AERB Standard Syllabi: AERB/RF/Training-Syllabi/2012

STANDARD SYLLABI FOR TRAINING COURSES ON RADIOLOGICAL SAFETY

Atomic Energy Regulatory Board
Mumbai-400094
India

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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 members of the public and occupational workers as well as 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, therefore, develops safety standards, codes, guides and manuals for the purpose, as well as undertake their periodic review. While some of these documents cover aspects such as siting, design, construction, operation, quality assurance and decommissioning of nuclear and radiation facilities, other documents cover regulatory aspects of these facilities.

The ionising radiation sources (radioisotopes and radiation generating equipment) are being used extensively in various fields such as medicine, industry, agriculture and research and efforts are being made throughout the world to reap maximum benefit from their applications for the societal benefit. With the advent of nuclear reactor and accelerator technology a variety of new radiation sources varying widely in quality and quantity have become available for various applications. While radiation sources have significant and indispensable uses in several fields, they may be harmful to the workers and public if used indiscriminately and without due caution. It is therefore necessary to ensure safety of radiation workers, patients, members of public and the environment, so that maximum benefit is 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. 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 ionizing radiation has been highlighted by the results of the AERB's investigations of radiological accidents. A significant contributory factor in a number of the radiation accidents has been a lack of adequate training, which gave rise to errors with serious consequences.

The need for education and training in the various disciplines of radiation protection has long been recognized by the AERB. This need has been partially met through many training courses undertaken by recognized organizations, either individually or in collaboration.

The existing syllabi of various training courses were formulated about a decade ago. In order to keep pace with the developments in the fields of medical, industrial and research applications of ionizing radiation, it was felt necessary to review the existing syllabi of various training courses. Therefore, the Task Group was constituted by AERB with an objective to revise existing syllabi of various training courses in radiological safety by taking in to consideration of developments in radiation protection, requirements of regulations, international basic safety standards, training methodology evolved in recent years; and prescribe the standard syllabi to achieve both consistency and a common level in the technical content that shall be included in the curricula of educational/training institutions involved in conducting radiation safety related training courses. The syllabi prescribed in this standard will be helpful in providing adequate and harmonized training to the concerned professionals.

This revised standard syllabi on training courses for radiological safety is effective from the date of issue of this document and supersedes all the earlier syllabi. It shall be noted that the requirement prescribed in the present syllabi will not affect the presently approved radiological safety officers (RSOs) and other certified professionals who may not be meeting the requirements/ qualifications/ experience specified in this document.

Task Group for Review of Syllabi of Training Courses on Radiological Safety (TGRTRS) and the specialist in the field of medical physics, nuclear medicine, diagnostic radiology and industrial applications drawn from the Atomic Energy Regulatory Board, the Bhabha Atomic Research Centre and other units of DAE have prepared this training course syllabi document. It has been reviewed by experts and the Safety Review Committee for Applications of Radiation (SARCAR) and the Board.

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

(S. S. Bajaj)
Chairman, AERB

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Training Course on Radiation Safety-1 (TCRS-1)

No. AERB/RSD/RSO-MRF/Syllabus/2012

RSO Certification for Medical Radiation Facilities (RSO-MRF)

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 very high activity sources (e.g. ^{60}Co, ^{137}Cs, ^{192}Ir) and highly penetrating ionising radiation from medical accelerators. While ionising radiations play significant and indispensable role in diagnosis and treatment of cancer, it must be borne in mind that it may be harmful to the radiation workers and general public, if used indiscriminately and without due caution. Concern for radiation protection is growing significantly not only due to the rapid increase in the use of ionising radiation but also because of better understanding of the risk and benefits attributable to it. It is therefore necessary to ensure safety of radiation workers, patients undergoing diagnosis and treatment, general public and environment, so that maximum benefit is derived from the safe use of ionising radiation with acceptable radiological risk.

As per existing regulations, each Medical Radiation Facility (MRF) shall appoint and designate a full time Radiological Safety Officer (RSO) with prior approval of the Competent Authority. RSO with Post M. Sc. Diploma in Radiological Physics (Dip. R. P.)/ Post M. Sc. Diploma in Medical Physics (Dip. M. P.)/ Post Graduate Degree in Medical Physics [M.Sc. (Med. Phys.)] qualification is especially required for those MRFs, where radiation therapy is practiced for treatment of malignant/benign diseases using teletherapy/brachytherapy modalities. The roles and responsibilities of RSO have been outlined in the relevant regulatory documents.

A number of universities are conducting Dip. R. P./Dip. M. P./M. Sc. (Med. Phys.) courses incorporating syllabus of radiological and medical physics with the consent of the Atomic Energy Regulatory Board (AERB). In view of the increasing number of these courses conducted by different universities, it is necessary to prescribe a syllabus for certification of RSO for medical radiation facilities (Diagnostic radiology, nuclear medicine/medical cyclotron and radiotherapy). The prescribed syllabus shall be the part of the syllabi of all the above mentioned courses. The RSO certification examination shall be an independent procedure to evaluate successful candidates of the above mentioned courses using a uniform examination system.

Eligibility Criteria:

(i) Post M. Sc. Diploma in Radiological Physics (Dip. R. P.) or; Post M. Sc. Diploma in Medical Physics (Dip. M. P.) or; Post Graduate Degree in Medical Physics [M.Sc. (Med. Phys.)], based on the minimum course content on radiation safety prescribed by the Competent Authority; from a recognized University/Institution; and

(ii) an internship of minimum 12 months in a well-equipped and recognized radiation therapy department.

Examination:

The examination shall consist of;

I. A written paper of 100 marks (80 marks descriptive + 20 marks objective)
II. Viva-voce of 100 marks.

Passing Criteria:

I. Not less than 50% each in written and viva-voce examinations
II. Not less than 60% in aggregate.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

Syllabus for the Examination

1. Basic Radiation Physics

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

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 materials.
Interaction of neutrons with matter, scattering, absorption, neutron induced nuclear reactions, radioactive capture reactions {(n, p), (n, γ)}, moderation, shielding materials.

3. Basic X-ray Physics

Production and properties of X-rays, characteristics and continuous spectra, basic requirements of medical diagnostic and therapeutic tubes, safety devices in X-ray tubes, technology of modern X-ray tubes, insulation and cooling of X-ray tubes, filtration and beam quality, mobile and dental units, malfunctions of X-ray tubes, limitations on loading, control panels, image intensifiers; technology of electron accelerators.

4. Radiation Quantities and Units

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, Annual Limit of Intake {ALI}, Derived Air Concentration {DAC}, personnel dose equivalent, committed dose.

5. Radiation Dosimetry

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, Burlin and Spencer-Attix cavity theories and their applications, dosimetry using ionization chambers, films, Thermoluminescence Dosimeters (TLDs,) calorimeters and chemical dosimeters; beam and source dosimetry, dosimetry of point source/line source/cylindrical source, neutron dosimetry, consistency check of dosimeters.

6. Radiation Detection and Measurement

6.1 Principles of Radiation Detection

Basic principles of radiation detection, Gas Filled detectors: Ionization chambers-Theory and design; Construction of condenser type chambers and thimble chambers; Gas multiplication, 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.

6.2 Radiation Measuring & Monitoring Instruments

Dosimeters based on condenser chambers, pocket chambers, dosimeters based on current measurement, different types of electrometers- MOSFET, Vibrating condenser and Varactor bridge types; secondary standard therapy level dosimeters, farmer dosimeters, radiation field analyzer (RFA), radioisotope calibrator, multipurpose dosimeter, water phantom dosimetry systems, brachytherapy dosimeters, Thermoluminescent dosimeter readers for medical applications, calibration and maintenance of dosimeters.
Instruments for personnel monitoring, TLD badge readers, glass dosimeter readers, digital pocket dosimeters using solid state devices and GM counters, teletector, radiation survey meter, gamma area/zone alarm monitors, contamination monitors for alpha, beta and gamma radiation; hand and foot monitors, laundry and portal monitors, scintillation monitors for X-ray and gamma radiations, neutron monitors, tissue equivalent survey meters, flux meter and dose equivalent monitors, pocket neutron monitors, teledose systems.
Instruments for counting and spectrometry, portable counting systems for alpha and beta radiation, gamma ray spectrometers, multichannel analyzers, liquid scintillation counting system, RIA counters, whole body counters, air monitors for radioactive particulates and gases.

7. Radiation Biology

Interaction of radiation with cells, chomosome aberrations, mutations, potentially lethal and sub-lethal damages, modification of radiation damage, LET, RBE, dose rate, dose fractionation, stochastic and deterministic effects of radiation, acute radiation sickness, $LD_{50/60}$, prenatal effect, 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, chemical and hyperthermic sensitizers, radio-protectors, tumour biology, non-conventional fractionation schemes, high LET radiation therapy, radiobiological basis of radiotherapy, time dose fractionation (TDF) and gap correction, linear quadratic model.

8. Diagnostic Radiology

Physical principles of X-ray diagnosis, density, contrast, detail and definition of radiographs, selection of kV, mAs, filtration, FSD, screens, films, grids, contrast media, basics of radiography, myelography, tomography, fluoroscopy, pelvimetry, stereoscopy, film processing, image intensifiers, optimization of patient dose, guidance levels, CT scanners and their applications, digital subtraction angiography (DSA), mammography, bone densitometry, dental radiography, interventional radiology, digital radiology, performance standards and acceptance criteria for diagnostic equipment, quality assurance (QA) in diagnostic radiology.

9. Nuclear Medicine

Clinical radioisotope laboratory and its organization, use of open isotopes including ^{99}Tc in functional studies, measurement of radioactivity, design aspects of collimators, use of whole body counters, physical principles of isotope dilution analysis, circulation time, radioisotope scanners and cameras, cyclotron produced radionuclides, SPECT, PET, radio-immunoassay(RIA), ^{131}I therapy, patient dose, guidance levels, protection principles and decontamination procedures, performance standards and acceptance criteria for nuclear medicine equipment, quality assurance (QA) in nuclear medicine.

10. Radiotherapy

Benign and malignant tumours, palliative and curative therapy, beam therapy equipments- kV X-ray machine, telecobalt units, medical electron linear accelerators; output calibration procedures for photon and electron beams, dosimetry parameters, patient dose calculations, neutron capture therapy, proton and heavy ion therapy, radioisotopes used in brachytherapy, LDR, MDR, HDR and PDR brachytherapy; remote afterloading brachytherapy units, source strength measurement, integrity checks for sources, treatment planning system (TPS) used in radiotherapy, IMRT/IGRT, recent advances in radiotherapy, patient and occupational safety measures, performance standards and acceptance criteria for radiotherapy equipment, quality assurance (QA) in radiotherapy.

11. Radiation Protection Standards

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, general public, comforters and trainees.

12. Radiation Hazard Evaluation and Control

Internal and external radiation hazards, evaluation and control of external radiation hazards, individual and workplace monitoring, application of time, distance and shielding; shielding calculations, planning of medical radiation installations, shielding calculation parameters- workload (W), use factor (U), occupancy factor (T); primary and secondary protective barriers, design and shielding requirements for diagnostic X-ray facilities, telecobalt, medical accelerator, brachytherapy installations and medical radioisotope laboratories.

Radiation monitoring instruments, calibration check of monitoring instruments, radiation monitoring procedures for radiation generating equipment and installations, protective measures to reduce radiation exposures to patients and occupational workers, radiation hazards in radioisotope laboratories, protective equipment.

13. Disposal of Radioactive Waste

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; geological, hydrological, media meteorological and ecological considerations for waste disposal, decontamination procedures.
Disposal of radioactive wastes, general methods of disposal, management of radioactive waste in medical radiation facilities.

14. Transport of Radioactive Material

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.

15. Regulatory Aspects for Medical Radiation Facilities

National legislation, regulatory framework, relevant regulatory documents such as Act, Rules, applicable safety codes, standards, guides and manuals, radiation surveillance procedures; regulatory control- licensing, inspection and enforcement; responsibilities of employer, licensee, Radiological Safety Officer (RSO), technologist, radiation workers and radioisotope supplier.
Regulatory requirements for import/export, procurement, use, handling, transfer and disposal of radioisotopes, inventory control, Radiation Protection Programme (RPP).

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.

16. Radiation Emergencies and Medical Management

Radiation accidents and emergencies in the use of radiation sources and equipment in radiotherapy, nuclear medicine and diagnostic radiology, radiation safety during source transfer operations, source stuck and handling procedures, loss of radiation sources, their tracing and recovery, case studies and lessons learned, Radiation injuries and medical management.

17. Emergency Response Plans and Preparedness

Normal and potential exposures, 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, responsibilities of employer, licensee, RSO, technologist, radiation workers and radioisotope/ equipment supplier in case of emergency.

Training Course on Radiation Safety (TCRS-2)

No. AERB/RSD/RSO-IRF/Syllabus/2012

RSO Certification for Industrial and Research Radiation Facilities (RSO-IRF)

Introduction

In recent times ionizing radiations have found wider applications in various industrial and research radiation facilities, such as food processing for food security and safety, sterilization of medical products, non-destructive testing (NDT), online monitoring of process parameters using nucleonic gauges, tracer studies and other research applications. In such radiation facilities safety of both, occupational workers and members of the public is of paramount importance. Supervising and operating personnel in such facilities must therefore possess in-depth knowledge of radiation safety, including design and operational aspects of the equipment/facility.

Industrial and research applications of ionizing radiations, related radiation safety aspects and comprehensive in-house training form the part of Diploma in Radiological Physics (Dip. R. P.) programme of Homi Bhabha National Institute (HBNI). Accordingly, Dip. R. P. qualified candidates are eligible for certification for RSO in industrial and research radiation facilities, such as Radiation Processing Facilities, Industrial Radiography, Industrial Accelerator, facilities using Ionising Radiation Gauging Devices/Nucleonic gauges and facilities involved in research applications with ionizing radiations. Therefore, candidates after successful completion of Dip. R. P. programme are required to undergo the certification examination as specified above. The prescribed syllabus shall be the part of the syllabi of the above mentioned course.

Eligibility Criteria:

I. Post M. Sc. Diploma in Radiological Physics (Dip. R. P.), based on the minimum course content on radiation safety prescribed by the Competent Authority; from a recognized University/Institution.

Examination:

The examination shall consist of;

I. A written paper of 100 marks (80 marks descriptive + 20 marks objective)
II. Viva-voce of 100 marks

Passing Criteria:

I. Not less than 50% each in written and viva-voce examinations
II. Not less than 60% in aggregate.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

Syllabus for the Examination:

1. Basic Radiation Physics

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

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

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

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

5.1 Principles of Radiation Detection

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

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

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

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

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

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

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

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

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

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

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

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 Aspects for Industrial and Research Radiation Facilities

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).

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)

17. Emergency Response Plans and Preparedness

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.

18. Radiation Emergencies and Medical Management

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.

Training Course on Radiation Safety (TCRS-3)

No. AERB/RSD/RSO-NM/Syllabus/2012

RSO Certification for Nuclear Medicine Facilities (RSO-NM)

Introduction:

Presently, medical institutions affiliated to universities and having nuclear medicine departments are conducting the degree and diploma courses in Nuclear Medicine Technology. In addition, physicians are also undergoing degree and diploma courses in radiation medicine from institutions recognized by Medical Council of India. Radiological Physics and Advisory Division (RP&AD), BARC conducts Radiological Safety Officer (RSO) examination and successful candidates are eligible to be approved as RSO by AERB on nomination by the respective institutions. Considering the viewpoint that the Nuclear Medicine courses may be conducted by various educational institutions, there is a need to evolve a unified syllabus on radiation safety and related regulatory aspects for its implementation by the concerned institutions.

The prescribed syllabus shall be the part of the syllabi of all the above mentioned courses. The RSO certification examination shall be an independent procedure to evaluate successful candidates of the above mentioned courses using a uniform examination system.

Eligibility Criteria:

(i) A post-graduate degree/diploma in Nuclear Medicine Technology from a recognized University/Institution; or

(ii) A post-graduate degree/diploma in Nuclear Medicine from a recognized University/Institution; or

(iii) A degree/diploma in Nuclear Medicine recognized by Medical Council of India.

Examination:

The examination shall consist of;

I. A written paper of 100 marks (80 marks descriptive + 20 marks objective)
II. Viva-voce of 100 marks

Passing Criteria:

I. Not less than 50% each in written and viva-voce examinations
II. Not less than 60% in aggregate.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

Syllabus for the Examination :

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), 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

Interaction of charged particles with matter, range of charged particles, 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), interaction of neutrons with matter.

3. Radiation Quantities and Units

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

Interaction of radiation with cell, direct and indirect interactions, mechanism of radiation damage in living cells, tissue/organ damage, pre-natal effects, modifying factors, chromosomal aberration, somatic and genetic effects, deterministic and stochastic 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, dose constraints for comforters of patients.

6. Radiation Detection and Measurement

Principle of radiation detection, gas detector (ionization chamber, proportional counter and GM counter), solid state detector (scintillator, semiconductor 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 devices, calibration and response of radiation monitoring instruments,.

7. Radiation Hazard Evaluation and Control

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

8. Working Principle of Nuclear Medicine Equipment

Working principle of isotope calibrators, Planar Gamma Camera, SPECT, PET, PET-CT and Medical Cyclotron.

9. Radiation Dosimetry

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.

10. Quality Control (QC) in Nuclear Medicine

Importance of QC in Nuclear Medicine, test parameters and procedures for QC of isotope calibrator, Planar Gamma Camera system, SPECT, PET, PET-CT and radiopharmaceuticals.

11. Radionuclide Therapy- Radiation Safety Aspects

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.

12. Disposal of Radioactive Waste

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

13. Planning of Nuclear Medicine (NM) Facilities

Classification and general features of NM laboratories (site, typical floor plans, ventilation, surface, walls, floor and ceiling, work surfaces, containment systems, fume-hood, glove box etc.), planning of NM laboratories, such as diagnostic and high dose therapy, PET-CT and medical cyclotron installation, shielding evaluation of NM laboratories and medical cyclotron, model layouts of various NM laboratories.

14. 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, general requirement of all packaging, requirements for transport of radioactive material in liquid form, preparation, marking, labelling of packages, preparation of transport documents (Consignors Declaration, TREM Card, Instructions to the Carrier & Emergency in Writing) and general instructions.

15. Radiation Accidents, Case Studies and Lessons Learned

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, fire accidents and explosions; follow up actions through emergency response plans, case studies and mitigation, lessons learned.

16. Regulatory Aspects for Nuclear Medicine Laboratories

Regulations with respect to nuclear medicine laboratories, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO), technologist and radioisotope supplier, Safety and security of radioactive sources during transport and storage, inventory control, security provisions: administrative and technical measures, graded approach in security provision, physical protection system.

Regulatory requirements for import/export, procurement, use, handling, transfer and disposal of radioisotopes; inventory control, Radiation Protection Program (RPP).

17. Emergency Response Plans and Preparedness

Normal and potential exposures, accident situations involving radioisotopes, 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.

18. Diagnostic Radiology

Physical principles of X-ray diagnosis, density, contrast, detail and definition of radiographs, 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, 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.

Training Course on Radiation Safety (TCRS-4)

No. AERB/RSD/RSO-DR/Syllabus/2012

RSO Certification for Service Engineers/QA Service providers in Diagnostic Radiology (RSO-DR)

Introduction:

Diagnostic radiology accounts for the largest fraction of human exposure to ionizing radiation from man-made sources. A large number of diagnostic radiology facilities are operational over the country which are highly diverse in nature, with respect to its application and associated hazard potential. The eligibility criteria for approval of RSO 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, periodic quality assurance tests of diagnostic x-ray equipment and proper training to radiological staff and service engineers are necessary. Therefore, a radiation safety module is prepared for personnel involved in servicing, maintenance, quality assurance and operation of medical x-ray equipment for enhancing their knowledge about radiation safety and quality assurance in diagnostic radiology. This training module is for RSO certification for service engineers of manufacturers/suppliers and QA service providers of medical x-ray equipment.

For registration category x-ray facilities, (i.e. general x-ray machine such as radiography/fluroscopy, mammography, dental, BMD), the appropriate Registrant/x-ray technologist is entrusted to discharge the duties and responsibilities of RSO. For licence category i.e. computed tomography and interventional radiology the Radiologist/Related Medical Practitioner/x-ray technologist with three years experience with appropriate knowledge of radiation safety are directly considered for Radiological Safety Officer.

Eligibility Criteria:

(i) Degree/Diploma in electrical/ electronics /biomedical/ mechanical engineering or in an associated discipline form a recognized University/Institution

or,

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

Duration: 7 (Seven) working days

Examination:

The examination shall 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.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

Course Content:

A. Lectures (24 h)

		Duration
1.	Basic Radiation Physics	1 h
2.	Production of X-rays	1 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 Hazard Evaluation and Control	2 h
9.	Principles of Diagnostic Radiology	2 h
10.	X-ray Imagining Devices	1 h
11.	X-ray Imaging Techniques	1 h
12.	Planning of Diagnostic X-ray Installation	2 h
13.	Quality Assurance of conventional X-ray equipments	2 h
14.	Quality Assurance of CT Scanners	2 h
15.	Quality Assurance of Interventional X-ray equipments	1 h
16.	Regulatory Aspects of Diagnostic Radiology	1 h
17.	Radiation Incidents and Case Studies	1 h

B. Discussion : 3 h

C. Practical : (12 h)

1.	Quality Assurance and radiation protection survey of a conventional X-ray installation	3 h
2.	Quality Assurance and radiation protection survey of interventional X-ray equipments	3 h
3.	Quality Assurance and radiation protection survey of a CT Scanner installation	6 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, X-rays and gamma rays, energy of ionizing radiation, half-life, effective half-life and production of radioisotopes.

2. **Production of X-rays**

   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).

3. **Interaction of Radiation with Matter**

   Interaction of electrons with matter, bremsstrahlung, 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**

   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, deterministic and stochastic (probabilistic) effects, effects of partial and whole body exposures.

6. **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, guidance level for patient dose reduction in radio-diagnosis, dose constraints for comforters of patients.

7. **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 devices, calibration and response of radiation monitoring instruments.

8. Radiation Hazard Evaluation and Control

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 calculation, requirement of filters with respect to kV of the machine, leakage radiation assessment by workload consideration, radiation protection in diagnostic radiology and radiation protection accessories.

9. Principles of Diagnostic Radiology

Fundamentals of diagnostic radiology, physical principle of image formation, limitations of conventional X-ray imaging, image contrast, contrast media, intensifying screens, optical density, characteristics of X-ray film, fluoroscopic screens, image intensified fluoroscopy, methods to reduce scattered radiation, Bucky grids and image quality.

10. X-ray Imagining Devices

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.

11. X-ray Imaging Techniques

Radiography and fluoroscopy, CT scanning, digital subtraction angiography (DSA), mammography, interventional radiology, digital radiology, bone densitometry and dental radiology.

12. Planning of Diagnostic X-ray Installation

General principles of planning of diagnostic installations, site selection, area requirement, workload, shielding material, openings and ventilation, illumination control, X-ray installation layout- control panel, patient waiting area, warning light and placard; model layouts of x-conventional x-ray, CT Scanner and interventional radiology installations.

13. Quality Assurance in Conventional X-ray equipments

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, QA mammography, dental equipment and bone mineral density (BMD) analysis equipment.

14. Quality Assurance of CT Scanners

Importance of QA for CT scanners, test parameters and procedures for electro-mechanical, imaging characteristic, dosimetry and leakage tests; CT number uniformity, linearity and reproducibility; slice width measurement, high and low contrast evaluation, measurement of CTDI/weighted CTDI, leakage through tube housing and collimator,

15. Quality Assurance of Interventional X-ray equipments

Importance of QA in interventional radiology equipments, test parameters and test procedures for congruence of optical and radiation fields, effective focal spot size, exposure time, applied tube potential, total filtration, table top exposure and 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.

16. Regulatory Aspects of Diagnostic Radiology

Regulations with respect to diagnostic radiology, relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO), radiologist and Medical Radiographer (Technician); regulatory requirements for import, procurement, installation, commissioning, operation, transfer, dismantling and decommissioning of diagnostic equipment, Radiation Protection Programme (RPP).

17. Radiation Incidents and Case Studies

Radiation incidents involving X-ray equipment, over-exposure investigation and case studies.

Training Course on Radiation Safety (TCRS-5)

No. AERB/RSD/RS-RTT/Syllabus/2012

Radiation Safety Certification for Radiotherapy Technologists (RS-RTT)

Introduction:

Radiotherapy is an effective technique of managing the cancer. It is a team work which utilizes services of different experts including trained radiotherapy technologists. Radiotherapy technologists play very important role in precise delivery of dose to the tumour. Radiotherapy technologists are responsible for the safe operation of radiotherapy equipment, which ensures the safety of the patient undergoing treatment, and safety of the radiation workers involved in the process. It is necessary for them to discharge their duty effectively. With the advancement of technology, conventional therapy machines in a radiotherapy department are being replaced by the state-of-the-art treatment delivery and simulation equipments. To be in phase with this change, the knowledge of technologists has to be up-dated periodically. The training course on Radiation Safety Certification for Radiotherapy Technologists has been structured for meeting the goal of treatment, simulation and safety.

Eligibility Criteria:

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

(ii) Two years' radiation therapy technologists' course or equivalent, based on the minimum course content on radiation safety prescribed by the Competent Authority; from a recognized Institution with in-field training in radiotherapy.

Duration: 7 (Seven) working days

Examination:

The examination shall consist of;

I. A written paper of 80 marks (60 marks Objective +20 marks Descriptive)

II. 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.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

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	2 h
7.	Radiation Hazard Evaluation and Control	2 h
8.	Planning of Radiotherapy Facilities	2 h
9.	Quality Assurance (QA) of Radiotherapy Equipments	2 h
10.	Safety Aspects and Work Practices in Beam Therapy	1 h
11.	Safety Aspects in Brachytherapy Applications	1 h
12.	Radiation Safety during Source Transfer Operation	1 h
13.	Radiation Accidents, Case Studies and Lessons Learned	2 h
14.	Regulatory Aspects for Radiotherapy Facility	1 h
15.	Emergency Response Plans and Preparedness	1 h

B. Discussions: 2 h

C. Practicals: 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 scattering and pair production), absorption, scattering and attenuation of photons, Half Value Thickness (HVT) and Tenth Value Thickness (TVT), shielding material, interaction of neutrons with matter.

3. Radiation Quantities and Units

Activity(Becquerel & Curie), energy, exposure(C/kg & Roentgen), air kerma, absorbed dose (Gray & rad), charge particle equilibrium, 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 cells, chromosomal aberration, somatic and genetic effects, deterministic and stochastic (Probabilistic) effects, partial body and whole body exposures.

5. Operational Limits

Introduction 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 devices, 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, 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 Equipments

Need and necessity of QA in radiotherapy, QA test parameters and role of technologist in periodic QA checks of Telecobalt, Medical Linear Accelerator and Remote Afterloading Brachytherapy.

10. Safety Aspects and Work Practices in Beam Therapy

Treatment Planning, control panels, warning signal, leakage radiation, beam control, familiarization and handling of treatment accessories (blocks, wedges, compensators etc.)

11. Safety Aspects in Brachytherapy Applications

Radiation safety in receipt of sources, inspection of applicators, radiographic localization of implants, patient monitoring prior to discharge, source storage and inventory control, radiation safety in Remote Afterloading Techniques.

12. 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 Afterloading Brachyrherapy equipments, role of technologist.

13. 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.

14. Regulatory Aspects for a Radiotherapy Facility

Regulations with respect to radiotherapy facilities, relevant regulatory documents such as Act, Rules, Codes, Standards and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO) and Radiation Therapy Technologist (RTT), radiotherapy source/equipment supplier.

Regulatory requirements for import/export, procurement, use, handling, transfer and safe disposal of radioactive material/equipment, inventory control, Radiation Protection Programme (RPP).

Safety and security of radioactive sources during transport and storage, security provisions: administrative and technical measures, graded approach in security provision.

Types of packages, category of packages, procedure for marking, labeling, transport index (TI), transport documents.

15. Emergency Response Plans and Preparedness

Normal and potential exposure, 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, technologist and radiotherapy source/equipment supplier in case of emergencies, probable emergency situations (failure of pneumatic system, improper functioning of timer, software mix-up in accelerator etc.)

Training Course on Radiation Safety (TCRS-6)

No. AERB/RSD/RS-SRE/Syllabus/2012

Radiation Safety Certification for Service Engineers of Radiotherapy Equipments (RS-SRE)

Purpose

Radiotherapy uses radiation beams from Co-60 gamma rays, high energy X-rays and electrons, protons, neutrons and high activity gamma and beta emitting sources for various implants. About 444 TBq (12000 Ci) of Co-60 and 370 GBq (10 Ci) of Ir-192 sources are generally loaded in telecobalt and remote afterloading brachytherapy units respectively. Because of use of high energy radiation and very high activity of sources negligence to safety during the servicing/maintenance or source loading operation of the equipment may lead to serious radiation accidents. Such radiation accidents necessitate elaborate and expensive management of the situation. Servicing of medical linear accelerators and remote operated brachytherapy machines also entail safety related problems of various proportion typical to these equipment. It is therefore necessary that personnel, who carry out the servicing/maintenance or source loading operation of these equipment, are trained in radiological safety aspects and radiation protection methodologies. This training course is meant for providing necessary training in these aspects to the service engineers. As per AERB stipulations, certification for handling radiotherapy equipment is a mandatory requirement for radiotherapy service engineers.

Eligibility Criteria:

(i) Basic Diploma/Degree in electrical/ electronics/ biomedical/ mechanical engineering from a recognized University/Institution; and

(ii) Certification from the Competent Authority for handling radiation therapy equipment.

Duration: 7 (Seven) working days

Examination: The examination shall 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.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

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	2 h
7.	Radiation Hazard Evaluation and Control	2 h
8.	Planning of Radiotherapy Facilities	2 h
9.	Quality Assurance (QA) of Radiotherapy Equipments	4 h
10.	Transport of Radioactive Material	1 h
11.	Radiation Safety during Source Transfer Operation	1 h
12.	Radiation Accidents, Case Studies and Lessons Learned	1 h
13.	Regulatory Aspects for Radiotherapy Facility	1 h
14.	Emergency Response Plans and Preparedness	1 h

B. Discussion : 2 h

C. Practicals: 8 hrs

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 devices, 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 Equipments

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 Afterloading Brachyrherapy equipments, role of service engineers.

12. 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.

13. 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.

Safety and security of radioactive sources during transport and storage, security provisions: administrative and technical measures, graded approach in security provision.

14. 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.).

Training Course on Radiation Safety (TCRS-7)

No. AERB/RSD/RSO-RPF/Syllbus/2012

RSO Certification for Radiation Processing Facilities (RSO-RPF)

Introduction:

In recent times ionizing radiations have found wider applications in various industrial processes. Its unique but remarkable effectiveness in food processing for food security and safety, sterilization of medical products, mutation breeding, cross-linking of wires, vulcanization of rubber, wood-polymer and other industrial processes have now been well established. Thus the utility of radiation and radioisotopes has helped immensely in streamlining protocol for many industrial processes.

Industrial radiation processing facilities commonly known as irradiators contains high intensity γ-radiation sources or machine sources (electrons and photon accelerators) along with source storage (DM plant), conveyer systems, ventilation system and other supportive electrical/ mechanical / electronic devices, hydraulic/pneumatic systems connected to each other by interlock systems for enhanced radiation safety.

Radiation doses required to achieve desirable effect range from a tens of Gy to several kGy. Since these radiation doses are detrimental to human health, utmost care needs to be taken during operation of these facilities. Even during the transportation of radiation sources (γ-sources) from the place of its supplier to radiation processing facility, radiation hazards could occur if proper care is not taken with respect to procedure for safe transport of radioactive material. In such irradiation facilities both personnel and product safety are therefore of paramount importance. Supervising and operating personnel in such facilities must therefore possess in-depth knowledge of radiation safety, including design and operational aspects of the equipment/facility. This necessitates the need of establishing effective training programme for the personnel involved in operation and safety of radiation processing facility.

Training course covering radiation safety aspects and operational features of industrial radiation processing facility caters to the need of imparting training to personnel to function as Radiological Safety Officer (RSO).

Eligibility Criteria:

I. Basic degree in Science with physics as one of the subject from a recognized University/Institution; or

II. Diploma in Engineering from a recognized University/Institution with minimum of five years experience in radiation surveillance; supported by personnel monitoring badge (TLD) service in a radiation processing facility.

Duration: **12 weeks (300 h)**
{6 weeks (150 h) Theory and Practical + 6 weeks (150 h) Field Training}

Examination:

The examination shall 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.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

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 (32 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	Transport of Radioactive Material	2 h
2.9	Disposal of Radioactive Waste	2 h
2.10	Quality, Health, Safety and Environment (QHSE)	1 h
2.11	Management of Radiation Processing Facility	2 h
2.12	Radiation Accidents, Case Studies and Lessons Learned	3 h
2.13	Emergency Response Plans and Preparedness	2 h
2.14	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: Practicals : 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: 10 h

Technical visits to Gamma and Electron beam radiation processing facilities.

E. FIELD TRAINING: 6 weeks (150h)

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).

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.

2.8 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.

2.9 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.

2.10 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.

2.11 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.

2.12 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

2.13 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.

2.14 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.

Training Course on Radiation Safety (TCRS-8)

No. AERB/RSD/RS-Operator-RPF/Syllbus/2012

Radiation Safety Certification of Operators for Radiation Processing Facilities

(RS-Operator-RPF)

Introduction:

Efficacy of radiation and radioisotopes in promoting industrial growth without compromising safety and quality of end product has been well established. Its status as an inseparable process parameter in many industrial processes has also been realized globally. Use of high intensity and highly penetrating ionizing radiations for sterilization of health care products is perhaps the most beneficial application. The other applications include processing of food & allied product, cross-linking of wires & cables, vulcanization of rubber, wood-polymer composites (WPC), imitation jewellery, etc. Radiation doses required to achieve desirable effect range from a tens of Gy to several kGy. Since radiation doses are detrimental to human health, these facilities need to be operated and maintained as per the stipulated regulatory procedures. Effectiveness of the process therefore will depend mainly on (i) proper delivery of dose, (ii) optimal operational period with minimal breakdown of the facility and (iii) trained manpower.

Industrial radiation processing facilities commonly known as irradiators contains high intensity γ-radiation sources or machine sources (electrons and photon accelerators) along with source storage (DM plant), conveyer systems, ventilation system and other supportive electrical/ mechanical / electronic devices, hydraulic/pneumatic systems connected to each other by interlock systems for enhanced radiation safety.

It is therefore imperative that such facilities are manned by personnel adequately trained in operation & maintenance, precise dose deliver and radiation safety aspects. They must also be capable of ensuring proper dose delivery to a given product. This necessitates the need of establishing effective training programme for the personnel involved in the facility operation/maintenance and radiation safety.

Training course covering above aspects caters to the need of imparting training to personnel to function as operators of such radiation processing facilities.

Eligibility Criteria:

I. Basic degree in Science from a recognized University/Institution; or,

II. Diploma in Engineering from a recognized University/Institution

Duration: Six Weeks (150 h)
{4 weeks Theory and Practical (100 h)+ 2 weeks Field Training (50 h)}

Examination : The examination shall 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.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

Course Content:

<u>Paper 1:</u> Radiation Physics, Radiobiology and Radiation Measurement (22 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	3 h
1.5	Operational Limits	2 h
1.6	Radiation Detection and Measurement	4 h
1.7	Radiation Hazard Evaluation and Control	4 h
1.8	Radiation Protection Standards	2 h
1.9	Radiation Sources/Generators and their Properties	2 h

<u>Paper 2:</u> Design Features, Radiation Safety and Regulatory Aspects of Radiation Processing Facility (17 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	Planning of Radiation Processing Facilities	1 h
2.5	Regulatory Aspects for Radiation Processing Facilities	2 h
2.6	Transport of Radioactive Material and Disposal of Radioactive Waste	2 h
2.7	Management of Radiation Processing Facility	1 h
2.8	Radiation Accidents, Case Studies and Lessons Learned	2 h
2.9	Emergency Response Plans and Preparedness	2 h
2.10	Medical Management of Radiation Accidents	1 h

<u>Paper 3:</u> **Radiation Dosimetry, Process Control and Radiation Processing Technology** **(24 h)**

A.3 **Lectures:** **Duration**

3.1	Radiation Dosimetry		**<u>8 h</u>**
	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		**<u>5 h</u>**
	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		**<u>4 h</u>**
	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		**<u>1 h</u>**
3.5	QA Programme in Commercial Irradiation Facility (Personnel and Product Safety)		**<u>1 h</u>**
3.6	Other Applications of Radiation Processing Technology		**<u>3 h</u>**
3.7	Food Irradiation Regulations (Codes, Standards, Guides)		**<u>2 h</u>**

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: 2 weeks (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, isotopes, radioisotopes, radioactivity, natural and artificial radioactivity, specific activity, electron capture, internal conversion, radioactive decay, decay constant, decay chain, half-life, mean life, general properties of alpha, beta and gamma radiation; beta ray spectra, gamma emission, , laws of radioactivity and successive transformation, radioactive equilibrium, 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

Activity, energy, exposure, cross section, linear and mass absorption coefficient, stopping power and LET, W-value, charge particle equilibrium (CPE), air kerma, absorbed dose, rate constant, 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 and collective effective dose.

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, 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

Principle of radiation detection, gas detectors (ionization chamber, GM detector, proportional counter), solid state detectors (scintillators, semiconductors and thermoluminescent Dosimeter {TLD}), chemical detectors, photochromic emulsion (films), dead time, resolving time, semiconductor devices and 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 devices, TLD badges, difference between area and personnel monitoring, 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, 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 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, types of encapsulation, method of preparation of sources, prototype type tests, acceptance criteria, leak test methods, sealed source classification.

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.

Design and safety features of industrial X-ray/electron accelerators, classification of EB accelerators, depth dose, categories of EB accelerators, principle of electron beam and photon accelerator, accelerator hazards: electrical safety, magnetic safety, RF and microwave safety, SF_6 gas safety: ventilation requirement, operation procedures, safety interlocks, preventive maintenance, merits and demerits of machine source applications.

2.4 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.

2.5 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, Food Irradiation Rules, licensing requirements, approval of Radiation Generating devices, consenting process: siting, design, construction, commissioning and operation, 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, Radiation Protection Programme (RPP).

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.

2.6 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, 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.

2.7 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.

2.8 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.

2.9 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.

2.10 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

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 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.

Training Course on Radiation Safety (TCRS-9)

No. AERB/RSD/RSO-GIC/Syllabus/2012

RSO Certification for Gamma Irradiation Chamber (Category-I Irradiators)

(RSO-GIC)

Introduction

The self-contained dry source storage gamma irradiator (Category-I) is also known as gamma irradiation chamber (GIC)/gamma cell (GC)/ blood irradiator (BI). GIC is used for variety of purposes, basically for research and development work such as sterilization or microbiological reduction in medical and pharmaceutical supplies, preservation of foodstuffs, radiation effect studies on material, chemical and polymer synthesis, whereas Blood Irradiator (BI) is primarily used for irradiation of blood and blood components. The number and types of irradiators supporting these applications are continually growing. Gamma irradiation chamber mainly contains Co-60 or Cs-137 as radiation source housed in Type B container. The source requirements for any particular irradiator may vary from several GBq to a few TBq. Due to high activity of radiation sources, there is potential to cause significant radiological hazards, if they are not handled as per the recommended safety procedures and not provided adequate physical security during their handling, transport and storage.

The Atomic Energy Regulatory Board (AERB) regulates the Gamma Irradiation Chambers (Category-I) irradiators by enforcing the regulatory provisions such as approval of planning and layout and availability of Radiological Safety Officer in such institutions. Training course on “RSO certification for Gamma irradiation Chamber”(Category-I Irradiator) caters to the need of imparting training to the candidates of these institutions for enhancing their knowledge to function as Radiological Safety Officer.

Eligibility Criteria:

I. Basic degree in Science from a recognized University/Institution; or
II. Diploma in Engineering from a recognized University/Institution

Duration: 7 (Seven) working days

Examination:

The examination shall 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.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

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	2 h
7.	Radiation Hazard Evaluation and Control	2 h
8.	Design, Principle and Applications of Gamma Irradiation Chamber	3 h
9.	Dosimetry and Calibration of Gamma Irradiation Chamber	2 h
10.	Planning of Gamma Irradiation Chamber Installation	1 h
11.	Quality Assurance (QA) of Gamma Irradiation Chamber	1 h
12.	Transport of Radioactive Material	1 h
13.	Regulatory Aspects of Gamma Irradiation Chamber Facility	2 h
14.	Radiation Accidents, Emergency Response Plans & Preparedness	1 h

B. Discussions : 2 h

C. Practical : 8 h (2 h each)

I. Radiation absorption characteristics, HVT & TVT measurement
II. Dose rate measurement in Gamma Irradiation Chamber
III. Radiation protection survey of Gamma Irradiation Chamber Facility
IV. Familiarization with the safety features and related regulatory requirements of Gamma Irradiation Chamber facility

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, deterministic and stochastic (probabilistic) effects, partial body and whole body exposures.

5. Operational Limits

Introduction to natural background radiation, concept of risk, philosophy of radiation protection, system of dose limitation, ALARA, dose limits to radiation workers and general public, AERB/ ICRP recommendation.

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 devices, 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 Irradiation Chamber

Design objective, types of irradiator, category-I irradiator and its principles of operation national/international design safety standards for gamma irradiation chamber (category-I irradiator) 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 Irradiation Chamber

Importance of dosimetry of GIC, types and working principles of dosimeters-film, chemical and soild state dosimeters used for GIC 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 Gamma Irradiation Chamber Installation

General principles of planning of GIC installation, site selection, area requirement, position of windows, openings and ventilation, shielding material, model layouts of GIC installations.

11. Quality Assurance (QA) of Gamma Irradiation Chamber

Need and necessity of QA of GIC, 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, 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.

13. Regulatory Aspects of Gamma Irradiation Chamber (GIC) Facility

Regulations with respect to handling of GIC, 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).

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.

14. Radiation Accidents, Emergency Response Plans and Preparedness

Radiation accidents involving GIC, orphan and vulnerable sources, handling of emergency situations resulting from damage to the GIC 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.

Training Course on Radiation Safety (TCRS-10)

No. AERB/RSD/RSO-IRGD-NG/Syllabus/2012

RSO Certification for Ionizing Radiation Gauging Devices (IRGDs)/Nucleonic Gauges (RSO-IRGD/NG)

Introduction:

The ionizing radiation has registered a phenomenal growth all over the world for a wide variety of peaceful purposes in industry, medicine, agriculture and research. In industry, a number of physical parameters are determined by using nucleonic gauges (NGs) also known as ionizing radiation gauging devices (IRGDs) containing sources of ionizing radiation, i.e. charged particles – alpha & beta rays; gamma rays, X-rays, and neutrons. IRGDs/NGs are used for online industrial process control and quality control parameters. These include measurement of level of product in huge silos, tanks, density measurement, moisture content of soil, thickness measurement, concentration of hydrocarbons, ash content in coals, exploration of coal and oil and so on. The number of IRGDs/NGs is increasing every year in the country because of their wide industrial applications.

Different types of radiation sources with activity ranging from several MBq to few GBq are being used for this purpose depending on the applications and characteristics of sources. These include mainly ^{241}Am, ^{85}Kr, ^{90}Sr, ^{147}Pm, ^{55}Fe, ^{109}Cd, ^{60}Co, ^{137}Cs, ^{241}Am-Be, ^{252}Cf etc. Although the activity of sources used in IRGDs/NGs is very small, they have reasonably long half-life. In view of this, the sources would still have the potential to cause significant radiological hazards, if they are not handled safely and not provided adequate physical security during their use, transport and storage. This necessitates the need of establishing effective training programme for the personnel involved in handling of IRGDs/NGs.

Training course on radiation safety aspects in the use of IRGD/NG caters to the need of imparting training to personnel in the field of radiation safety and security of radiation sources for enhancing their knowledge to function as Radiological Safety Officer (RSO)

Eligibility Criteria :

I. Basic degree in Science from a recognized University/Institution; or;
II. Diploma in Engineering from a recognized University/Institution

Duration: 7 (Seven) working days

Examination:

The examination shall 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.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

Course Content:

A.	**Lectures**	**(19 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	3 h
	7.	Radiation Hazard Evaluation and Control	3 h
	8.	Principle and Applications of IRGDs /NGs	3 h
	9.	Design Safety Standards of IRGDs/NGs	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	1 h
	13.	Emergency Response Plans and Preparedness	1 h

B. **Discussions:** 3 h

C. **Practicals:** 8 h

1.	Radiation absorption characteristics and HVT/ TVT measurements, calibration of survey instruments	3 h
2.	Radiation protection survey of IRGDs /NGs installations	3 h
3.	Familiarization with regulatory requirements of IRGD/NGs and radiation protection program (RPP)	2 h

<u>Syllabus</u>

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, 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 TLD), radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, direct reading devices, 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; shielding materials, design of source housing and operational safety, storage facility for source housings, 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; X-ray fluorescence (XRF) techniques, neutron scattering gauges and principle of well logging, applications of sources in well logging, planning of gauging installations, storage requirement, safety and security of radioactive sources.

9. Design Safety Standards of IRGDs /NGs

Design objective, national/international design standard of IRGDs/NGs and sealed sources used in IRGDs/NGs, performance classification of IRGDs/NGs and sealed sources, acceptance criteria, leak testing, prototype tests, consideration of ambient environmental conditions, interlocks, auxiliary shielding, servicing/maintenance procedures, administrative controls, quality assurance.

10. 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, 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 Accidents, Case Studies and Lessons Learned

Radiation accidents involving IRGDs/NGs, orphan and vulnerable sources, handling of emergency situations resulting from damage to the source housing, unsafe disposal, missing/theft of IRGDs, fire accidents and explosions, transport accident, case studies and lessons learned.

12. Regulatory Aspects of IRGDs /NGs

Regulations with respect to handling of IRGDs/NGs, 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; regulatory requirements for import/export, procurement, use, handling, transfer and safe disposal of IRGDs/NGs, inventory control, Radiation Protection Program (RPP).

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. Emergency Response Plans and Preparedness

Normal and potential exposure, accident situations involving IRGDs/NGs, elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical procedures, responsibilities of employer, licensee, RSO and manufacturer /supplier in case of emergency.

Training Course on Radiation Safety (TCRS-11)

No. AERB/RSD/RSO-RA/Syllabus/2012

RSO Certification for Research Applications of Ionizing Radiation (RSO-RA)

Introduction

Radioisotopes have wide spectrum of applications in research studies especially in physio-chemical, bio-medical, agricultural, veterinary sciences, pharmaceuticals and industrial research. Unsealed radiation sources of different strength and physical forms are handled in such studies in open field as well as in laboratories. This could cause radiation incidents/accidents like surface contamination and air-borne contamination. Apart from these probable incidents, research activities in these fields generate radioactive wastes of different magnitude, from simple laboratory swipe to animal carcasses. Hence handling of radiation sources in such applications necessitates supervision from radiological safety standpoint. The Competent Authority of the country has regulated the research applications using radiation sources by enforcing that the supervision of Radiological Safety Officer is mandatory in such institutions. 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 etc.

Although the activity of sources used in research applications is very small, these sources will still have the potential to cause significant radiological hazards, contamination, if they are not handled safely. This necessitates the need of establishing effective training programme for the personnel involved in handling of radiation source for research applications.

Training course on radiation safety aspects in the research applications of ionizing radiation caters to the need of imparting training to personnel for enhancing their knowledge to function as Radiological Safety Officers.

Eligibility Criteria :

I. Basic degree in Science from a recognized University/ Institution; or,

II. Basic degree in Health Sciences (Veterinary/Pharmacy/biotechnology) from recognized University/ Institution; or,

III. Diploma in Engineering from a recognized University/Institution.

Duration: 7 (Seven) working days

Examination:

The examination shall 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.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

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	3 h
	7.	Radiation Hazard Evaluation and Control	3 h
	8.	Research Application of Ionizing Radiation in Medicine, Agricultural and Industry	2 h
	9.	Planning of Radioisotope Laboratories	1 h
	10.	Production of Radioisotopes and Labeled Compounds	1 h
	11.	Transport of Radioactive Material	1 h
	12.	Disposal of Radioactive Waste	1 h
	13.	Radiation Accidents, Case Studies and Lessons Learned	1 h
	14.	Regulatory Aspects for Radioisotope Laboratories	1 h
	15.	Emergency Response Plans and Preparedness	1 h

B. **Discussions:** 2 h

C. **Practicals:** 6 h

1.	Radiation absorption characteristics and HVL/TVL measurement, calibration of survey instruments	2 h
2.	Contamination measurement & decontamination procedures	2 h
3.	Radiation protection survey of radioisotope laboratory	2 h

D. **<u>Technical Visit to Radioisotope Laboratory</u> :** 6 h

1. Radiation protection survey of radioisotope laboratory.
2. Safety aspects during preparation of radio-labeled compounds

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, 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 TLD), liquid scintillation counting systems, nuclear counting statics, radiation monitoring instruments, personnel monitoring, area monitoring, survey meters, contamination monitor, direct reading devices, 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; shielding materials, specific gamma ray constant, external radiation monitoring, survey meters, Internal hazard evaluation and control, Annual limit of intake (ALI), control of open source (e.g. fumehood, glove box etc.), 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. Research Application of Ionizing Radiation in Medicine, Agricultural and Industry

Application of ionizing radiation (IR) in medicine, agricultural and industry, using sealed and unsealed sources, carbon-dating, tracer studies.

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, typical floor plans, ventilation, surfaces, walls, floor and ceiling, work surfaces, containment systems, fume-hood, glove box), 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), production of labeled compounds, storage of radio-labeled compounds, quality and purity of radio-labeled compounds.

11. 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, 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.

12. Disposal of Radioactive Waste

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

13. Radiation Accidents, Case Studies and Lessons Learned

Radiation accidents involving radioisotopes, orphan and vulnerable sources, handling of emergency situations resulting from spillage of liquid radioisotope solution, loss of radioisotope, theft/missing of isotope consignment, unsafe discharge of contaminated material, fire accidents and explosions, case studies and lessons learned.

14. Regulatory Aspects for Radioisotope Laboratories

Regulations with respect to handling of radioisotopes in radioisotope laboratories, relevant regulatory documents such as Act, Rules, Code, Standard and Guides, responsibilities of employer, licensee, Radiological Safety Officer (RSO) and radioisotope supplier; regulatory requirements for import/export, procurement, use, handling, transfer and safe disposal/discharge of radioisotopes; inventory control, Radiation Protection Program (RPP).

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.

15. Emergency Response Plans and Preparedness

Normal and potential exposure, 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 and radioisotope supplier in case of emergency.

Training Course on Radiation Safety (TCRS-12)

No. AERB/RSD/RSO-RCL/Syllabus/2012

RSO Certification for Radiological Calibration Laboratories (RSO-RCL)
(Radiation Monitoring Instruments and Personnel Monitoring Badges)

Introduction

The ionizing radiation has registered a phenomenal growth for various applications in medicine, industry, agriculture and research. Different types of radiation sources are being used for these purposes depending on the application and characteristics of sources. It is very essential to monitor the radiation fields involved in the handling of radiation sources with the help of radiation monitoring instruments. 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 radiation monitoring instruments and other interested agencies may setup the calibration facilities for radiation monitoring instruments with due regulatory approval. Handling of radiation sources in calibration laboratories for monitoring instruments requires the availability of properly trained and certified Radiological Safety Officer (RSO). This necessitates the need of establishing effective training programme for the personnel involved in handling of radiation sources in radiological calibration laboratories.

Routine monitoring of the radiation workers is the regulatory requirement for assessing their occupational doses at the workplace. To cater to the need of providing personnel monitoring service to the workers through established personnel monitoring badges, a few laboratories have been accredited to render this service. The personnel monitoring badge service providing laboratories require to possess and handle the radiation source with activity in the range MBq to GBq for routine calibration of personnel monitoring badge reader system.

Adequate safety measures need to be observed while handling of radiation sources during calibration of radiation monitoring instruments and personnel monitoring badges. In view of this requirement a training programme has been evolved for providing adequate knowledge to Radiological Safety Officers (RSO) who will be ensuring safety during handling of radiation sources. In addition to knowledge of radiation safety aspects the RSO of these laboratories should have adequate knowledge of radiation dosimetry in respect of calibration of radiation monitoring instruments and personnel monitoring badges.

Eligibility Criteria:

I. Basic degree in Science from a recognized University/Institution; or
II. Diploma in Engineering from a recognized University/Institution

Duration: 10 (Ten) working days

Examination:

The examination shall 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.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

Course Content:

A.	**Lectures (26)**	**Duration**
1.	Basic Radiation Physics	1h
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
7.	Radiation Detection and Measurement including Personnel Monitoring Devices	3 h
8.	Design and Operation of Calibration Exposure Devices (CED)	1 h
9.	Radiation Hazard Evaluation and Control	2 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.	Radiation Accidents, Emergency Response Plans and Preparedness	1 h

B. Discussions : 2 h

C. Practical : 14 h

1.	Radiation absorption characteristics, HVT & TVT measurement	2 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), interaction of neutrons with matter.

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, deterministic and stochastic (probabilistic) effects, partial body and whole body exposures.

6. Operational Limits

Introduction to natural background radiation, concept of risk, philosophy of radiation protection, system of dose limitation, ALARA, dose limits to radiation workers and general public, AERB/ ICRP recommendation.

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 devices, calibration and response of radiation monitoring instruments and personnel monitoring badges.

8. Design and Operation of Calibration Exposure Devices (CED)

Types of exposure devices, design principles, construction, source housing, built in safety features, attenuators, operational aspects, performance standards, quality assurance of CED.

9. 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.

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 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 (Consignors 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).

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.

15. 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 of radioisotope, fire accidents 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.

Training Course on Radiation Safety (TCRS-13)

No. AERB/RSD/RSO-NORM/Syllabus/2012

RSO Certification for Industries handling Naturally Occurring Radioactive Material {NORM} (RSO-NORM)

Introduction

The predominant industrial processes which require handling of Naturally Occurring Radioactive Materials (NORMs) are processing of Beach Sand Minerals, Columbite Tantalite Ore and Rock Phosphate and Phosphogypsum.

In India heavy mineral sand deposits containing ilmenite, rutile, leucoxene, zircon, garnet, sillimanite and monazite occur mostly along the coastal areas of the peninsular regions and in the form of inland sand dunes near the coast. Mining and processing of these heavy Beach Sand Minerals (BSM) other than monazite is carried out in different parts of the country by many Private and Public Sector Industries. However, during preferential separation of BSM other than monazite, the tailings generated get enriched in monazite containing uranium and thorium.

Similarly processing of Columbite Tantalite Ore and Rock Phosphate results in generation of uranium and thorium bearing slag and radium bearing phosphogypsum respectively. Oil & gas shales, fly ash, metal slag from processing of aluminium, zinc, tin, copper etc. are also known to contain enhanced concentration of NORMs. The presence of these NORMs warrant the need to control exposures of workers and members of the public in accordance with the various regulatory and safety requirements. This necessitates the need of establishing effective training programme for the personnel involved in handling the NORMs.

Training course covering above aspects caters to the need of imparting training to personnel for enhancing their knowledge to function as Radiological Safety Officers for NORM industries.

Eligibility Criteria :

I. Basic degree in Science from a recognized University/Institution.

Duration: 7 (Seven) working days

Examination: The examination shall 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.

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

Course Content:

A. Lectures (19 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	3 h
7.	Radiation Hazard Evaluation and Control	2 h
8.	Generation of NORM in Industrial Process	2 h
9.	Disposal of NORM & TENORM: Principles and Practices	3 h
10.	Regulations applicable to Transport of NORM	1 h
11.	Regulatory Aspects for NORM Industries	1 h
12.	Operational Health Physics Aspects in NORM Industries	2 h

B. Discussions: 3 h

C. Practical: 8 h (2h each)

1. Demonstration on counting system, survey instruments, contamination monitors
2. Calibration check of radiation monitoring instruments
3. Radioactivity monitoring in workplace and environment
4. Sample counting

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 (physical and biological), natural radioactive series, radioactive equilibrium, radioactive daughter products of uranium and thorium, NORM & TENORM, cosmic radiation

2. Interaction of Radiation with Matter

Alpha and beta particles, ionization and excitation, specific ionization, linear energy transfer (LET), 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, shielding materials, Half Value Thickness (HVT) and Tenth Value Thickness (TVT).

3. Radiation Quantities and Units

Activity(Becquerel & Curie), specific activity, 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), collective effective dose (Person Sv), ALI (Bq) and DAC (Bq/m^3).

4. Biological Effects of Radiation

History of radiation effects, interaction of radiation with cell, direct and indirect interactions, effect of radiation on living cells, formation of free radicals, chromosomal aberration, somatic and genetic effects, acute & chronic exposures, deterministic and stochastic (probabilistic) effects, dose, dose rate dependence, typical levels of exposures from natural and man-made sources, studies of high background radiation areas (HBRA),

5. Operational Limits

Introduction to natural background radiation, concept of risk, philosophy of radiation protection, system of dose limitation, ALARA, radon working levels (WL), dose limits to radiation workers and general public, AERB/ ICRP recommendations.

6. Radiation Detection and Measurement

Principle of radiation detection, gas filled detectors (ionization chamber, proportional counter and GM counter), solid state detectors: scintillators (organic, inorganic), semiconductor detectors, other detectors, Thermoluminescence detectors (TLD): principle and personnel dose measurement; direct reading devices, radiation monitoring instruments, basic counting statistics, personnel monitoring, survey meters, area/zone monitoring, calibration and energy response of radiation monitoring instruments, maintenance-do's & don't's.

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, survey meters, internal hazard evaluation and control, ALI, environmental control, protective clothing, contamination monitoring (direct and indirect), air contamination monitoring, general bioassay procedures, derived air concentration (DAC) (Bq/m^3), personnel contamination monitoring, decontamination procedures, personnel decontamination, external and internal decontamination.

8. Generation of NORM in Industrial Process

Radiation hazard in various steps of beach sand minerals processing, columbite-tantalite (COLTAN) ore processing, rock phosphate processing, metal slags, oil and gas shales handling and other NORM industries.

9. Disposal of NORM & TENORM: Principles and Practices

Radioactive waste disposal philosophy, origin and types of NORM and TENORM residues, classification of wastes and methods of disposal, selection of disposal sites, environmental safety analysis.

10. Regulations applicable to Transport of NORM

Criteria for exemption of NORM from transport regulations, Types of packages, category of packages, procedure for marking, labelling and transport index (TI), prepration of transport documents (Consignors Declaration, TREM card, instruction to the Carrier & Emergency in writing) and general instructions.

11. Regulatory Aspects for NORM Industries

Regulations with respect to handling of NORM, relevant regulatory documents such as Act, Rules, Code, Standard and Guides; responsibilities of employer, licensee, Radiological Safety Officer (RSO), regulatory requirements for import/export, procurement, use, handling, transfer and disposal of waste, maintenance of records and periodic document submission.

12. Operational Health Physics Aspects in NORM Industries

Radiation survey, monitoring of waste, personnel monitoring, dose evaluation, ambient dosimetry.

Training Course on Radiation Safety (TCRS-14)

No. AERB/RSD/RT-1/Syllabus/2012

Certification in Industrial Radiography Testing: Level -1 (RT-1)

Introduction:

Radiography is one of the important non-destructive testing (NDT) techniques. Radiography ensures the integrity of equipment and structures such as vessels, pipes, welded joints, castings etc. The device, which is used for housing radiography source, is Industrial Gamma Radiography Exposure Device (IGRED), commonly known as radiography camera. Sealed radiation sources such as Cobalt-60 and Iridium-192 are loaded in the device. Industrial X-ray equipment is also used for radiography. During radiography, a sealed source is driven OUT/IN of the radiography camera through a guide tube with the help of a driving cable coupled to the source pencil assembly. Negligent and careless operation of the radiography camera can lead to radiation incidents/accidents like source getting stuck-up in the guide tube, disengagement of source pencil from the drive cable etc., which may result in excessive exposure to radiation workers and unnecessary exposure to members of the public. Since industrial radiographers are responsible for the operation of radiography camera, it is necessary that they are properly trained, so that radiography is carried out with proper radiological safety. On successful completion of the training course, the approval is issued to the candidates to work as certified-radiographers. It is mandatory to employ the certified radiographers only, for carrying out industrial radiography. The training course is conducted as per the guidelines of ISO-9712.

Eligibility Criteria :

I. 10+2 or equivalent examination passed with Science subjects, and Mathematics in 10^{th} standard or equivalent from a recognized Board; and

II. minimum of six months experience supported by personnel monitoring badge service (TLD) as a trainee radiographer

Duration: 15 (Fifteen) working days

Examination:

The examination on Radiography Technique and Radiation Safety shall consist of;

I. Written Examination:

(a) Radiography Testing General (100 marks)
(b) Radiography Testing Specific (100 marks)
(c) Radiation Safety (100 marks)

II. Practical Examination including vive-voce

(a) Radiography Testing Specific (100 marks)
(b) Radiation Safety (50 marks)

Passing Criteria:

I. Not less than 70% each in written and practical examinations
II. Not less than 80% in aggregate

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

Course Content:

1. Radiation Safety

A. Lectures: (19 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 and Operational Safety Aspects of Radiography Device/Equipment	2 h
9. Transport of Radioactive Material	1 h
10. Radiation Accidents, Case Studies and Lessons Learned	2 h
11. Regulatory Aspects of Industrial Radiography	1 h
12. Emergency Response Plans and Preparedness	1 h

B. Practical: 12 hrs

1. Verification of inverse square Law, determination of the activity of a given source and calibration of radiation survey meter	3 h
2. Evaluation of HVT/TVT of the gamma radiation source	3 h
3. Assessment of the shielding adequacy of a radiography device	3 h
4. Functional performance test for industrial radiography devices	3 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), 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, deterministic and stochastic (probabilistic) effects, partial body and whole body exposures.

5. Operational Limits

Introduction to natural background radiation, concept of 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, survey meters, area/zone monitoring, direct reading devices, 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; 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, lost source tracking, source storage facilities, safe work practices, safety aspects of high energy accelerators, survey of radiography installation.

8. Design and Operational 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 equipments/exposure devices as per ISO 3999, leak testing, prototype tests, interlocks, auxiliary shielding, servicing/maintenance procedures, marking, labeling and identification, test requirements, administrative controls, quality assurance.

9. 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, 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.

10. Radiation Accidents, Case Studies and Lessons Learned

Radiation accidents involving industrial gamma radiography exposure devices (IGRED), orphan & vulnerable sources, causes of radiation accidents (detachment of source pigtail, loss of source, locating the lost sources, damage to source capsule, source housing, transport incident, fire accident and explosives etc., precautions to be taken for avoiding accidents, guidelines to handle radiation emergency situations, case studies and lessons learned.

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, 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).

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 provisions: administrative and technical measures, graded approach in security provision, physical protection system.

12. Emergency Response Plans and Preparedness

Normal and potential exposure, potential accident situations involving IGRED, elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical procedures, responsibilities of employer, licensee, RSO, radiographer and manufacturer /supplier of IGRED or sources in case of emergency, unsafe disposal of disused source.

2. Radiography Testing

A. Lectures: (32 h)

		Duration
1.	General Concepts of RT	4 h
2.	Physical Principles of the Test	3 h
3.	Equipment and Radiation Sources	3 h
4.	Photographic & Non-photographic Recording	3 h
5.	Work Parameters and Conditions	7 h
6.	Defectology	3 h
7.	Selection of Radiography Techniques	4 h
8.	Radiography Standards and Selection of Test Methods	3 h
9.	Advances in Radiography	2 h

B. Practicals: {15 h (3 h each)}

1. Familiarization with radiography equipment (X-rays & Gamma Rays) and their operation
2. Dark room practices
3. Selection of radiographic techniques for inspection of objects with different Geometries – Plates & Pipes
4. Selection of test methods according to standards
5. Viewing of radiographs, interpretation of radiographs & preparation of reports

Syllabus

1. General Concepts of RT

1.1 Basic principles of NDT, Non-destructive testing of materials, definitions, reasons for using NDT, description and field of application of the most common methods, comparison between methods.

1.2 Properties of material,: Physical, Chemical, Mechanical; defects in materials, properties of metallic materials, discontinuities and defects in metallic materials

1.3 Defects originating from melting, pouring, cooling; processing defects from: welding, forging, rolling, heat treatment, machining, plating, etc; service defects due to overload, fatigue, corrosion, brittle, fracture and others.

2. Physical Principles of the Test

2.1 Elements of atomic and nuclear physics, principles of radioactive decay and radioactivity, alpha, beta, gamma, neutron radiations, half-life, artificial and natural sources etc.; nature of penetration of radiations, X-rays and gamma-ray spectra, kVp, keV, inverse-square-law for distance/intensity, production of radioisotopes.

2.2 Interaction of radiation with matter, absorption/dispersion/photoelectric effect/ Compton scattering/pair production, absorption coefficient, Half-value thickness (HVT) and Tenths value thickness (TVT) etc.

2.3 Detection of ionizing radiations

3. Equipment and Radiation Sources

3.1 X-ray equipment, generators and X-ray tubes, materials and target characteristics, focus/heat dissipation, head/control cabin/power source and accessories

3.2 Gamma ray sources used for industrial radiography, types of radiography exposure devices, activity, shielding and handling, source changers

3.3 High Energy Radiation Generating Equipments- Accelerators and accessories

4. Photographic & Non-photographic Recording

Photographic recording (Gamma-ray, X-ray), film/principles/properties, emulsions/ classes/characteristic curves, radiographic quality, lead and fluorescent screens, types of film for industrial radiography, basics of image intensifier and fluoroscope systems.

5. Work Parameters and Conditions

5.1 Parameters and work conditions, image density and factors affecting it, geometric principles/penumbra, image quality/contrast and definition; disperse radiation; causes and control, use of screens/masks/filters, exposure curves; X-rays/gamma-rays, exposure calculations, image quality indicators (IQI): procedure for selection and placement

5.2 Film processing, principle of image formation, processing in dark room, equipment reagents, care to be taken in handling and conserving the film, checking on the use of reagents/temperatures/processing time, special situations, safety lamps

5.3 Viewing of radiographs, general information/lighting/viewer, influence of the observation conditions on the detection of defects, checking the lighting in viewer, brightness requirements.

5.4 Evaluation of radiograph quality, causes and corrections of defective radiographs, film artifacts processing defects/high density/low density/ contrast/ definition of fog; image quality indicators (IQI), identification, density measurements, systematic control of radiographic quality.

6. **Defectology**

Basic factors, relationship between image and object, defect definition, defect indications, general information on the nature of discontinuities in radiography, interpretation of radiographic images of welds, casting, corrosion etc.

7. **Selection of Radiography Techniques**

Influence of the properties of the material, compound material, exposure techniques according to the geometry and accessibility of the object, Single wall/single image, Double wall/single image, Double wall/double image, panoramic exposure, thickness compensation masks, filters, latitude technique

8. **Radiographic Standards and Selection of Test Methods**

Influence of properties of the material, general features of Codes and Standards, specifications and procedures, performance of tests in accordance with written instructions, recording of tests

9. **Advances in Radiography**

Principles and applications of neutron radiography, electron radiography, xero-radiography, overview of microfocal radiography, real time and digital radiography, X-ray radiography, computed tomography, high energy accelerator radiography.

Training Course on Radiation Safety (TCRS-15)

No. AERB/RSD/RT-2/Syllabus/2012

Certification in Industrial Radiography Testing : Level-2 (RT-2)

Introduction

Training and certification of NDT Personnel has a significant role in the country's industrializations programme since 'Quality' is the key word in its growth and prosperity. The reliability and success of NDT application greatly depends upon the technical skill and ability of their practitioners, as the data generated during these tests has to be analysed and interpreted to arrive at a correlationship with the soundness of the material under test. The training course on Radiography Testing Level–2 (RT–2) has been tailored to meet the professional needs in Industrial Radiography and to provide instructions on proper and safe use of radiation sources.

The course is conducted as per the guidelines of ISO-9712, with the syllabus as prescribed in Bureau of Indian Standards, IS – 13805. This course is mandatory in our country for those who would like to obtain radiography exposure devices/radiography sources to set up radiography testing facilities or to work as Radiological Safety officer (RSO) in the radiography practice. Successful completion of this course qualifies the candidate to become eligible to be nominated as Radiological Safety officer (RSO) and to procure radiography sources/equipments for radiography practice in the country.

Eligibility Criteria:

A. Experience & Certified Radiographers (RT-1):

I. 10+2 or equivalent examination passed with Science subjects, and Mathematics in 10th standard or equivalent from a recognized Board, and minimum of 36 months practical experience in radiography testing; or;

II. Diploma in Engineering or Basic Degree in Science with Physics and Mathematics and a minimum of 12 months practical experience in radiography testing.

The candidate is required to produce the proof of their experience from their employer(s). The radiography experience should be supported with enrolment in personnel monitoring badge (TLD) service.

B. Direct Access :

I. Diploma in Engineering or Basic Degree in Science with Physics and Mathematics, and;

(a) minimum of 24 months practical experience in radiography testing, or;

(b) minimum of 18 months practical experience with two testing methods, (RT + one other method), or;

(c) minimum of 16 months practical experience with three or more testing methods (RT + two other methods)

The candidate is required to produce the proof of their experience from their employer(s). The radiography experience should be supported with enrolment in personnel monitoring badge (TLD) service. Qualifications in other NDT methods should be supported with the relevant passing certificates.

II. Degree in Engineering or M. Sc. with Physics and Mathematics; and

(a) minimum of 18 months practical experience in radiography testing

(b) minimum of 14 months practical experience with two testing methods, (RT + one other method);

(c) minimum of 12 months practical experience with three or more testing methods (RT + two other methods)

The candidate is required to produce the proof of their experience from their employer(s). The radiography experience should be supported with enrolment in personnel monitoring badge (TLD) service. Qualifications in other NDT methods should be supported with the relevant passing certificates.

Duration: 22 (Twenty two) working days (132 h)

Examination:

The examination on Radiography Technique and Radiation Safety shall consist of;

I. Written Examination
   (a) Radiography Testing General (100 marks)
   (b) Radiography Testing Specific (100 marks)
   (c) Radiation Safety (100 marks)

II. Practical Examination
   (a) Radiography Testing Specific (100 Marks)
   (b) Radiation Safety (50 Marks)

Passing Criteria:

I. Not less than 70% each in written and practical examinations

II. Not less than 80% in aggregate

Re-appearance for Examination:

There shall be at least three months gap between two consecutive examinations.

Course Content:

1. Radiation Safety

A. Lectures (26 h)	**Duration**
1. Basic Radiation Physics	3 h
2. Interaction of Radiation with Matter	2 h
3. Radiation Quantities and Units	1 h
4. Biological Effects of Radiation	2 h
5. Operational Limits	2 h
6. Radiation Detection and Measurement	2 h
7. Radiation Hazard Evaluation and Control	4 h
8. Design and Operational Safety Aspects of Radiography Device/Equipment	2 h
9. Transport of Radioactive Material	2 h
10. Radiation Accidents, Case studies and Lessons Learned	2 h
11. Regulatory Aspects of Industrial Radiography	2 h
12. Management of Industrial Radiography	1 h
13. Emergency Response Plans and Preparedness	1 h

B. Discussion : 3h

C. Practicals: 12 h (2h each)

1. Verification of inverse square law, determination of the activity of a source and calibration of radiation survey meter
2. Familiarization with radiation safety equipments, monitors, dosimeters, warning symbols etc.
3. Procurement, transport and packaging of radioisotopes (*Demonstration)*
4. Area monitoring and calculation of cordoning-off distance
5. Handling of radiation accidents *(Demonstration)*
6. Assessment of the shielding adequacy and functional performance test for industrial radiography exposure devices

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), 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 (Siever & rem), effective dose (Sievert & rem)

4. Biological Effects of Radiation

Introduction to cell, interaction of radiation with cell, direct and indirect interactions, effects of radiation on living cells, chromosomal aberration, somatic and genetic effects, deterministic and stochastic (probabilistic) effects, acute and chronic exposure, partial body and whole body exposures.

5. Operational Limits

Introduction to natural background radiation, concept of 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 Dosimeters {(TLD}), radiation monitoring instruments, personnel monitoring, survey meters, area/zone monitoring, direct reading devices, 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; shielding material, exposure rate constant, types of radiography installations: enclosed installation, open top, open field; planning of radiography enclosure, 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, calculation of cordon-off distance, safety in radiography installations: enclosed , open top and field radiography, tracking of lost sources, source storage facilities, safe work practices, safety aspects of high energy accelerators, survey of radiography installation.

8. Design and Operational 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 equipments/exposure devices as per ISO 3999, leak testing, prototype tests, interlocks, auxiliary shielding, servicing/maintenance procedures, marking, labeling and identification, test requirements, administrative controls, quality assurance.

9. 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, 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.

10. Radiation Accidents, Case Studies and Lessons Learned

Radiation accidents involving industrial gamma radiography exposure devices (IGRED), orphan & vulnerable sources, causes of radiation accidents (detachment of source pigtail, loss of source, locating the lost sources, damage to source capsule, transport incident, fire accident and explosives etc.), precautions to be taken for avoiding accidents, guidelines to handle radiation emergency situations, case studies and lessons learned.

11. Regulatory Aspects of Industrial Radiography

Regulations with respect to handling of industrial radiography exposure devices (IRED), relevant regulatory documents such as Act, Rules, Code, Standards and Guides, responsibilities of employer, licensee, RSO, radiographer and manufacturer/ supplier of IRED; regulatory requirements for import/export, procurement, use, handling, transfer of IRED and Safe disposal of radioisotopes/radioactive material, inventory control, Radiation Protection Programme (RPP).

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 provisions: administrative and technical measures, graded approach in security provision, physical protection system.

12. Management of Industrial Radiography

Radiation protection programme (RPP) followed in the industrial radiography institutions, assignment of duties, management of industrial radiography sites, inventory control and safe movement of the IGRED at industrial radiography sites, site selection and approvals, evaluation of work for radiation safety, Quality Health Safety & Environment (QHSE) programme and its implementation, radiation safety audits and corrective actions.

13. Emergency Response Plans and Preparedness

Normal and potential exposure, potential accident situations involving IGRED, elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical procedures, responsibilities of employer, licensee, RSO, radiographer and manufacturer /supplier of IGRED or sources in case of emergency.

2. Radiography Testing

Course Content:

A. Lectures (46 h)

		Duration
1.	General Concepts of RT	7 h
2.	Physical Principles of the Test	10 h
3.	Equipment and Radiation Sources	3 h
4.	Photographic & Non-photographic Recording	5 h
5.	Parameters and Work Conditions	5 h
6.	Defectology	2 h
7.	Selection of Techniques	3 h
8.	Selection of Test Methods	3 h
9.	Special Applications	2 h
10.	Recording of Test and Interpretation of Results	2 h
11.	Other Radiography Techniques	2 h
12.	Advances in Radiography	2 h

B. Discussion : 3h

C. Practicals: 30 h (3 h each)

1. Familiarization with Radiography equipment (X-ray and Gamma ray) and their operation aspects
2. Dark room practices and preparation of sensitometer curves
3. Evaluation of reference radiographs
4. Relating discontinuities with the radiographic images of standard defects in castings, welds and materials having corrosion.
5. Selection of radiography techniques for inspection of objects with different material and geometrics and accessibilities (plates)
6. Selection of radiography techniques for inspection of objects with different material and geometrics and accessibilities (pipes)
7. Preparation of test procedures as per different codes
8. Determination of depth of flaw
9. Tangential Radiography
10. Preparation of model reports, acceptance, repair or rejection of materials based on evaluation of radiographs as per applicable standards and codes

Syllabus

1. General Concepts of RT

1.1 Basic principles of NDT, definitions, methodology of applications, areas of application of common method, range and limitations of common methods

1.2 Materials and defects, structure of metals and alloys, physical, chemical and mechanical properties of metallic materials, discontinuities and defects in metallic materials

1.3 Processing defects, primary processes and related defects, manufacturing processes and related defects

1.4 Material in service, behavior of materials in service, service conditions leading to defects and failures: a) corrosion, b) fatigue, c) wear, d) overload, e) brittle fracture; concepts of rupture development in metals

1.5 Quality and standardization, definition of quality, quality control and standardization, development of a quality system, examination, testing and inspection, standards, codes, specifications and procedures, reports, records and protocols

2. Physical Principles of the Test

2.1 Elements of atomic and nuclear physics, elements of radioactive decay, alpha, beta, gamma and neutron radiation, the nature of penetration radiation, corpuscular and electromagnetic radiation, X-rays and Gamma rays, wavelength and energy, X-ray and gamma ray spectra, kVp – keV, inverse- square-law for distance/intensity; general properties of the propagation of penetrating radiation, production of radioisotopes

2.2 Interaction of radiation with matter, absorption, dispersion/photoelectric effect/Compton scattering/pair production; absorption coefficient, Half value thickness (HVT) and Tenth value thickness (TVT), use of tables for calculating attenuation coefficients

2.3 Radiation units, exposure, absorbed dose, dose equivalent, radioactivity etc., dose intensity and concept of specific emission (R/Ci-h at 1m Gy/Bq-h at 1m).

2.4 Principles of X-ray and gamma ray detection, methods of ionization/electronics, film/ fluorescent material, accuracy of measurement, limits of application

3. Equipment and Radiation Sources

3.1 X-ray equipment, generators and X–ray tubes, materials and target characteristics/configurations/focus/heat dissipation, head/control cabin/power source, auxiliaries, equipment design, emission, work cycle, determination of focus

3.3 Gamma-ray sources, types, spectrum/activity/shielding, handling; exposure techniques, decay schemes, energy spectrum, emission factor, use of collimation.

3.3 High Energy Radiation Generating Equipments– Linear accelerators, betatrons and accessories

4. Photographic & Non-photographic Recording

Photographic recording (Gamma-ray, X-ray), film/principles/properties, emulsions, types, characteristic curves, radiographic quality, lead and fluorescent screens, types of film for industrial radiography, use of sensitometric curves, exposure curves, brightness and penumbra responses of fluorescent screens

5. Parameters and Work Conditions

5.1 Image density and factors which affect it, geometrical principles/penumbra, image quality/contrast and definition, disperse radiation; cause and control, use of screens/masks/filters, exposure calculations, image quality indicators (IQI)/ positioning, choice of films, preparation of exposure curves, choice of screens, magnification and distortion of the projection image, fluoroscopy: evaluation of sensitivity; selection of kVp.

5.2 Film processing, principle of image formation, processing in darkroom, equipment reagents, care to be taken in handling and conserving the film, checking on the use of reagents/temperatures/processing time, special situation, safety lamps

5.3 Viewing of the radiographs, general information, lighting/viewer, influence of the observation conditions on the detection of defects, checking the lighting in viewer, brightness requirements

5.4 Evaluation of radiographic quality, causes and correction of defective radiographs, processing defects/high density/contrast/definition of fog, image quality indicators (IQI), identification, density measurement, systematic control of radiographic quality

6. Defectology

Basic factors, relation between image and object, general information on the nature of discontinuities in radiography, interpretation of radiographic images of welds, casting, corrosion etc.

7. Selection of Techniques

Influence of the properties of the material, compound material, exposure technique depending on the geometry and accessibility of the object, Single wall/single image, Double wall/single image, Double wall/double image, panoramic exposure, thickness compensation, masks, filters, detection probability depending on type, size, position and orientation of the defect/ high and low sensitivity technique

8. Selection of Test methods

General features of Codes and Standards, specification and procedures, performance test in accordance with written instructions, records of operating conditions on test forms, evaluation of tasks carried out by Level -1 operators, instructions for testing in special situations, range of application of the test, equipment and technique

9. Special Applications

Multiple film techniques, projection and magnification techniques, panoramic exposure, determination of depth of defects, radiography of radioactive objects.

10. Recording of Test and Interpretation of Results

The recording of test and documentation, evaluation of results according to applicable Standards and Codes.

11. Other Radiography Techniques

Neutron radiography, electron radiography, Xero-radiography principle and applications

12. Advances in Radiography

Microfocal radiography, real time and digital radiography, X-radiography, Tomography and image processing, brief outline of principles and applications.

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LIST OF PARTICIPANTS

TASK GROUP FOR REVIEW OF SYLLABI OF TRAINING COURSES ON RADIOLOGICAL SAFETY (TGRTRS)

Total No. of Meetings: 28

Members

Dr. B.C. Bhatt (Chairman)	:	BARC (Former)
Dr. Arun Behere	:	BARC (Former)
Shri T. K. Jayakumar	:	BRIT (Former)
Dr. S. D. Sharma	:	BARC
Shri R. Kannan	:	AERB (Former)
Dr. A.U. Sonawane (Member-Secretary)	:	AERB
Shri Pravin J. Patil (Permanent Invitee)	:	AERB

Invitees

Dr. Gursharan Singh	:	BARC
Shri P. Sreeramakrishna	:	BARC (Former)
Dr. P. K. Dash Sharma	:	AERB
Dr. Pankaj Tandon	:	AERB
Shri Sudesh M. Tripathi	:	BARC
Shri Soumen Sinha	:	AERB

SAFETY REVIEW COMMITTEE FOR APPLICATIONS OF RADIATION (SARCAR)

Date of Meeting: June 21-22, 2011 (117th meeting)

October 24, 2011 (119th meeting)

Shri A.R. Sundararajan (Chairman)	: AERB (Former)
Dr. A.N. Nandakumar (Vice-Chairman)	: AERB (Former)
Dr. Suleman A. Merchant	: Lokmanya Tilak Memorial Medical College and Hospital, Sion, Mumbai
Dr. G.K. Rath	: Department of Radiotherapy, IRCH, All India Institute of Medical Sciences, New Delhi
Dr. A.S. Pradhan	: BARC (Former)
Dr. B. Venkataraman	: IGCAR, Kalpakkam,
Shri E. Balachandran	: Bureau of Indian Standards, Mumbai
Dr. Vikram Lele	: Nuclear Medicine Department, Jaslok Hospital, Mumbai
Dr. Y.S. Mayya	: BARC
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Dr. A. U. Sonawane	: AERB
Dr. P.K. Dash Sharma (Member-Secretary)	: AERB