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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 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; all the chemical cycles of separation and purification (including solvent removal from aqueous solutions, solvent treatment and rework); the concentration of fission products and plutonium and uranium nitrates; the conversion of plutonium and uranium nitrate to oxides; the storage of these products; interim waste storage from the process stream and prior conditioning (e.g. fission products solutions in vessels).

In reprocessing facilities, the full range of radioactive materials and risks that may be encountered in the nuclear fuel cycle, are present.

Although out of scope of this Appendix, it is worth noting that specific attention to some of the processes at the reprocessing facility will be required, including:

- receiving and unloading (dry or wet) spent fuels;
- pool storage of spent fuel;
- vitrification of high level waste and the storage of associated glass containers, if located within the reprocessing facility.

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.

IV.2. Investigation and assessment regarding the safety aspects of site selection for a reprocessing plant shall be mainly focused on the site conditions through the potential effects of natural and man-induced events or aggressions on the facilities. The site shall also be evaluated with respect to:

- safety aspects of storage and transportation (both from and to the site) of materials or waste.
- the possibility for the environment to receive liquid or aerial radioactive and chemical discharges.

DESIGN

SAFETY FUNCTIONS

IV.3. Reprocessing facilities shall be designed to:

- Prevent criticality accidents;
- Prevent the uncontrolled release of hazardous (including radioactive) materials;
- Keep radiation exposure during normal operation and accident conditions as low as reasonably achievable.

ENGINEERING DESIGN

IV.4. The design shall take into account the operating experience feedback of similar facilities.

Cooling

IV.5. Cooling systems, including any support features, shall have adequate capacity, availability and reliability to remove heat from radioactive decay and for removing heat due to chemical reactions, e.g. during the dissolution of spent fuel in nitric acid.

IV.6. Cooling systems shall be designed for preventing coolant from leaking into moderation control areas designated for criticality safety.

Sampling and analysis

IV.7. Process sampling systems and post-accident sampling systems shall be provided for determining in a timely manner the concentration of specified radionuclides in fluid process systems, and in gas and liquid samples taken from systems or from the environment, in all operational states and in accident conditions and as required by material control and accounting.

IV.8. Appropriate means shall be provided at the reprocessing facility for the monitoring of activity in fluid systems that have the potential for significant contamination, and for the collection of process and waste samples. The timescale of sample analysis and assessment shall be commensurate with any processing lag in the system.

IV.9. Equipment shall be provided for monitoring, prior to or during discharges from the plant to the environment, radioactive effluents and effluents with possible contamination.

CRITICALITY PREVENTION

IV.10. Criticality accidents shall be prevented and controlled by means of design, as far as is reasonably practicable.

IV.11. As part of the overall safety assessment of the facility, 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 controlled parameters, such as geometry, mass, enrichment or moderation.

IV.12. A reference fissionable material composition or medium shall be defined. The criticality safety assessment performed using this reference shall be a conservative bounding case of the actual fissionable material composition being handled or processed, e.g. mass, volume, isotope vector. Such a reference shall be used in engineering studies performed prior to the initial start-up of any process step. These studies shall be designed to assure that processes, in-process measurements, and analytical measurements perform within established limits.

IV.13. Particular attention shall be paid to those system interfaces where there is a change in the fissionable material state or in the control mode. Particular attention shall also be paid to the transfer of fissionable material between equipment with a safe geometry to equipment with an unsafe geometry. Stringent controls shall be considered for any processing steps performed before an analytical value is determined for the materials in process.

IV.14. If the design of the reprocessing facility accounts for burn-up credit, its use shall be appropriately justified.

IV.15. In the criticality safety assessment, account shall be taken of the potential for mis-direction, overflow, spills and leaks of fissionable material e.g. mis-transfer due to human error or potential carry over, e.g. from evaporators.

IV.16. In the criticality safety assessment, the choice and safety of the use of fire extinguishing media, e.g. water or powder, shall be addressed.

IV.17. In the criticality safety assessment, account shall be taken of the effects of corrosion, erosion and vibration cracking in systems exposed to oscillations.

IV.18. In the criticality safety assessment, consideration shall be given to the potential for internal and external flooding and other internal and external hazards that may compromise criticality prevention measures.

CONFINEMENT OF RADIOACTIVE MATERIAL

Occupational protection

IV.19. During normal operation, internal exposure shall be minimized by design as far as reasonably practicable.

IV.20. The design and layout of plant equipment shall include provisions to minimize exposures arising from maintenance, inspection and testing activities as far

as reasonably practicable. However, such measures shall be reviewed with safeguards staff before being finalized and installed.

IV.21. Systems shall be provided for the ventilation of buildings at the reprocessing facility with appropriate capability for cleaning of air:

- to prevent unacceptable dispersion of airborne radioactive substances within the plant;
- to reduce the concentration of airborne radioactive substances to levels compatible with the need for access by personnel to the area;
- to keep the levels of airborne radioactive substances in the plant below authorized limits and as low as reasonably achievable;
- to ventilate rooms containing inert gases or noxious gases without impairing the capability to control radioactive effluents;

IV.22. In the design of a reprocessing facility, account shall be taken of the performance criteria for ventilation and containment systems, including the pressure difference between zones, the types of filter to be used, the differential pressure across filters and the appropriate flow velocity for operational states.

IV.23. The efficiency of filters and their resistance to chemicals, high temperatures of the exhaust gases and fire conditions shall be taken into consideration.

Public and environmental protection

IV.24. Systems shall be provided for treating solid radioactive waste and liquid radioactive waste at the reprocessing facility to keep the amounts and concentrations of radioactive releases below the authorized limits on discharges and as low as reasonably achievable.

IV.25. Systems shall be provided at the reprocessing facility for treating liquid and gaseous radioactive effluents to keep their amounts below the authorized limits on discharges and as low as reasonably achievable.

IV.26. In the design of the reprocessing facility it shall be ensured that radioactive liquids discharged from the reprocessing facility site are collected, treated and confirmed to be within authorised limits prior to discharge to the environment. Analytical results from such discharges shall be reported to material control and accounting personnel at the facility.

POSTULATED INITIATING EVENTS

IV.27. The following initiating events shall also be considered in the design of the reprocessing facility:

Internal initiating events

Fire and Explosion

IV.28. The risk of fire, explosion or of excess internal pressure resulting from:

- the use of explosive gases, flammable liquids and chemical substances such hydrogen or hydrogen peroxide, nitric acid, tributyl phosphate (TBP) and diluents, hydrazine nitrate;
- the generation of hydrogen by radiolysis in aqueous or organic solutions and solids;
- the forming of explosive products due to chemical reaction, e.g. nitrated organic substances (red oils), or thermal runaway reaction;
- pyrophoric materials (zircaloy fines);

Shall be considered and appropriate safety measures implemented.

IV.29. The potential formation of explosive materials inside ventilation equipment due to gaseous mixtures shall be considered and appropriate safety measures implemented.

IV.30. In areas with potentially explosive atmospheres, the electrical network and equipment shall be protected in accordance with industrial safety regulations.

IV.31. A detection and/or suppression system shall be installed that is commensurate with the risks of fires and is in compliance with national requirements.

IV.32. Extinguishing devices, automatically or manually operated, shall be installed in areas where a fire is possible.

Equipment Failure

IV.33. 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 for ensuring industrial safety of non-nuclear equipment, e.g. guards, fuses, seals, insulation, installed in glove boxes or hot cells shall be adapted to their radiological environment.

Leaks

IV.34. Provisions to prevent, detect and collect leaks arising from corrosion, vibration and erosion shall be implemented. Specific attention shall be given to equipment containing concentrated acid solutions, especially when at high temperatures.

Flooding

IV.35. Reprocessing facilities shall be designed to prevent the leakage of contaminated liquid to the environment in the event of internal flooding.

Loss of support systems

IV.36. During the design of a reprocessing facility, the loss of safety related items and safety systems (including their supporting features) shall be considered and their impact on safety shall be assessed.

IV.37. The design of electrical power supplies to reprocessing facilities shall ensure their adequate availability and reliability. In case of the loss of normal power, an emergency electrical supply shall be provided to the relevant items important to safety, taking into account the reprocessing facility's operational status (e.g. normal operation, shutdown, maintenance and clean-out). The restoration of the electrical supply shall be pre-planned and exercised to ensure adequate and timely deployment.

Use of pressurised and vacuum equipment

IV.38. 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. Safety measures to minimize the consequences of potential failure or leak in high active area shall be implemented.

Load drops

IV.39. Handling systems shall be designed to reduce the frequency of occurrence of load drops. The consequences of possible load drops shall be minimized.

External Initiating Events

Earthquake

IV.40. Provisions, e.g. instrumentation, support systems and procedures, for post-earthquake monitoring of the safety status and safety functions of the reprocessing facility shall be provided.

Extreme weather conditions

IV.41. Extreme weather conditions shall be taken into account in the design of items important to safety, in particular cooling systems associated with the storage of heat generating high level waste.

INSTRUMENTATION AND CONTROL SYSTEMS

Instrumentation

IV.42. Adequate instrumentation shall be provided for measuring the variables that are relevant to the safety of the reprocessing facility, both:

- in normal operation to ensure that the process is being operated within the safety limits and to monitor its environmental impact;

- for detecting and managing accident conditions, such as criticality or earthquake detection.

Automated safety control systems

IV.43. Where prompt and reliable action is necessary, provision shall be made in the design for automatic safety control or action.

IV.44. Automated safety control systems, e.g. safety interlock systems, shall be designed to ensure their adequate availability and reliability.

RADIOACTIVE WASTE AND EFFLUENT MANAGEMENT

IV.45. The design of the reprocessing facility shall enable safe management of radioactive waste and effluents arising from operational states, maintenance and periodic wash-out of the facility. Due consideration shall be paid to the various nature, composition and activity level of the waste generated in the facility.

COMMISSIONING

COMMISSIONING PROGRAMME[1]

IV.46. Special attention shall be paid to ensuring that no commissioning tests are performed that might place the plant in an unanalysed condition. Each safety function shall be verified as fully as practicable before the stage in which the function becomes necessary to ensure safe commissioning.[2]

IV.47. The following activities shall, as a minimum, be performed:

1. During inactive commissioning:[3]

- 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;
- Demonstration of the availability of emergency power supply.

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

[2] 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.

[3] 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.

IV.48. The ability to test and maintain the reprocessing facility and its systems, once commercial operation has started, shall be addressed in the commissioning programme, especially for hot cells and remote equipment.

ORGANIZATION AND RESPONSIBILITIES

IV.49. During commissioning, the safety committee shall include members with expertise in the design and construction of reprocessing facilities.

COMMISSIONING STAGES

Active commissioning

IV.50. 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.51. 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.52. The emergency plan shall be prepared, tested and reviewed (commissioned) prior to the introduction of radioactive material to the reprocessing facility.

OPERATION

IV.53. A spent fuel acceptance and reprocessing feed programme[4] of a reprocessing facility shall be prepared and assessed to ensure that the requirements established in the operating licence and in the safety assessment are met throughout the reprocessing processes, and to ensure that there is no unacceptable impact on the reprocessing facility products and waste/discharges generated.

MANAGEMENT SYSTEM

[4] The feed programme is the planned sequence of fuel feeding to the head end facility and dissolver in a given campaign; a campaign is a 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.

IV.54. 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;
- 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.55. Procedures shall be developed to ensure that radioactive material received at each facility is appropriately characterized and acceptable before it is allowed to be stored or used within the facility. The timescale of sample analysis and assessment shall be commensurate with any processing lag in the system.

FACILITY OPERATION

IV.56. 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.57. 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.

IV58. 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.59. Operating procedures shall include the action(s) to be taken in the event that operational limits and conditions are exceeded.

IV.60. 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.

IV.61. The operator shall document the following:

- all incident/accidents/events and associated radionuclide releases;
- all environmental monitoring data as required by regulations or license conditions;
- radioactive waste inventory including those disposed or stored onsite;

- all inspection records and corrective actions.

Specific provisions

IV.62. The operating organization shall take actions to minimize the risks associated with maintenance during shutdowns (inter-campaign periods).

CRITICALITY PREVENTION

IV.63. Relevant facility personnel shall be trained in the general principles of criticality control, including the requirements of the emergency response plan.

IV.64. Procedures for the transfer or movement of fissionable material during operational states (including maintenance) shall be defined and submitted for approval from criticality safety staff that are, to the extent necessary, independent of the operations management.

IV.65. Fissionable 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.66. Prior to modifying the location, or neutron reflectors or connections of process equipment installed in inaccessible cells, the criticality assessment shall be updated to determine whether such change is acceptable.

IV.67. Specific provisions shall be provided to reduce the risk of accumulation of organic phase in tanks which handle aqueous solutions containing fissionable materials.

IV.68. All transfers of fissionable material including waste and residues shall be in accordance with the criticality safety requirements of both the sending area and the receiving area and shall be subject to certification by the sending plant and acceptance by the receiving plant prior to sending.

IV.69. The inadvertent addition of water or neutralizing chemicals (often used for decontamination) to fissionable 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.

IV.70. The lack of accumulation of fissionable material in tanks, for which sub-criticality is not guaranteed only by the geometry shall be periodically reviewed by appropriate means after draining and rinsing, if any.

IV.71. 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.72. Appropriate equipment, either stationary or mobile, shall be provided at the reprocessing facility to ensure that there is adequate radiation monitoring in operational states and, as far as is practicable, in accident conditions.

Prevention of internal and external exposure

IV.73. 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.74. The potential for fire or explosion and the control of ignition sources and potential combustible materials, including hazardous and toxic process chemicals, shall be carefully considered, including during maintenance operations.

IV.75. Each handling device used for transferring loads containing radioactive substances or loads in line of equipment containing radioactive materials or participating in safety functions shall be subjected to appropriate check and operating instructions.

RADIOACTIVE WASTE AND EFFLUENT MANAGEMENT

Waste management

IV.76. Waste generation, treatment and storage shall be organised according to pre-established criteria and shall take into consideration both on-site storage capacity and disposal.

IV.77. Heat generating high level waste shall be stored in facilities that address the need to maintain suitably reliable cooling.

IV.78. Liquid waste shall be transferred into a solid and neutralized to enhance safety.

DECOMMISSIONING

IV.79. Special procedures shall be implemented to ensure that criticality control is maintained in dismantling equipment whose criticality is controlled by geometry.

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), separated isotopes (fissionable and non-fissionable), fission products, activated materials and irradiated fuel. Furthermore, a wide range of other materials are used in such facilities, for example graphite, boron, gadolinium, hafnium, zirconium, aluminium, heavy water and various metal alloys.

Fuel cycle research and development facilities are generally characterized by the need for high flexibility in their operations and processes, but typically have low inventories of fissionable materials and can include both hands-on and remote handling operations.

Fuel cycle 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.

Some safety issues specific to fuel cycle research and development facilities are:

- the manipulation of small amounts of radioactive material;
- the diversity of the experiments carried out and the associated safety assessment, which might be covering several different experiments;
- the potential manipulation of unusual radionuclides, such as “exotic” actinides, with the associated risks;
- the organizational and human factors as the operations are mainly manual and require the cooperation between the operating personnel of the facility and R&D personnel.

DESIGN

SAFETY FUNCTIONS

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

ENGINEERING DESIGN

V.2. The design shall, as far as reasonably practicable, prevent hazardous concentrations of gases and other explosive or flammable materials.

CRITICALITY PREVENTION

V.3. Criticality safety shall be ensured by means of preventive measures. Preference shall be given to achieving criticality safety by design, to the extent practicable, rather than by means of administrative measures.

CONFINEMENT OF RADIOACTIVE MATERIALS

V.4. Containment shall be the primary method for ensuring confinement against the spreading of contamination. Containment can be provided by two complementary containment systems — static (e.g. physical barriers) and/or dynamic (e.g. ventilation). 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 with respect to the nature and number of the barriers and their performance, in accordance with the severity of the potential radiological consequences of their failure.

PROTECTION AGAINST EXPOSURE TO RADIATIONS

V.5. 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.

POSTULATED INTIATING EVENTS

Internal initiating events

Fires and explosion

V.6. A fire detection system shall be installed that is commensurate with the risks of fires and is in compliance with national requirements.

V.7. In areas with potentially explosive atmospheres, the electrical network and equipment shall be protected in accordance with industrial safety regulations.

OPERATION

MANAGEMENT SYSTEM

Receipt of radioactive material

V.8. 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.

Qualification and training of personnel

V.9. An inappropriate response to a fire or explosion at the facility could increase the consequences of the event (e.g. radiological hazards including criticality, chemical hazards). Specific training and drills for personnel and external fire and rescue staff shall be organized by the operating organization.

CRITICALITY PREVENTION

V.10. 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.11. In the criticality safety assessment, the choice and safety of the use of fire extinguishing media, e.g. water or powder, shall be addressed.

V.12. 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.

EMERGENCY PLANNING AND PREPAREDNESS

V.13. 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.14. In dealing with a fire or a release of hazardous materials (e.g. UF_6), the actions taken or the medium used to respond to the emergency shall not create a criticality hazard or add to the chemical hazard.

DECOMMISIONING

V.15. Special procedures shall be implemented to ensure that criticality control is maintained in dismantling equipment whose criticality is controlled by geometry."

V.16. Criticality safety shall be ensured for the temporary storage of radioactive waste contaminated with plutonium that is generated by the dismantling of gloveboxes and their contents.

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