Bhabha Atomic Research Centre
Industrial Tomography & Instrumentation Section
Mumbai - 400085

Certification in Industrial Radiography Testing : Level-2 (RT-2)
[Ref: Training Course on Radiation Safety (TCRS-15) No. AERB/RSD/RT-2/Syllabus/2012]

Course Content:

1. Radiation Safety

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

1.1 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

3.1 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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