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ADDENDUM TO NS-R-5

APPENDIX IV – REPROCESSING FACILITIES

APPENDIX V – FUEL CYCLE RESEARCH & DEVELOPMENT FACILITIES

DRAFT SAFETY REQUIREMENTS DS439

The general text in NS-R-5 "Safety of Nuclear Fuel Cycle Facilities", provides safety requirements that are applicable to all fuel cycle facilities, to be applied in a graded way, whilst the appendices in NS-R-5 provide supplementary safety requirements which are specific to a facility.

This document, comprising NS-R-5 Appendices IV & V, should therefore be read inconjunction with NS-R-5, as these appendices will be added to NS-R-5.

Appendix IV

REQUIREMENTS SPECIFIC TO REPROCESSING FACILITIES

The following requirements are specific to reprocessing facilities using liquid-liquid extraction processes (e.g. PUREX processes) on an industrial scale. Reprocessing facilities are involved in the treatment of spent fuel from nuclear power plants (e.g. Magnox, GCR, LWR, AGR and FBR) and from research reactors to recover fissile material (uranium and plutonium) for manufacturing of fresh fuel, e.g. MOX fuel for light water reactors or fuel for fast breeder reactors. The processes covered here are: the shearing, decladding and dissolution of spent fuel; the chemical cycles of separation and purification (including solvent removal from aqueous solutions and solvent treatment); the concentration of fission products and plutonium and uranium nitrates; the conversion of plutonium and uranium nitrate to oxides (including MOX powder); the storage of these products; and associated waste conditioning and storage.

SITING

IV.1. In siting new reprocessing facilities on complex and large site areas, which may contain a number of facilities, account shall be taken of potential interactions with existing facilities regardless of their status, i.e. under construction, commissioning, operation, shutdown or being decommissioned.

DESIGN

SAFETY FUNCTIONS

IV.2. Reprocessing facilities shall be designed to:

- Prevent criticality accidents;
- Prevent the accidental release of hazardous materials;
- Keep radiation exposure during normal operation as low as reasonably achievable;
- Provide adequate cooling.

ENGINEERING DESIGN

IV.3. The design shall as far as reasonably practicable prevent hazardous concentrations of gases from radiolysis and other hazardous explosive or flammable

materials, e.g. pyrophoric metals (uranium or zircaloy fines), chemicals (tributyl phosphate (TBP), nitric acid and hydrazine) and formation of explosive nitrated organic substances (red oils).

Cooling

IV.4. Cooling systems, including any support features, shall have adequate capacity, availability and reliability as established in the safety assessment[1] to remove heat from radioactive decay and for removing heat due to chemical reactions.

IV.5. Cooling systems shall be designed according to the safety assessment for preventing coolant from leaking into moderation control areas designated for criticality safety.

Sampling and analysis

IV.6. The design and operational procedures of the reprocessing facility shall allow representative sampling of process and waste streams, either manual or automatic, for ensuring compliance with the requirements established in the safety assessment.

CRITICALITY PREVENTION

IV.7. A criticality safety assessment shall be performed prior to the commencement of any activity involving fissionable material. The wide range of forms of fissionable material and their associated process conditions shall be taken into account in the assessment. Safety criteria and safety margins shall be developed to ensure sub-criticality, based on either the neutron multiplication factor, K_{eff}, or on controlled parameters, such as geometry, mass, enrichment or moderation.

IV.8. A reference fissile material composition shall be defined. The safety assessment performed using this fissile material composition shall be a bounding case of the actual fissile material composition being handled or processed.

IV.9. Particular attention shall be paid to those system interfaces where there is a change in the fissile material state.

IV.10. If the design of the reprocessing facility takes credit for burn-up, its use shall be appropriately justified.

IV.11. In the criticality safety assessment, account shall be taken of the potential for mis-direction, overflow and leaks of fissile material e.g. mis-transfer due to human error or potential carry over, e.g. from evaporators.

[1] The requirements to be fulfilled in conducting safety assessments are detailed in IAEA Safety Standards Series No. GSR Part 4, Safety Assessment for Facilities and Activities, 2009.

IV.12. In the criticality safety assessment, the choice and safety of the use of fire extinguishing media, e.g. water, shall be addressed.

IV.13. In the criticality safety assessment, account shall be taken of the effects of corrosion and erosion.

IV.14. In the criticality safety assessment, consideration shall be given to the potential for internal and external flooding.

CONFINEMENT OF NUCLEAR AND RADIOACTIVE MATERIAL

Occupational protection

IV.15. During normal operation, internal dose shall be minimized by design to the extent possible and the need to use personal protection equipment shall be minimized.

IV.16. The design and layout of plant equipment shall include provisions to minimize exposures arising from maintenance, inspection and testing activities.

Public and environmental protection

IV.17. In the design of the reprocessing facility it shall be ensured that, during reprocessing facility operation, airborne discharges of radioactive materials pass through a filter system prior to discharge to the environment and that the release of volatile and gaseous radionuclides remain within authorized limits.

IV.18. In the design of the reprocessing facility it shall be ensured that known and potentially radioactive liquids discharged from the reprocessing facility site are collected, treated and confirmed to be within authorised limits prior to discharge to the environment.

POSTULATED INITIATING EVENTS

Internal initiating events

IV.19. Criticality accidents shall be controlled by means of design, as far as is reasonably practicable. The following initiating events shall also be considered in the design of the reprocessing facility:

Fire

IV.20. The use of fire extinguishing media shall be consistent with the requirements established in the safety assessment, e.g. criticality safety.

Explosion

IV.21. During the design of a reprocessing facility, the potential for the formation of red oil and any resulting explosion shall be considered in the safety assessment and appropriate safety measures identified and implemented.

Equipment Failure

IV.22. During the design of a reprocessing facility, plant equipment used in a radiological environment shall be suitably assessed for its actions or failure. Measures required to ensure industrial safety of non-nuclear equipment installed in glove boxes or hot cells shall be adapted to their nuclear environment.

Corrosion/Erosion

IV.23. Provision for leaks shall be implemented according to the requirements established in the safety assessment.

Flooding

IV.24. Reprocessing facilities shall be designed to prevent the leakage of contaminated liquid to the environment in the event of internal or external flooding.

Loss of support systems

IV.25. During the design of a reprocessing facility, the loss of safety system supporting features shall be considered and their impact on safety shall be assessed.

IV.26. The design of electrical power supplies to reprocessing facilities shall ensure the necessary levels of availability and reliability as established in the safety assessment. In case of the loss of normal power, emergency electrical supply shall be provided to the items important to safety according to the reprocessing facility's operational status (e.g. normal operation, shutdown, maintenance, clean-out), and the requirements established in the safety assessment. The restoration of the electrical supply shall be pre-planned to avoid further hazards.

Use of pressurised and vacuum equipment

IV.27. Provision for in-service inspection and testing of equipment installed in high active areas shall be defined according to the national requirements on pressurized and/or vacuum equipment. The potential consequences of a failure or leak shall be assessed in order to determine complementary safety measures to minimize the consequences.

External Initiating Events

Earthquake

IV.28. Provision for post-earthquake monitoring of the safety status and safety functions of the reprocessing facility shall be provided.

Extreme weather conditions

IV.29. Extreme weather conditions shall be taken into account in the design of cooling systems associated with the storage of heat generating high level waste.

INSTRUMENTATION AND CONTROL SYSTEMS

Instrumentation

IV.30. Adequate instrumentation shall be provided for measuring the variables that can affect the safety of the reprocessing facility to ensure that the process is being operated within the safety limits and to monitor its environmental impact.

Automated safety control systems

IV.31. Automated safety control systems, e.g. safety interlock systems, shall be designed to ensure the necessary levels of availability and reliability as established in the safety assessment to ensure that the related process parameters remain within the operational limits and conditions.

Environmental protection systems

IV.32. Instrumentation shall be provided to confirm that filtration systems are working effectively. Discharges shall be monitored continuously.

RADIOACTIVE WASTE AND EFFLUENT MANAGEMENT

IV.33. Requirements for the safe management of radioactive waste and effluents arising from normal operation, maintenance and periodic wash-out of the facility shall be established.

COMMISSIONING

COMMISSIONING PROGRAMME[2]

[2] Due to the large size of commercial reprocessing facilities, handover from construction to commissioning is often phased.

IV.34. In reprocessing facilities, commissioning shall be divided into stages (typically inactive and active). Consideration shall be given to defining commissioning activities as early as possible to avoid difficulties in performing a test satisfactorily or with a higher risk, at a later stage.

IV.35. Each safety function shall be verified as fully as practicable before the stage in which the function becomes necessary to ensure safe commissioning.[3] For example, shielding is generally ensured by inspection in the construction stage and testing and checking during inactive commissioning and confirmed during active commissioning.

IV.36. The following activities shall, as a minimum, be performed:

1. During inactive commissioning:[4]

- Confirmation of the performance of shielding and confinement systems, including confirmation of the weld quality of static containment;
- Confirmation of the performance of criticality control measures;
- Demonstration of the availability of criticality detection and alarm systems;
- Demonstration of the performance of emergency shutdown systems.

2. During active commissioning:

- Verification that actual external and internal doses to workers are consistent with the hypothesis and calculations performed during the design;
- Verification that actual discharges are consistent with the hypothesis and calculations performed during the design.

IV.37. The capability of the reprocessing facility and systems to be maintained shall be addressed in the commissioning programme, especially for hot cells and remote equipment.

ORGANIZATION AND RESPONSIBILITIES

IV.38. During commissioning, the safety committee shall include members with expertise in the design and construction of reprocessing facilities.

COMMISSIONNING STAGES

[3] If such verification is carried out at later stage the probability of problems occurring and the time and cost for its corrective action, may increase.

[4] Inactive commissioning includes all commissioning and inspection activities with and without the use of non-active solutions, before the introduction of radioactive materials. Tests carried out in the construction stage may also be included in accordance with national regulations.

Inactive commissioning

IV.39. Relevant items important to safety shall be tested for loss of or failures in, the supporting systems, as far as practicable in the inactive stage, in accordance with the requirements established in the safety assessment.

Active commissioning

IV.40. By the end of active commissioning, all the safety requirements for active operations shall be applied. Any exceptions shall be justified in the commissioning safety case.

Commissioning report

IV.41. The commissioning report shall identify any updates required to the safety case and identify any changes made to safety measures or work practices during commissioning.

EMERGENCY PLANNING

IV.42. The emergency plan shall be prepared, tested and reviewed (commissioned) prior to the introduction of radioactive material to the reprocessing facility.

OPERATION

IV.43. A spent fuel acceptance and reprocessing feed programme[5] of a reprocessing facility shall be prepared and assessed to ensure that the requirements established in the safety assessment are met throughout the reprocessing processes, and to ensure no unacceptable impact on the reprocessing facility products and waste.

MANAGEMENT SYSTEM

IV.44. Related to the complexity of the reprocessing facility design and its hazard potential, the operating organization shall:

- Establish and maintain the quality of the interfaces & communication channels between different worker groups within the reprocessing facility and between the reprocessing facility and other facilities both on-site and off-site;

[5] The feed programme is the planned sequence of fuel feeding to the dissolver in a given campaign; a campaign is period of operation with a sequence of fuel feed that does not require any adjustment to the reprocessing facility control parameters to meet safety control requirements.

- In addition to meeting the requirement of para 9.14, covering the minimum staffing for operation, define the minimum staffing level to ensure safety of the reprocessing facility in its shut-down state.

Receipt of radioactive material

IV.45. Procedures shall be developed to ensure that radioactive material received at the facility is appropriately characterized and acceptable before it is allowed to be stored or used within the facility.

FACILITY OPERATION

IV.46. The feed programme shall be supported by appropriate fuel data, prior to committing to dissolution of the fuel, to confirm that the fuel characteristics match the feed programme safety requirements.

IV.47. For each reprocessing campaign, the values of control parameters shall be based on the fuel and fuel solution characteristics derived from the actual fuel feed programme for that campaign, as required by the safety assessment.

IV48. The operating organisation shall ensure control of, and be able to account for, all nuclear material on the facility at all times.

Operating documentation

IV.49. Operating procedures shall include the action(s) to be taken in the event that operational limits and conditions are exceeded.

IV.50. Particular attention shall be paid to the arrangements for the efficient and accurate transfer of information and records between shift teams (shift handovers) and between shift and day teams.

Specific provisions

IV.51. The operating organization shall take actions to minimize the risks associated with maintenance during shutdowns (inter-campaign periods).

CRITICALITY PREVENTION

IV.52. All facility personnel shall be trained in the general principles of criticality control, including the requirements of the emergency response plan.

IV.53. Procedures for the transfer or disturbance of fissile material during operational states (including maintenance) shall be defined, including hold-points submitted to clearance from a person who is independent of the operations management.

IV.54. Fissile material, in particular waste materials that have not been monitored for fissile content, shall not be collected or placed in containers unless they have been specifically designed and approved for that purpose.

IV.55. All transfers of fissile material including waste shall be in accordance with the criticality safety requirements of both the sending area and the receiving area and shall be subject to certification as such by the sending plant and acceptance by the receiving plant prior to sending.

IV.56. The inadvertent addition of water or neutralizing chemicals (often used for decontamination) to fissile solutions, which can cause precipitation with a criticality risk, shall be minimized. Such liquid feed lines shall be isolated or shall be subject to appropriate administrative controls during normal operations according to the requirements established in the safety assessment.

IV.57. Adequate arrangements for responding to a criticality accident shall be established and maintained. These arrangements shall include the development of an emergency plan, definition of responsibilities and provision of equipment and shall include emergency operating procedures.

RADIATION PROTECTION

IV.58. Due to the wide range of radiation types and physical and chemical forms of radioactive materials, the type of monitor used, either fixed or mobile monitors, shall be specified by suitably qualified radiation protection personnel.

Prevention of internal and external exposure

IV.59. During operation (including maintenance interventions), the prevention of internal and external exposure shall be controlled by both physical and administrative means, in order to limit the need to use personnel protective equipment as far as reasonably practicable.

FIRE, CHEMICAL & INDUSTRIAL SAFETY MANAGEMENT

IV.60. The potential for fire and the control of ignition sources and potential combustible materials, including process chemicals, shall be carefully considered, included during maintenance operations.

RADIOACTIVE WASTE AND EFFLUENT MANAGEMENT

Solid waste management

IV.61. Solid waste generation, treatment and storage shall be organised according to pre-established criteria and shall take into consideration disposal.

Liquid waste management

IV.62. Heat generating high level waste shall be stored in facilities that address (through design and operation measures) the need to maintain suitably reliable cooling, in accordance with the requirements established in the safety assessment.

Aerial discharges

IV.63. As required by the safety assessment, the efficiency and effectiveness of gaseous waste treatment equipment and last stage filters shall be confirmed and action shall be taken if results are not compliant with those specified in the operational limits and conditions.

Liquid discharges

IV.64. As required by the safety assessment, the effectiveness of liquid waste treatment systems shall be confirmed and action shall be taken if results are not compliant with those specified in the operational limits and conditions.

Appendix V

REQUIREMENTS SPECIFIC TO FUEL CYCLE RESEACH AND DEVELOPMENT FACILITIES

The following requirements are specific to fuel cycle research and development facilities at laboratories and at pilot and demonstration scales that receive, handle, process, examine and store a large variety of radioactive materials with very different physical characteristics (e.g. uranium, thorium, plutonium), other actinides (e.g. americium, neptunium, curium), fission products, activated materials and irradiated fuel.

Research and development facilities can be used to investigate various fuel manufacturing techniques, reprocessing and waste handling techniques and processes, as well as to investigate material properties of fuel before and after irradiation in the reactor, and to develop equipment, the use of which is envisaged later at an industrial scale.

DESIGN

SAFETY FUNCTIONS

V.1. The facility shall be designed to prevent a criticality accident and the accidental release of hazardous materials. The design shall keep radiation exposures during normal operation as low as reasonably achievable.

Confinement of radioactive materials

V.2. Containment shall be the primary method for ensuring confinement against the spreading of contamination. Containment can be provided by two complementary containment systems — static and dynamic. In view of the large range of potential radiological hazards presented by fuel cycle research and development facilities, a graded approach shall be used in the design of the containment systems.

Protection against exposure to radiations

V.3. The activities involved in fuel cycle research and development facilities generally rely on analytical data from samples. Sampling devices, sample transfer methods, sample storage and the analytical laboratories shall be designed to minimize doses to workers.

OPERATION

MANAGEMENT SYSTEM

Receipt of radioactive material

V.4. Procedures shall be developed to ensure that radioactive material received at the facility is appropriately characterized and acceptable before it is allowed to be stored or used within the facility.

CRITICALITY PREVENTION

V.5. Criticality hazards may be encountered during any research and development activity, including maintenance work. If fissile material has to be removed from equipment, only approved containers shall be used.

V.6. Any wastes and residues arising from experiments or pilot processes, decontamination, or maintenance activities that contain fissile material shall be collected in containers with a favourable geometry and shall be stored in dedicated criticality safe areas.

RADIATION PROTECTION

V.7. During operation, radiation protection personnel shall be part of the decision-making process prior to an activity commencing.

EMERGENCY PLANNING AND PREPAREDNESS

V.8. An emergency plan shall be prepared and shall focus on the following aspects for immediate response:

- Fires and explosions;
- Criticality accidents;
- Release of hazardous materials, both radioactive and chemical.

V.9. In dealing with a fire, a fire fighting medium shall be used that does not itself create a criticality hazard.

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