Operational Radiation Protection

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Introduction

- The operational radiation protection programme is subjected to the requirements of the IAEA Safety Standard SSR-3;
- Requirement 84 of SSR-3:
  - “***The operating organization for a research reactor facility shall establish and implement a radiation protection programme***”

Introduction

- The main objectives of radiation protection are to:
  - ***Ensure the effective control of both external and internal exposures to workers and of the members of the public, and the release to the environment;***
  - ***To ensure conformance with all regulatory requirements***;
  - ***To enable further optimization of operational practices***.
- In order to achieve the above objectives, the operational radiation protection programme should be in place.

Introduction

- Recommendations on the contents of a radiation protection programme are provided in GSG-7

Scope of the radiation protection programme

- The radiation protection programme should document the following, with an appropriate level of detail: (GSG-7)
  - The assignment of responsibilities for protection and safety for workers to different management levels;
  - The designation and functions of qualified experts;
  - The integration of occupational radiation protection with other areas of health and safety, such as industrial hygiene, industrial safety and fire safety;
  - The system for accountability for radiation generators and radioactive sources;
  - The designation of controlled areas and supervised areas;
  - The local rules for workers to follow and the supervision of work;

Scope of the radiation protection programme (cont'd)

- The provision of personal protective equipment, if applicable;
- The arrangements for monitoring workers and the workplace, including the acquisition and maintenance of suitable instruments;
- The system for recording and reporting all of the relevant information relating to the control of exposures, the decisions regarding measures for occupational radiation protection and safety, and the monitoring of individuals;
- The education and training programme on the nature of the hazards and on measures for protection and safety;

Scope of the radiation protection programme (cont'd)

- The methods for periodically reviewing and auditing the performance of the radiation protection programme;
- The emergency plan, where the need for such a plan is indicated by the safety assessment;
- The programme for workers' health surveillance;
- The requirements for the assurance of quality and process improvement.

Operational radiation protection programme (cont'd)

- OPTIMIZATION PRINCIPLE AND DOSE CONSTRAINTS
  - The operating organization should take appropriate measures to ensure that protection and safety is optimized so that the magnitude of individual doses, the number of people exposed and the likelihood of incurring exposures are kept *as low a reasonably achievable*, *economic* and *social factors* being taken into account;
  - Optimization of protection and safety associated with any particular source should be subject to dose constraints;
  - To apply the optimization principle, the individual doses for the various options under consideration should be predicted in the planning stage and compared with the appropriate dose constraint;
  - The regulatory body is responsible for establishing or approving dose constraints- para. 3.22(c) of GSR Part 3;
  - The dose constraint should be used to ensure that the dose limit for the public exposure is not exceeded.

Operational radiation protection programme (cont'd)

- ADMINISTRATIVE CONTROL LEVELS
  - Administrative control levels are values of measured quantities such as *dose rates*, *activity*, *activity concentrations* above which some action should be taken;
  - A recording value is a level of dose, exposure or intake specified by the regulatory body at or above which the values of dose, exposure or intake received by workers are to be entered in their individual exposure records;
  - Operational intervention levels are used to protect members of the public in the event of an emergency. These intervention levels are typically expressed in terms of dose rates or activity of radioactive material released, time integrated air activity concentrations, ground or surface concentrations, or activity concentrations of radionuclides in environmental, food or water samples.

Dose Limitation

- DOSE LIMITS
  - *"The radiation protection programme shall ensure that for all operational states and accident conditions, doses due to exposure to ionizing radiation at the research reactor facility or doses due to any planned releases of radioactive material from the facility are kept below authorized limits and as low as reasonable achievable (ALARA)"*;
  - In meeting the above requirement, it needs to be assured that the exposure of individuals from normal operation (NO) of the research reactor is such that neither the total effective dose nor the total equivalent dose to the relevant organs and tissues exceeds any relevant dose limit set by national regulations.

Possible sources of radiation at a research reactor

- Reactor core and fuel;
  - Fission products;
  - Transuranic nuclides;
  - Activation products;
  - Prompt radiation.
- Fresh and spent fuel;
- Reactor components;
- Coolant, moderator and associated piping and equipment;
- Ventilation air and associated ducting and equipment.

Possible sources of radiation at a research reactor (cont'd)

- Beam tubes and associated experimental facilities;
- Radioactive waste;
- Special radioactive sources:
  - Neutron source for the start-up of the reactor;
  - Neutron and gamma sources for the calibration and checking of monitoring instrumentation;
  - Irradiated targets for radioisotope production, neutron activation analysis and material testing.

Research reactor design considerations

- Material selection:
  - Structural materials of core components, grids, guide tubes, experimental devices, etc. should be carefully selected to ensure that, during operation and decommissioning, accumulated activity does not enhance the radiological risk.

- Maintainability:
  - Accessibility, shielding, remote handling;
  - Optimization of the facility’s layout and access routes.

Research reactor design considerations (cont'd)

- Decommissioning:
  - Provisions for easy decontamination;
  - Provisions for removal of large components;
  - Provisions for storage of radioactive waste;
  - Use of structural materials that do not give rise to formation of long-lived activation or fixed contamination products.

Source control by operating practices

- Control by quality of reactor coolant;
- Control of beam ports and experiments;
- Control by minimising the production of gaseous radioactive material;
- Control of irradiated fuel;
- Control by minimization of radioactive waste.

Source control by operating practices (cont'd)

- ON-SITE RADIATION PROTECTION AND DOSE CONTROL AT A RESEARCH REACTOR
  - ➢ Radiation protection through source control
    - ✓ Control by material selection
  - ❖ A large reduction in exposure can be achieved at the design stage of a research reactor and *during the design of individual experiments*, i.e. care should be taken in a choice of materials likely to be activated, with account taken of neutron activation cross-sections, half-lives and corrosion resistance;
  - ❖ Impurities in standard materials should be carefully investigated as part of minimizing doses to operating personnel and experimenters;

Source control by operating practices (cont'd)

- ON-SITE RADIATION PROTECTION AND DOSE CONTROL AT A RESEARCH REACTOR
  - ➢ Radiation protection through source control
    - ✓ Control by quality of reactor coolant
  - ❖ The reactor coolant should be kept as free from impurities as possible to minimize dose rates from exposures due to coolant activation and to minimize problems that might arise owing to contamination. Good coolant chemistry should be maintained to reduce corrosion and thereby minimize the activation of corrosion products;
  - ❖ Cleanup systems such as filters and ion-exchange columns should be used to remove contaminants from the reactor coolant. These systems can themselves become significant sources of radiation, and the design should provide features to optimize protection
  - ❖ In reactors that are moderated or cooled by heavy water, the release of such material would also generate a hazard from inhalation or absorption of tritiated water in vapour form

Source control by operating practices (cont'd)

- ON-SITE RADIATION PROTECTION AND DOSE CONTROL AT A RESEARCH REACTOR
  - ➢ Radiation protection through source control
    - ✓ Control of beam ports and beam tubes
  - ❖ The beam ports and similar devices can be significant sources of radiation;
  - ❖ These devices should be designed, controlled and maintained;
  - ❖ Beam tubes are required to be adequately shielded;
  - ❖ Beam ports that are not in use should be properly closed and shielded.

Source control by operating practices (cont'd)

- ON-SITE RADIATION PROTECTION AND DOSE CONTROL AT A RESEARCH REACTOR
  - ➢ Radiation protection through source control
    - ✓ Control by minimizing the production of gaseous material
  - ❖ Noble gases produced in research reactors consist of activation products such as Ar-41 (in the case of irradiation of air) and isotopes of krypton and xenon as fission products
  - ❖ Production of radioactive gases can be minimized, through the following mean:
    a) Reducing the ingress of air near the core;
    b) Sealing air spaces to let the radioactive material decay, or purging the spaces with a gas such as carbon dioxide or helium;
    c) Removing and sealing failed fuel and defective devices containing radioactive gases;
  - ❖ Filters are usually installed in ventilation systems to retain particulate radioactive material within the building and reduce releases to the environment and public exposure.

Source control by operating practices (cont'd)

- ON-SITE RADIATION PROTECTION AND DOSE CONTROL AT A RESEARCH REACTOR
  - ➢ Radiation protection through source control
    - ✓ Control of irradiated fuel
    - ❖ Irradiated fuel is a significant source of radiation and should be handled and stored in such a way that the corrosion and/ or failure of cladding, melting of fuel and possibility of unintentional criticality are avoided;

Source control by operating practices (cont'd)

- ON-SITE RADIATION PROTECTION AND DOSE CONTROL AT A RESEARCH REACTOR
  - ➢ Radiation protection through source control
    - ✓ Control by minimization of radioactive waste
  - ❖ Radioactive waste produced by the research reactor is also a source of radiation;
  - ❖ Radioactive waste should be segregated, contained, shielded and placed in designated collection points prior to its predisposal management and disposal.

Physical control

- ON-SITE RADIATION PROTECTION AND DOSE CONTROL AT A RESEARCH REACTOR
  - Radiation protection through physical controls and the use of time and distance
  - Appropriate engineered controls such as the following are included in the design:

    a. Shielding;
    b. Ventilation;
    c. Decay systems;
    d. Distance;
    e. Time.

Shielding

- ON-SITE RADIATION PROTECTION AND DOSE CONTROL AT A RESEARCH REACTOR
  - The design shall include the shielding required not only for the reactor but also for experimental devices and associated facilities such as beam tubes, particle guides, etc;

Shielding (cont'd)

- The need for shielding should be considered for all sources of radiation at the research reactor, which includes the following:
  a. The reactor core and irradiated fuel;
  b. The reactor coolant system;
  c. Ducts and filters of ventilation systems;
  d. Ion exchange columns, delay/decay tanks;
  e. Argon vent pipes;
  f. Beam ports, beam tubes and beam targets;
  g. Irradiated samples and equipment;
  h. Storage tanks for radioactive gases or liquid effluents.
- In the design of the shield, the following consideration should be considered:
  a. Specific radiation source;
  b. Expected dos rate;
  c. Gamma and neutron or only gamma radiation;

Shielding (cont'd)

d. Build-up factors;
e. Combinations of shielding materials;
f. Penetrations through the shielding;
g. Losses in efficiency of shielding;
h. Heat generation in shielding;
i. Mass of additional shielding.

Ventilation

- Maintain clean conditions in working areas by:
  - Supplying fresh air;
  - and for removing and/or diluting the radioactive contaminants present in the working environment;
  - Making sure that the efficiency of the ventilation systems be routinely checked for integrity, the number of air changes per hour for different areas, flow rates, velocities and pressures;
  - Controlling the temperature and humidity.
- Control the release of radioactive gases to the environment by:
  - Appropriate pressure differences in different areas;
  - Air cleaning filters;
  - Controlling the concentration of radioactive gases.

Distance

- Personnel should be made aware of the need to make effective distance between themselves and source of radiation;
- Distance control maybe be used in combination with shielding, such as operating the manipulators or robots behind shielded hot-cells.

Time

- The time spent by persons in areas of high dose rates should always be minimized;
- Tasks that have to be performed in areas with high dose rates, such task must be planned before hand;
- This will enable the personnel involved to refine the procedure and to perform the task faster.

Radioactive decay

- All activated materials, equipment and samples should be allowed to decay as long as possible before they be handled or processed;
- In some cases, time for appropriate decay is facilitated by means of the delay systems such as decay tanks (decay of N-16 coming from coolant activated).

Decontamination

Decontamination should be considered at the design phase by provision of:

- Decontamination facilities;
- Easily cleanable surfaces of working areas, equipment and experimental devices.

Select decontamination method according to:

- Target decontamination level versus estimated dose to workers;
- Non-radiological hazards (toxicity of solvents) an aerosol;
- Estimation of the volume of waste generated;
- Possible adverse effects on the item being decontaminated.

Decontamination (cont’d)

- Procedures and materials for decontamination of skin, clothes, tools and surfaces in controlled areas should be provided as necessary;
- All items transported from the controlled area should be measured and decontaminated as necessary;
- Decontamination activities should be carried out in accordance with approved procedures in a properly designated and equipped facility (e.g. a decontamination cell for highly active items)

Personal Protective Equipment (PPE)

- PPE should be used in accordance with appropriate procedures, training and retraining in its correct use;
- PPE is used to prevent external and internal contamination of workers;
- Respirators should be recommended:
  - Against specific contaminants;
  - Based on the concentration of air activity present in work area;
  - Based on the protection factor it offers.

Personal Protective Equipment (PPE) (cont'd)

- PPE includes:
  - Protective clothing including, as appropriate:
    1. Overcoats,
    2. Gloves;
    3. Overshoes;
    4. Overalls.
  - Respiratory protective equipment such as:
    1. Oro-nasal half face or full-face masks;
    2. Airline respirators.
  - Self protective equipment, such as:
    1. Self-contain breathing apparatus (SCBA);
    2. Ventilate plastic suits;
    3. Lead aprons.

Determination of the boundaries of the controlled area

- In defining the boundaries of the controlled area the following considerations should be taken into account:
  - The magnitudes of the exposures expected in normal operation;
  - The likelihood and magnitude of exposures in anticipated operational occurrences and in accident conditions;
  - The type and extent of the procedures required for protection and safety.

Means for controlling exposures and preventing spread of contamination

- Controlled areas should be:
  - Delineated by physical barriers;
  - Indicated by signage with appropriate warning symbols;
  - Controlled by means of administrative procedures;
  - Equipped with PPEs;
  - Provided with monitoring equipment;
  - Reviewed periodically.

Means for controlling exposures and preventing spread of contamination (cont’d)

- Administrative procedures:
  - Dosimeters;
  - PPEs

Means of preventing or limiting potential exposures

- Proper use of PPEs;
- Provision of appropriate training;
- Periodic workplace monitoring and survey;
- Decontamination.

Designation of supervised areas

- Controlled areas are normally surrounded by *supervised areas*;
- Supervised areas should be:
  - Delineated by appropriate means;
  - Indicated by approved signs at appropriate access points;
  - Monitored as appropriate;
  - Periodically reviewed.

System of radiation work permits

- All work to be done in radiological area requires approval;
- Types of work approvals related to radiation safety:
  - Radiation work permit
    1. Any work undertaken in the facility that may have a radiological hazard must be approved through a radiation work permit (RWP) system;
    2. The RWP is issued and approved in collaboration with the Radiation Protection Officer of the facility;
    3. A RWP may be part of a conventional work permit needed to carry out any work in the facility;
    4. Nature and intensity of hazards & dose history of workers should be identified in the RWP.

System of radiation work permits (cont'd)

- Experiment approvals:
  1. The safety assessment of an experiment should include an assessment of the radiological hazards likely to arise during installation, normal and abnormal operation of the experiment.

- Routine irradiation approvals:
  1. Usually approved at a lower level based on a list containing those materials and their allowed quantities that can be irradiated, for which a detailed safety assessment has previously been carried and approved.

- Modification to the facility:
  1. Considerations for radiological approval are similar to those for experiments.

Radiation protection procedures

- Administrative controls to achieve objective safe operation:
  - Operational procedure;
  - Radiation protection procedures for:
    1. Defining the methodology for workplace monitoring;
    2. Delineation of controlled and supervised areas;
    3. Periodic testing and calibration of RP instruments;
    4. Control of controlled and supervised areas;
    5. Control of the radiation sources;
    6. Emergency procedure;
    7. Training in radiation protection.

Training needs

- The operating organization is responsible for the recruitment, training and periodic retraining of all personnel;
  - Specific training for operating personnel:
    1. Operating staff of the research reactor facility should be adequately trained and confirmed/ licensed.
  - Specific training for workers:
    1. Workers who need to work in zones of high radiation levels should be trained in their specific work activities.
  - Specific training for users of research reactor:
    1. Users of experimental and other facilities at the RR need training specific to the facilities they will be using.

Training needs (cont'd)

- Specific training of temporary workers:
  1. Operating organization should ensure that any personnel of other organizations (e.g. contractors) have received proper training and induction.

- Instructions to visitors:
  1. Before visitors enter the controlled area, they should be provided with information and instructions on the provisions for RP.

- Emergency training:
  1. Periodic exercises and training on onsite and offsite emergency preparedness and response.

- Retraining:
  1. Periodic retraining and refreshers courses for reactor operations and RP personnel.

Instructions for abnormal situations

- Radiological assessment:
  - The process of evaluation of radiological hazards.
- Emergency plan:
  - Designation of shelter area, availability of emergency equipment, emergency preparedness and response manual.
- Implementation:
  - Emergency response (ER) team- includes persons with knowledge of the RR operation;
  - Prompt deployment of ER team to gather data;
  - Early individual monitoring provides additional data on the event;
  - Emergency procedure- based on events analysed in the SAR as well as additional postulations for emergency planning;
  - Emergency equipment- availability not affected by the event;
  - On-site- off-site response.

Monitoring

- Purpose of monitoring may include:
  - Confirmation of good working practices;
  - Provision of information about conditions in the workplace;
  - Estimation of the actual exposure of workers;
  - Evaluation and development of operating procedures;
  - Provision of information to motivate workers to reduce exposure;
  - Provision of information relating to accidental exposure.

Establishment of surveillance programme

- Objectives of a surveillance programme:
  - Monitor exposures of individual workers;
  - Control any environmental impacts;
  - Assess trends in radiological parameters;
  - Detect degradation in systems, such as corrosion and leaks.
- Considerations for a surveillance programme:
  - Responsibility of the reactor management;
  - Sensitivity of monitoring systems should be sufficient to ensure that limits are not exceeded;
  - instruments should be calibrated by an accredited calibration laboratory as their measurements may have a legal impact;
  - Record keeping is important.

Types of surveys

- Types of surveys that are needed in any workplace depend on the following:
  - The types and forms of the radionuclides and radiations that may be present;
  - The objectives of the particular survey.
- Three major groups of surveys that should be considered for radiation protection purposes:
  - Routine surveys;
  - Task related surveys;
  - Special surveys.
- For each type of survey, *reference levels* should be established.

Selection of instruments

- Workplace monitors are primarily intended to provide information on the dose rates within the working area;
- Instruments for area monitoring can be either fixed or portable and can be divided into the following categories
  - Instruments for photons;
  - Instruments for beta particles and low energy photons;
  - Instruments for neutrons;
  - Passive gamma monitors;
  - Passive neutron survey meters;
  - Spectrometry systems.

Individual monitoring

- Measurement of external doses:
  - Dosimetry for beta-gamma radiation:
    1. film dosimeters;
    2. Thermo-luminescent dosimeters (TLDs);
    3. Optically Stimulated Luminescence dosimeters.
  - Dosimetry for neutron radiation:
    1. Nuclear track detectors;
    2. Activation detectors;
    3. Bubble detectors;
    4. Electronic dosimeters;
    5. Albedo dosimeters.

Individual monitoring (cont'd)

- Measurement of internal doses:
  - Bioassay;
  - Whole body monitoring (counting);
  - Partial body monitoring (counting).

Emergency slides

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Requirements for instruments in the Operational Research Reactor

- The following factors should be considered in the determination of the number of instruments required:
  - Characteristics of the facility and the types of experiments carried out concurrently;
  - Technical specification of the instruments;
  - Frequency of use for each type of instrument;
  - Feedback from audits and experience of workers;
  - Fraction of instruments out of service;
  - Number of instruments for emergency use only.

Requirements for instruments in the Operational Research Reactor (cont'd)

- The following features of the technical performance of the instruments should be considered:
  - Suitability for the type of radiation monitored;
  - Accuracy;
  - Appropriate ranges and sensitivity;
  - Energy response;
  - Linearity;
  - Measuring time;
  - Effects of ambient factors;
  - Ruggedness, reliability and serviceability.

Requirements for instruments in the Operational Research Reactor (cont'd)

- The following features of the technical performance of the instruments should be considered (cont'd):
  - Power supply, battery condition indication;
  - Angular directional response and radiation field size;
  - Effect of other types of radiation on its reading;
  - Fail-safe features;
  - Testability;
  - Reliability and maintainability.

Requirements for instruments in the Operational Research Reactor (cont'd)

- Human factors may be an important aspect in the selection of instruments as well. The following should be considered in assessing portable instruments:
  - Ease of use and preference of the users;
  - Clear display of the unit;
  - Ergonomic factors;
  - Robustness for typical field use;
  - Risk of data loss or distortion;
  - Transfer of contamination to the instrument by the user.
- Some of these aspects should also be considered in the selection of non-portable radiation monitoring instruments.

Maintenance and calibration of instruments

- Responsibility should be assigned for the maintenance and calibration of instruments. The following factors need to be considered:
  - Instruments should have acceptable reliability;
  - Ease of maintenance is desirable;
  - Availability of spare parts;
  - Contamination and decontamination aspects;
  - Certified calibration facilities;
  - Traceability of calibration to national standards;
  - Performance of the calibration process.
- A preventative maintenance programme for instruments should be established;
- Facilities should be provided to allow accurate calibration.

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