Hazard Evaluation and Control	1 h
8.	Radioactive Sources Classification and Its Applications	1 h
9.	Overview of Consumer products & other Similar Equipment using small Activity sources	2 h
10.	Regulatory Aspects in Manufacturing and supply	2 h
11.	Security of Radioactive Sources	1 h
12.	Transport and Disposal of Radioactive Material	1 h
13.	Emergency Response Plans and Preparedness	1 h

B. Discussions: (2 h)

C. Practical/Demonstration: **(**2 h)

1.	Radiation absorption characteristics and HVL/TVL measurement, functional performance check of radiation survey instruments	1 h
2.	Demonstration on radiation protection survey	1 h

Syllabus:

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, radioisotopes, radioactivity, specific activity, types of radioactive disintegrations, characteristics of alpha, beta and gamma rays; energy of ionizing radiation, half-life (physical), production of radioisotopes and X-rays (Characteristic and Bremsstrahlung), neutron sources.

2. Interaction of Radiation with Matter

Interaction of charged particles with matter, bremsstrahlung, range of charged particles, interaction of photon with matter (photoelectric, Compton scattering and pair production), absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

3. Radiation Quantities and Units

Activity(Becquerel & Curie), energy, exposure (C/kg & Roentgen), Linear energy transfer (LET), absorbed dose (Gray & rad), radiation weighting factors (W_R), tissue weighting factors(W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem), Annual limit of intake (ALI), derived air concentration (DAC).

4. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, and stochastic (probabilistic) effects and tissue reaction (deterministic effects), effect of partial body and whole body exposures, threshold doses, biological dosimetry.

5. Operational Limits

Introduction to natural background radiation, concept of occupational risk, philosophy of radiation protection, system of dose limitation, ALARA, AERB/ICRP recommendations on dose limits to radiation workers and general public.

6. Radiation Detection and Measurement

Principle of radiation detection, familiarization with gas filled detectors (ionization chamber, proportional counter and GM counter), scintillators, semiconductors detectors, TLD, radiation monitoring instruments, personnel monitoring, survey meters, contamination monitor, direct reading dosimeter (DRD).

7. Radiation Hazard Evaluation and Control

Internal and external hazard and their perspective, evaluation and control of hazard due to external radiation, individual and workplace monitoring; application of time, distance and shielding; shielding materials, specific gamma ray constant, external radiation monitoring, survey meters.

Internal hazard evaluation and control, Annual limit of intake (ALI), derived air concentration (DAC), external and internal decontamination, surface decontamination.

8. Radioactive Sources Classification and Its Applications

Sealed and unsealed sources, sealed source classification, beam collimation, applications of sealed and unsealed sources in medicine, agricultural, industry research and academic institutions.

9. Overview of Consumer products &other similar Equipment using Small Activity Sources

Definition of consumer products, familiarization with consumer products, ionization chamber smoke detector, Gaseous Tritium Light Sources (GTLS), Gaseous Tritium Light Devices (GTLD), tritium filled sources (TFS), Fluorescent Lamp Starters,

Introduction to devices consisting of low activity sealed sources, radioactive source based XRF, ion mobility spectrometer, explosive detectors, chemical detectors, narcotic detectors, electron capture detector (ECD), suspended particulate matter, application of tritium sources, ignition exciters in aircrafts, classification of radioactive self-luminous light source.

10. Regulatory Aspects in Manufacturing and Supply

Regulations for consumer products and supplier, safety requirements for registration/approval of these equipment, relevant regulatory documents such as Act, Rules, Code, Standard and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO) and radiation worker, manufacturer, radioisotope supplier, end user;

Regulatory requirements for import/export, procurement, use, handling, transfer and safe disposal/discharge of radioisotopes; servicing and maintenance, inventory control, Radiation Protection Program (RPP).

11. Security of Radioactive Sources

Physical protection of sources, categorization of sources, safety and security of radiation sources during storage, use, transport and disposal, security measures (administrative and technical), graded approach in security provision, physical protection system.

12. Transport and Disposal of Radioactive Material

Regulatory aspects of safe transport of radioactive material, terms used {e.g. Competent Authority, A1&A2 values, transport index (TI) etc.}, transport scenarios (routine, normal & accident), variety of packages covered under the transport regulations, general requirement of all packaging, preparation, marking, labelling of packages, preparation of transport documents (Consignor's Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general instructions.

Disposal of short-lived solid, liquid and gaseous radioactive waste; disposal of long lived and indispersible radioactive wastes, management of disused sealed sources.

13. Emergency Response Plans and Preparedness

Unusual occurrences, orphan and vulnerable sources, handling of emergency situations resulting from loss of radioisotope, theft/missing of isotope consignment, spillage of liquid radioisotope solution; elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical procedures, responsibilities of employer, licensee, RSO and supplier in case of emergency.

****

ANNEXURE-14: RADIATION SAFETY CERTIFICATION FOR RSO IN GAS MANTLE MANUFACTURING FACILITY

Duration: 5 (Five) working days

Examination:
The examination should consist of,

(i) A written paper of 80 marks (60 marks Objective + 20 marks Descriptive)
(ii) Viva-voce of 20 marks.

Passing Criteria:

(i) Not less than 50% each in written and viva-voce examinations
(ii) Not less than 60% in aggregate.

Course Content:

A.	**Lectures (16 h)**	**Duration**
1.	Basic Radiation Physics	1 h
2.	Interaction of Radiation with Matter	1 h
3.	Radiation Quantities and Units	1 h
4.	Biological Effects of Radiation	1 h
5.	Operational Limits	1 h
6.	Radiation Detection and Measurement	1 h
7.	Radiation Hazard Evaluation and Control	2 h
8.	Planning of Gas Mantle Manufacturing Facility	1 h
9.	Radiation Safety in Gas Mantle Manufacturing Facility	3 h
10.	Transport and Disposal of Radioactive Material	1 h
11.	Regulatory Aspects in Manufacture and supply of Gas Mantle	1 h
12.	Security of Radioactive Sources	1h
13.	Radiation Emergency, Case Studies and Lessons Learned	1h

B. Discussions: (1 h)

C. Practical/Demonstration: (3 h)

1.	Functional performance check of radiation survey instruments	1 h
2.	Contamination measurement & decontamination procedures	1 h
3.	Demonstration on Radiation protection survey	1 h

Syllabus:

1. Basic Radiation Physics

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, types of radioactive disintegrations, characteristics of alpha, beta and gamma rays; energy of ionizing radiation, half-life (physical, biological), effective half-life, production of radioisotopes.

2. Interaction of Radiation with Matter

Interaction of charged particles with matter, bremsstrahlung, range of charged particles, interaction of photon with matter (photoelectric, Compton scattering and pair production),

absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

3. Radiation Quantities and Units

Activity(Becquerel & Curie), energy, exposure (C/kg & Roentgen), Linear energy transfer (LET), air kerma, absorbed dose (Gray & rad), radiation weighting factors (W_R), tissue weighting factors(W_T), equivalent dose (Sievert & rem), effective dose (Sievert & rem), collective effective dose (Person Sv), Annual Limit of Intake{ALI} (Bq) and Derived Air Concentration {DAC} (Bq/m^3).

4. Biological Effects of Radiation

Interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, chromosomal aberration, somatic and genetic effects, and stochastic (probabilistic) effects and tissue reaction (deterministic effects), effect of partial body and whole body exposures, threshold doses, biological dosimetry.

5. Operational Limits

Introduction to natural background radiation, concept of occupational risk, philosophy of radiation protection, system of dose limitation, ALARA, AERB/ICRP recommendations on dose limits to radiation workers and general public.

6. Radiation Detection and Measurement

Principle of radiation detection, over view of radiation detectors- gas filled detectors, (ionization chamber, proportional counter and GM counter), scintillators, semiconductors and TLD, radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, contamination monitor, direct reading dosimeter (DRD), functional checks of radiation survey meters.

7. Radiation Hazard Evaluation and Control

Internal and external hazard and their perspective, evaluation and control of hazard due to internal and external radiation, individual and workplace monitoring; application of time, distance and shielding; shielding materials, specific gamma ray constant, external radiation monitoring, survey meters.
Annual limit of intake (ALI), control of open source, environmental control, protective clothing, contamination monitoring (direct and indirect), air contamination monitoring, derived air concentration (DAC), personnel contamination monitoring and decontamination procedures, external and internal decontamination, surface decontamination.

8. Planning of Gas Mantle Manufacturing Facility

Demarcation of areas for storage and handling of radioisotopes, radio-toxicity and activity, general features of manufacturing unit (site, typical floor plans, ventilation, surfaces, walls, floor and ceiling, work surfaces, containment systems), model layout plans of various manufacturing facilities.

9. Radiation Safety in Gas Mantle Manufacturing Facility

Definition of consumer products, introduction to unsealed sources, general safety requirements in handling of unsealed sources, thorium nitrate and its properties, Hazard associated with Thorium nitrate & Thorium oxide, rationalization for use of thorium nitrate in gas mantle, operational radiation safety in gas mantle manufacturing procedure, safety during preparation and handling of solution, soaking, washing, squeezing the solution, drying, cutting/colouring/ironing, packaging of gas mantle, labelling and marking of packages.
Requirement for storage of ready product, activity build up during storage, radiation survey of storage area.

10. Transport and Disposal of Radioactive Material

Regulatory aspects of safe transport of radioactive material, introduction, terms used {e.g. Competent Authority, A1&A2 values, transport index (TI) etc.}, transport scenarios (routine, normal & accident), general requirement for packaging, preparation, marking, labelling of packages, preparation of transport documents (Consignor's Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general instructions. Disposal of solid, liquid and gaseous radioactive waste generated in manufacturing unit, procedure for discharge of solution to the public sewage system, procedures for
Disposal of empty radioisotope (thorium nitrate) container.

11. Regulatory Aspects in Manufacture and Supply of Gas Mantle

Regulatory requirements for manufacturing and supply gas mantles, relevant regulatory documents such as Act, Rules, Code, Standard and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO) and radiation worker, radioisotope supplier; regulatory requirements for import/export, procurement, use, handling, transfer and safe disposal/discharge of radioisotopes; inventory control, Radiation Protection Program (RPP).Training to the supplier on safety on packaging, labelling and safe transport.

12. Security of Radioactive Sources

Physical protection of sources, safety and security of radiation sources during storage, use, transport and disposal, security provisions: administrative and technical measures, graded approach in security provision, physical protection system.

13. Radiation Emergency, Case Studies and Lessons Learned

Normal and potential exposure, accident situations involving unsealed sources, handling of emergency situations resulting from spillage of liquid radioisotope solution, theft/missing of isotope consignment, unsafe disposal/discharge of contaminated material, fire accidents and explosions, case studies and lessons learned, procedures for notification and communication.

****

ANNEXURE-15: RADIATION SAFETY CERTIFICATION FOR RSO IN INDUSTRIAL AND RESEARCH RADIATION FACILITIES (RSO-IRF)

Course Duration: As prescribed by University/Institution subject to fulfilling the minimum course duration and minimum desirable entry level qualifications stipulated in this document.

Infrastructure: As per Appendix 5 of this document

Examination: As prescribed by University

Passing Criteria: As prescribed by University.

Syllabus: (68 h)

1. Basic Radiation Physics (3 h)

Atomic structure, atomic number, mass number, isotopes, radioisotopes, radioactivity, specific activity, general properties of alpha, beta and gamma rays; laws of radioactivity and successive transformations, half-life, decay constant, mean life, natural radioactive series, radioactive equilibrium, artificial radioactivity, production of radioisotopes by neutron and charged particle bombardments, nuclear cross sections.

2. Interaction of Radiation with Matter (3 h)

Interaction of charged particles with matter, energy transfer mechanisms, scattering, excitation and ionisation, range-energy relationship, Bragg curve, stopping power, bremsstrahlung, passage of heavy charged particles though matter, specific ionization.

Interaction of X- and gamma rays with matter {photoelectric effect, Compton scattering, pair production}, exponential attenuation, modes of interactions, attenuation and mass energy absorption coefficients, relative importance of various processes, buildup correction, shielding material.

Interaction of neutrons with matter, scattering, absorption, neutron induced nuclear reactions, radioactive capture reactions {(n, p), (n, γ)}, moderation, shielding material.

3. Radiation Quantities and Units (3 h)

Particle flux and fluence, energy flux and fluence, cross section, energy, linear energy transfer (LET), linear and mass attenuation coefficients, mass stopping power, w-value, exposure (rate), Kerma (rate), Terma, absorbed dose (rate), activity, rate constants, charged particle equilibrium (CPE), radiation weighting factors, tissue weighting factors, equivalent dose, effective dose, collective effective dose, personnel dose equivalent, committed dose.

4. Radiation Dosimetry (4 h)

Absorbed dose, Kerma, exposure, activity, rate constants, Charged particle equilibrium (CPE), relationship between Kerma, absorbed dose and exposure under CPE; determination of exposure and air kerma, ionization chambers for low, medium and high

energy X-rays and gamma rays, electrometers, determination of absorbed dose, Bragg-Gray cavity principle, dosimetry using ionization chambers, films, Thermoluminescence Dosimeters (TLDs,) calorimeters and chemical dosimeters; dosimetry of point source/line source/cylindrical source, neutron dosimetry, consistency check of dosimeters.

5. Radiation Detection and Measurement (5 h)

5.1 Principles of Radiation Detection (2 h)

Basic principles of radiation detection, Gas Filled detectors (Ionization chamber, Proportional and GM Counters); Characteristics of organic and inorganic counters, dead time and recovery time, solid state detectors, scintillation detectors, semiconductor detectors. Chemical systems - Radiographic and Radiochromic films; Thermoluminescent Dosimeters (TLD), Optically stimulated Luminescence dosimeters (OSLD), radiophotoluminescent dosimeters, neutron detectors, nuclear track emulsions for fast neutrons, solid state nuclear track (SSNTD) detectors, calorimeters.

5.2 Radiation Measuring & Monitoring Instruments (3)

Instruments for personnel monitoring - TLD badge readers, digital pocket dosimeters using solid state devices and GM counters, teletector, industrial gamma radiography survey meter, gamma area (zone) alarm monitors, contamination monitors for alpha, beta and gamma radiation, hand and foot monitors, scintillation monitors for X and gamma radiations, neutron monitors, tissue equivalent survey meters, flux meter and dose equivalent monitors, pocket neutron monitors, teledose systems, whole body counters, air monitors for radioactive particulates and gases.

6. Radiation Biology (4 h)

Interaction of radiation with cell, chomosome aberrations, mutations, potentially lethal and sub-lethal damages, modification of radiation damage, LET, RBE, dose rate, stochastic and deterministic effects of radiation, acute radiation sickness, $LD_{50/60}$, prenatal effects, effects of radiation on skin, blood forming organs, digestive tract and reproductive system; effects of chronic and acute exposure to radiation, induction of leukemia and radiation carcinogenesis, genetic effects of radiation, physical and biological factors affecting cell survival.

7. Radiation Protection Standards (3 h)

Radiation dose to individuals from natural radioactivity in the environment and man-made sources, basic concepts of radiation protection standards, International Commission on Radiological Protection (ICRP) and its recommendations, categories of exposures, risk factors, international/national radiation protection standards- ICRP, BSS and AERB, overview of UNSCEAR recommendations, factors governing internal exposures, radionuclide concentrations in air and water and contamination levels, dose limits for occupational workers, trainees and general public.

8. Radiation Hazard Evaluation and Control (4 h)

Internal and external radiation hazard, evaluation and control of external radiation hazards: individual and workplace monitoring, application of time, distance and shielding; shielding calculations, radiation hazard evaluation and control measures in industrial and research installations: design and planning of radiation installations: primary and secondary protective barriers, shielding calculation parameters- workload (W), use factor (U), occupancy factor (T), albedo factor, sky shine, industrial radiography enclosure, ionising radiation gauging devices/nucleonic gauges installation and storage, tracer studies, gamma irradiation chamber, radiation processing facilities, radiation instrument calibration facilities, consumer products facility, radiation control measures.

Radiation monitoring instruments, calibration check of monitoring instruments, radiation monitoring procedures for radiation generating equipment and installations; protective measures to reduce radiation exposures to occupational workers and members of the public, radiation hazards in radioisotope laboratories, protective equipment.

9. **Disposal of Radioactive Waste (3 h)**

Radioactive wastes, sources of radioactive waste, classification of waste, treatment techniques for solid, liquid and gaseous effluents; permissible limits for disposal of waste, sampling techniques for air, water and solid, decontamination procedures, geological, hydrological media, meteorological and ecological considerations for waste disposal.

Disposal of radioactive wastes, general methods of disposal, management of radioactive waste in industrial, agricultural and research facilities.

10. Transport of Radioactive Material (3 h)

Regulatory aspects of transport of radioactive material (RAM), introduction, terms used (e.g. Competent Authority, A1&A2 values, unilateral & multilateral approvals, special form radioactive material, special arrangement, transport index (TI) etc.), transport scenarios (routine, normal and accidental), variety of packages covered under the transport regulations (including designing, testing, transport and storage); general requirements of all packaging, requirements for transport by air mode, test requirements, preparation, marking, labeling of packages, preparation of transport documents (consignors declaration, TREM Card, instructions to the carrier & emergency preparedness in writing), responsibilities of consignor, general instructions and response to off-normal situations during transport.

11. Industrial Radiography (8 h)

Principles of industrial radiography techniques: X-ray, gamma-ray, neutron and electron radiography; selection of source, industrial radiography exposure devices (IRED), source changer and container, radiography films and processing, characteristic curves, image receptor, contrast and sensitivity, intensifying screens, image quality indicators, industrial fluoroscopy/digital radiography, real time radiography and special scanning techniques, various exposures techniques and special radiography techniques: microradiography, auto-radiography, flash radiography, stereo-radiography, hot radiography, computed tomography (CT); planning of industrial radiography installations, skyshine, safety and security measures, enclosed and open top installation.

12. Ionising Radiation Gauging Devices (IRGDs)/Nucleonic Gauges (5 h)

Classification of IRGDs/Nucleonic gauges, principles of ionizing radiation gauging devices, criteria for radiation sources and detector selection, condition for maximum

sensitivity and accuracy, radioisotope and X-ray gauges, principle of measurement: transmission and back backscattering; types of gauges: α-gauges, beta gauges, bremsstrahlung, gamma and X-ray gauges and their applications: level, thickness, density, elemental composition measurement etc., X-ray fluorescence (XRF) techniques, neutron gauges: principle and application; well logging: principle and applications; planning of gauging installations, storage requirement, safety and security measures.

13. Research Applications (2 h)

Applications of radioisotopes in research, principles of radioisotope tracer techniques, selection of radiotracer, dilution technique, use of radiotracers in biology studies, agriculture and industry, planning of radioisotope laboratories.

14. Radiation Processing Facilities (6 h)

Type of radiation processing facilities (irradiators), categories of irradiators (dry and wet source storage irradiators), radiological safety objectives and safety philosophy in design, i.e. concept of defence-in-depth applied to the design process; design features and requirements; transport, loading and unloading of sources; DM plant objective, integrity of water pool, pool water level and contamination monitoring, pH, conductivity, temperature monitoring, periodic servicing and maintenance of safety systems/components; maintenance of records, noxious gas production, ventilation requirements, shielding requirements for transport and storage containers for high activity sources, safety and security measures.

Design safety features; special safety provisions for electron beam accelerator facilities, planning of gamma/X-rays and electron radiation processing facilities, effects of scattering, albedo, sky shine.

15. Radiation Processing of Food and Allied Products (2 h)

Radiation processing technology, purpose of radiation processing, conventional methods for food preservation (plant and animal origin), low, medium and high dose irradiation, general properties of food {fruits and vegetables, cereals and legumes, fleshy Foods (Fish, Meat and Chicken)}, shelf-life parameters and control of spoilage, climacteric and non-climacteric fruits, delayed ripening, sprout inhibition, different methods of insect control, disinfestation for quarantine purpose, effect of radiation on sensory and nutritional quality of food, elimination of pathogens and parasites in fleshy foods, radurization, radicidation and radappertisation, good manufacturing practices (GMP) and good irradiation practices (GIP), regulatory aspects for food irradiation, codex.

16. Regulatory Aspectsfor Industrial and Research Radiation Facilities (2 h)

National legislation, regulatory framework, relevant regulatory documents such as Act, Rules, radiation surveillance procedures, applicable safety codes, standards, guides and manuals for industrial, agricultural and research applications of ionizing radiation, regulatory control: licensing, inspection and enforcement; responsibilities of employer, licensee, Radiological Safety Officer (RSO), operators/radiographers, radiation workers and radioisotope supplier(s); regulatory requirements for import/export, procurement, use, handling, transfer and disposal of radioisotopes, inventory control, Radiation Protection Programme (RPP).

17. Security of Radioactive Sources (2 h)

Categorization of radiation sources, Safety and security of sources during use, storage, transport and disposal, security principles, security culture, security functions, categorization of radiation sources, security levels and security objectives, security threat and vulnerability assessment, security provisions: administrative and technical measures, graded approach in security provision, physical protection system (PPS)

18. Emergency Response Plans and Preparedness (2 h)

Normal and potential exposures, accident situations involving radioisotopes, elements of emergency planning and preparedness including procedures for notification and communication, emergency response accessories, responsibilities of employer, licensee, RSO, technologist and radioisotope/equipment supplier in case of emergency.

19. Radiation Emergencies and Medical Management (4 h)

Radiation accidents and emergencies in the use of radiation sources and equipment in industrial and research radiation facilities, source replenishment, loss of radiation sources, their tracing and recovery, incidents/accidents and case studies and lessons learned. Radiation injuries and their medical management.

****

ANNEXURE-16: TYPICAL CONTENTS FOR RADIATION SAFETY AWARENESS TO AUXILIARY STAFF IN RADIATION FACILITIES

(Auxiliary Staff : Nurses, Anesthetist, Ayah, Attendants, Carer/Comforter, Drivers involved in transport of radioactive material, helpers etc.)

The employer/licensee should ensure that the Radiological Safety Officer of the institution conducts periodic training and refresher training to the auxiliary staff on the following topics (as applicable) and maintain the training records. It should be ensured that the radiation awareness is provided to every auxiliary staff prior to its posting in radiation area.

- Basic Radiation types (Non-Ionizing/Ionizing)
- Biological effects of radiation, risks and benefits
- Radiation protection (Time, Distance and Shielding)
- Basic radiation safety procedures and ALARA principle
- Practice specific safety procedures to minimize exposure to staff members
- Concept of Radiation Dose and its measurement
- Dose limits
- Use of protective equipment and personnel monitoring devices (Dos and Don'ts)
- Rules, regulations for handling radiation sources and information on where the rules can be viewed/accessed
- Responsibilities of the auxillary staff towards safe work practice & optimization of exposures
- Instructions to pregnant and breast feeding workers
- Instructions to patients carer/comforter, as applicable
- Emergency response preparedness, as appropriate for the practice
- Security of radiocative sources
- Medico-legal or other legal considerations, record keeping as appropriate, including patient dose records, where applicable.

****

BIBLIOGRAPHY

1. Atomic Energy Act, 1962 (33 of 1962).

2. 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.

3. Atomic Energy (Radiation Protection) Rules,2004 G.S.R.303.

4. Atomic Energy Regulatory Board, Safety Code for 'Radiation Therapy Sources, Equipment and Installations', AERB/RF-MED/ SC-1(Rev. 1), Mumbai, India, 2011.

5. Atomic Energy Regulatory Board, Safety Code for 'Nuclear Medicine Facilities', AERB/RF-MED/SC-2 (Rev. 2), Mumbai, India, 2011.

6. Atomic Energy Regulatory Board, Safety Code for 'Radiation Safety in Manufacture, Supply and Use of Medical Diagnostic X-Ray Equipment', AERB/RF-MED/SC-3 (Rev-2), Mumbai, India, 2016.

7. Atomic Energy Regulatory Board, Safety Guide for 'Medical Cyclotron Facilities', AERB/RF-RS/SG-3 (Rev.1), Mumbai, India, 2016.

8. Atomic Energy Regulatory Board, Safety Code for 'Radiation Processing Facilities', AERB/RF-RPF/SC-1 (Rev.1), Mumbai, India, 2015.

9. Atomic Energy Regulatory Board, Safety Code for 'Industrial Radiography', AERB/RF-IR/SC-1, Mumbai, India, 2015.

10. Atomic Energy Regulatory Board, Safety Guidelines for 'Gamma Irradiation Chamber', AERB/RF-RPF/SG-2, Mumbai, India, 2015.

11. Atomic Energy Regulatory Board, Safety Guidelines for 'Nucleonic Gauges and Well Logging Applications'', AERB/RF-IGD/SG-1, Mumbai, India, 2015.

12. International Commission on Radiological Protection, ICRP-103, 2007

13. International Atomic Energy Agency (IAEA),SafetySeries No, 'Radiation Protection and Safety of Radiation Sources :International Basic Safety Standards' GSR Part 3, Vienna, 2014

14. International Atomic Energy Agency (IAEA), Health Series No. 25, on 'Role and Responsibilities and Education and Training Requirements for Clinical Qualified Medical Physicists', Vienna, 2013.

15. International Atomic Energy Agency (IAEA),Technical Course Series 25, on 'A Syllabus for the Education and Training of RTTs'(Radiation Therapists and Therapy Radiographers) , Vienna, 2005

16. International Atomic Energy Agency (IAEA), Safety Report Series No. 20, on 'Training in Radiation Protection and the Safe Use of Radiation Sources', 2001.

17. International Atomic Energy Agency (IAEA), Technical Course Series No. 36, on 'IAEA Syllabus for the Education and Training of Radiation Oncologists' Vienna, 2015

18. International Atomic Energy Agency(IAEA), Safety Report Series No.40 on 'Applying Radiation Safety Standards in Nuclear Medicine', Vienna, 2005

19. International Atomic Energy Agency (IAEA), Training Course Series No. 50 on 'Clinical Training of Medical Physicists Specializing in Nuclear Medicine; Vienna, 2011.

20. International Atomic Energy Agency (IAEA), Training Course Series No. 56, on 'Postgraduate Medical Physics Academic Programmes', Vienna, 2013.

21. International Atomic Energy Agency (IAEA), Technical Course Series 58, 'A Handbook For The Education of Radiation Therapists (RTTs), Vienna, 2014.

22. International Atomic Energy Agency (IAEA), Technical Report Series No. 471 on 'Cyclotron Produced Radionuclides: Guidelines for Setting up a facility', Vienna, 2009.

23. Radiation Protection 116: European Commission guidelines on education and training in radiation protection for medical exposures.

24. International Standard on 'Non-destructive Testing- Qualification and Certification of Personnel' ISO 9712:1999 (E).

25. European Commission Radiation Protection No 175: Guidelines On Radiation Protection Education and Training of Medical Professionals In The European Union,

26. The Ionizing Radiation (Medical Exposure) Regulations 2000: No. 1059 Health and Safety Regulations (UK).

LIST OF PARTICIPANTS
Working Group

For Preparation of Draft Regulation on "Qualification & Training Aspects for Employment of Persons and their Approval /Licensing at Radiation Facilities"
(WG-RQTL)

Date of Meeting: February 06, 10, 13, 20, 21 & 27, 2017
March 7, 9 & 21, 2017
April 20 & 27, 2017
May 03, 16 & 31, 2017
July 26, 2017
November 10, 2017
February 02, 2018

Convenor and Members of WG-RQTL:

Smt. S. Mahalakshmi (Convenor)	: RSD, AERB
Shri Amit Sen	: RSD, AERB
Smt. Manisha V. Inamdar	: RSD, AERB
Smt. Arti Kulkarni	: RSD, AERB
Shri Neeraj Dixit	: RSD, AERB
Shri Pradip Kumar	: DRI, AERB
Smt. Shimja Bhanu	: RSD, AERB
Shri Alok Pandey (Co-opted Member)	: RSD, AERB
Shri Pravin J. Patil (Member-Secretary)	: R&DD, AERB

Acknowledgement: (For contribution in preparation of document)

Dr. Ghanshyam Sahani	: RSD, AERB
Shri D. M. Rane	: RSD, AERB
Shri Rajoo Kumar	: R&DD, AERB
Shri G. K. Panda	: RSD, AERB
Shri Subrata Pathak	: RSD, AERB
Shri Ashish Ramteke	: RSD, AERB