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Design of Fuel Handling and Storage Systems for Nuclear Power Plants

DRAFT SAFETY GUIDE

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DESIGN OF FUEL HANDLING AND STORAGE SYSTEMS FOR NUCLEAR POWER PLANTS

FOREWORD

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D 9 (Step 10: Second internal review of the draft publication).

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. This Safety Guide provides recommendations on how to meet the ~~was prepared in support of safety~~ requirements established in IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [1]~~[1]~~, in relation to the design of fuel handling and storage systems for nuclear power plants. ~~which was published in 2012 and was revised (as Rev.1) in 2016.~~

~~1.1.~~1.2. This Safety Guide is a revision of ~~supersedes~~ IAEA Safety Standards Series No. NS-G-1.4, Design of Fuel Handling and Storage Systems for Nuclear Power Plants[1], which it supersedes~~published in 2003~~.

~~1.2.~~1.3. This Safety Guide takes into account lessons from the accident at the Fukushima Daiichi nuclear power plant in 2011, in particular in respect of ~~with~~ the application of strengthened defence in depth to the design of fuel handling and storage systems in nuclear power plants.

OBJECTIVE

~~1.3.~~1.4. The objective of this Safety Guide is to provide recommendations for the design of fuel handling and storage systems in nuclear power plants, in order to meet the ~~application of safety~~ requirements established ~~stated~~ in SSR-2/1 (Rev.1) [1]~~[1]~~ for these systems~~to the design of fuel handling and storage systems in nuclear power plants~~.

SCOPE

~~1.4.~~1.5. This Safety Guide ~~is intended for~~ applies~~cation~~ primarily to land based stationary nuclear power plants with water cooled reactors. All statements are applicable to light water reactors, i.e.~~,~~ pressurized water reactors and boiling water reactors, and are generally applicable to pressurized heavy water reactors unless otherwise specified. The concepts in this~~is~~ Safety Guide can be ~~referenced for conceptual~~ applied~~cation~~, with judgement, to other reactor types (e.g.~~,~~ gas-cooled reactors, small and modular reactors, innovative reactors).

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Design of Fuel Handling and Storage Systems for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-1.4, IAEA, Vienna (2003).

1.5.1.6. This Safety Guide addresses the design aspects of fuel handling and storage systems for fuel that remains part of the operational activities of a nuclear reactor(s). From this perspective, this Safety Guide covers the following stages of fuel handling and storage in a nuclear power plant:

(a) Receipt of new fuelfresh fuel ;

(b) Storage and inspection of new fuelfresh fuel before use;

(c) Transfer of new fuelfresh fuel into the reactor;

(d) Removal of irradiated fuel from the reactor and transfer of the irradiated fuel to the spent fuel pool;

(e) Reinsertion (shuffling) [TC1]of irradiated fuel from the spent fuel pool into the reactor, when as requirednecessary;

(f) Storage, inspection and repair of irradiated or spent fuel[2] in the spent fuel pool, and its the preparation for the removal of this fuel from the spent fuel pool;

(g) Handling of fuel casks in the spent fuel pool; and

(h) Transfer of spent fuel casks.[TC2]

Spent fuel sHandling and sStorage systems with associated fuel handling systems for spent fuel that does not remain as part of the operational activities of a nuclear reactor(s) (e.g. as needed for, interim wet or dry storage) are addressed in IAEA Safety Standards Series No. SSG-15, Storage of Spent Nuclear Fuel [2][2].

1.6.1.7. Limited consideration is also given in this Safety Guide to the handling and storage of certain irradiated core components, such as reactivity control devices.

1.7.1.8. This Safety Guide is intended for application to UO_2 fuels (natural, enriched or reprocessed uranium) and plutonium-blended UO_2 fuel (mixed-oxide fuel) with metal cladding.

1.9. This Safety Guide is mainly primarily intended for application to fuel handling and storage systems in for new nuclear power plants. For nuclear power plants designed to earlier standards, it is expected that in the safety assessments of such designs a comparison will be made with the current standards (for example as part of the safety reassessment of the plant), to determine whether the safe

[2] Spent fuel means fuel removed from the a reactor core following irradiation and that is no longer usable in its present form [3].

operation of the plant could be further enhanced by means of reasonably practicable safety improvements: see para. 1.3 of SSR-2/1 (Rev. 1) [1].It can be used for revising the design of nuclear power plants in operation, for instance in the context of a periodic safety review. It might be however not possible or practicable to apply all the recommendations in this Safety Guides to existing nuclear power plants.

1.10. The terms used in this Safety Guide are to be understood as defined and explained in the IAEA Safety Glossary [3].

STRUCTURE

1.8.1.11. Section 2 provides general recommendations for the design of fuel handling and storage systems for nuclear power plants to meet the requirements mainly established provided in Sections 3 and 4 of SSR-2/1 (Rev. 1) [1][1]. The subsequent Sections 3– through 6 provide specific recommendations to achieve fulfil the fundamental safety functions in frame terms of the general design approach and to meet the safety requirements mainly established in Sections 5 and 6 of SSR-2/1 (Rev. 1) [1]. Sections 3 and 4 provide specific recommendations for the safe design of fuel storage systems and fuel handling systems, respectively. Section 5 provides specific recommendations for the safe design of equipment used for spent fuel inspection and repair of spent fuel, and for handling of damaged fuel. Section 5 also provides specific recommendations for the safe design of handling and storage systems for irradiated core components. -Section 6 provides guidance on the design of handling equipment for spent fuel casks in the spent fuel pool.

1.9.1.12. The Annex I provides describes some operating aspects of simplified information with regard to the handling of spent fuel casks. in the spent fuel pool.

2. SAFE DESIGN OBJECTIVES AND DESIGN APPROACH

MANAGEMENT SYSTEM

2.1. The design of fuel handling and storage systems should is required to be conducted in accordance with Requirements 1–3 of SSR-2/1 (Rev. 1) [1][1] and the requirements established in IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety . taking into account The recommendations of provided in IAEA Safety Standards Series No. GS-G-3.1, Application of the Management System for Systems and Activities [5][5] and IAEA Safety Standards Series No. GS-G-3.5, The Management System for Nuclear Installation [6][6] to meet Requirementsshould also be taken into account.~~ 1 3 of SSR-2/1 (Rev. 1) [1] and requirements in IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [5].~~

FUNDAMENTAL SAFETY FUNCTIONS

2.2. In ~~A~~accordance~~ing~~ ~~to~~ with Requirement 4 of SSR-2/1 (Rev. 1) [1]~~[1]~~, the design should identify the fuel handling and storage structures, systems and components ~~which~~ that ~~in all plant states provide~~ are necessary to fulfil the following fundamental safety functions in all plant states:

(a) Maintaining subcriticality of the fuel;

(b) Removal of the decay heat from irradiated fuel; ~~and~~

(c) Confinement of radioactive material, shielding against radiation as well as ~~and~~ limitation of accidental radioactive releases.

DESIGN APPROACH

Maintaining subcriticality of the fuel

2.3. ~~Recommendations in p~~Paragraphs 2.4~~2.4~~–2.6~~2.6~~ address ~~provide guidance recommendations on to fulfill~~~~meeting~~ the requirements in ~~Requirement 80,~~ para. 6.66 (a) of SSR-2/1 (Rev. 1) [1]~~[1]~~.

2.4. ~~The design of f~~Fuel handling and storage systems are required to ~~should~~ be designed~~such as~~ to prevent criticality by maintaining specified subcriticality margins under all operational states and accident conditions.

2.5. The ~~design of~~ storage systems for authorized fuel[3] should be designed~~such as~~ to prevent criticality preferably by ~~control~~ the use of geometrically safe configurations.

2.6. The design of fuel storage systems ~~should is also required to~~should consider the use of physical means or physical processes to increase subcriticality margins in normal operation ~~in order~~ to ~~prevent~~ avoid ~~from~~ reaching ~~the~~ criticality during postulated initiating events including those postulated initiating events arising from the effect of internal and external hazards[TC3].

[3] Authorized fuel refers to s~~S~~pecific fuel type(s) licensed for use in the fuel handling and storage systems.

Removal of the decay heat from irradiated fuel

2.7. To fulfill In accordance with Requirement 80, para. 6.67 (a) of SSR-2/1 (Rev. 1) [1][1], the design of fuel handling and storage systems should are required to be designed such as to maintain adequate fuel cooling capabilities for irradiated fuel. As such, these systems should be designed to ensure that and not to exceedthe fuel cladding temperature limits and/or theor coolant temperature limits, as defined for operational states and accident conditions, are not exceeded.

Confinement of radioactive materials and limitation of radioactive releases

2.8. Recommendations in pParagraphss 2.92.9–2.112.11 provide guidance recommendations on meetingto fulfill Requirements 5 and 80 of SSR-2/1 (Rev. 1) [1][1]:

2.9. Design provisions should are required be introduced to prevent damage to fuel (rods and assemblies) [TC4] during handling: see para. 6.66(d) of SSR-2/1 (Rev. 1) [1]. There should also be design provisions, and to collect and filter radioactive releases material from the spent fuel storage in order to keep radioactive releases as low as reasonably achievable during in operational states.

2.10. Ventilation systems should are required to be implemented, as necessary, to reduce the concentrations of airborne radioactive materials, and, thus, to prevent or reduce direct exposure and contamination in areas with radiation hazards: see Requirement 73 of SSR-2/1 (Rev. 1) [1].

2.11. Design provisions should be provided to collect and filter radioactive materials released in case the event of handling accidents, and to prevent uncovering of irradiated fuel assemblies in the spent fuel storage in accident conditions .

Shielding against radiation

2.12. Recommendations in pParagraphss 2.132.13–2.142.14 provide guidance recommendations to fulfillon meeting Requirements 5 and 81 of SSR-2/1 (Rev. 1) [1][1].

2.13. Fuel handling equipment and fuel storage systems should include shielding as necessary to keep occupational doses as low as reasonably achievable in operational states.

2.14. Design provisions should be implemented as necessary to prevent a loss of shielding from irradiated fuel resulting in high radiation doses for workers for in operational states and accident conditions (see also para. 2.11 of SSR-2/1 (Rev. 1) [1][1]).

Interfaces of safety with security and safeguards

2.15. To ~~fulfill~~ meet Requirement 8 of SSR-2/1 (Rev. 1) [1]~~[1]~~, items important to safety ~~of~~ in relation to fuel handling and storage should be designed taking into account ~~design recommendations for~~ safety and nuclear security in an integrated manner in such a way that safety measures do not compromise nuclear security and nuclear security measures do not compromise ~~each other~~safety. Nuclear ~~S~~security measures should be consistent with the objective and essential elements established in IAEA Nuclear Security Series No. 20 ~~guidance in~~ [7]~~[7]~~ and the recommendations provided in IAEA Nuclear Security Series No. 13 [8]~~[8]~~.

2.16. The design of fuel handling and storage systems should also facilitate the application and maintenance of IAEA safeguards, and the State system of accounting for, and control of, nuclear material~~ accountancy and control~~.

Proven engineering practices

2.17. To ~~fulfill~~ meet Requirement 9 of SSR-2/1 (Rev. 1) [1]~~[1]~~, ~~the design of~~ items important to safety ~~of~~ in relation to fuel handling and storage should ~~should is required to~~ be of a design~~such a design~~ that has been proven either ~~by~~ in equivalent applications based on ~~operational~~ operating experience or ~~on~~ by the results of a relevant research programme. Alternatively, such items should ~~, or according~~ confirm to the design and design verification and ~~/~~validation processes stated in applicable codes and standards.

Safety assessment in design process

2.18. To ~~fulfill~~ meet Requirement 10 and para. 4.17 of SSR-2/1 (Rev. 1) [1]~~[1]~~, the safety assessment of fuel handling and storage systems ~~should~~ is required to be performed as part of the design process, with iterations between ~~the~~ design stages and safety analyses, and with increasing ~~in the~~ scope and level of detail as the design progresses. ~~Guidance~~ Recommendations on ~~the~~ deterministic safety assessment ~~is~~ are provided~~described~~ in IAEA Safety Standards Series No. SSG-2, Deterministic Safety Analysis for Nuclear Power Plants [9]~~[9]~~, and ~~guidance~~ recommendations on ~~the~~ probabilistic safety assessment ~~is~~ are provided~~described~~ in IAEA Safety Standards Series No. SSG-3, Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants [10]~~[10]~~ and IAEA Safety Standards Series No. SSG-4, Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants [11]~~[11]~~.

Other considerations

2.19. ~~Beside~~ In addition to ensuring that fuel is stored safely ~~storage~~, fuel handling and storage systems are also required to facilitate the following activities (~~Requirement 80,~~ see paras 6.66 and 6.67 of SSR-2/1 (Rev. 1) [1]~~[1]~~):

(a) Inspection of the fuel (rods and assemblies);[TC5]

(b) Maintenance, periodic inspection, calibration and testing of items important to safety;

(c) Identification of individual fuel assemblies;

(d) Arrangements to permit accounting for and control of nuclear fuel; ~~and~~

(e) Decontamination of areas, maintenance and future decommissioning.

2.20. To ~~fulfill~~ meet Requirement 12 of SSR-2/1 (Rev. 1) [1]~~[1]~~, design provisions ~~should~~ ~~are required to~~ should be introduced to minimize the potential for generating radioactive effluents and waste~~s~~ during normal operation.

2.21. The effects of irradiation should be considered in the design of structures, systems and components of fuel handling and storage systems.

3. DESIGN BASIS FOR STRUCTURES, SYSTEMS AND COMPONENTS OF FUEL STORAGE

GENERAL

3.1. In the context of this Safety Guide, items important to safety ~~of fuel storage~~ include the~~:~~ pool structure, pool liner, pool cooling systems, pool purification systems, make-up systems, gates and fuel storage racks.

~~GENERAL~~

3.2. Items important to safety are required to be designed in compliance with Requirement 80 of SSR-2/1 (Rev. 1) [1]~~[1]~~, with account taken ~~of~~ of Requirements 14–28~~all other requirements~~ of SSR-2/1 (Rev. 1) [1]~~[1]~~ relevant to:

(a) The ~~P~~protection of workers, the public and the environment ~~against~~ from ~~the~~ harmful effects of ionizing radiation in operational states and in accident conditions

(b) Adequate reliability of the various systems;

(c) Prevention of high radiation doses, practical elimination of [TC6]early or large radioactive releases.

3.3. To ~~fulfill~~ meet Requirement 14 of SSR-2/1 (Rev. 1) [1], the design basis of items important to safety should ~~be established~~ take ~~ing~~ into account ~~inter alia~~the following:

(a) The safety function(s) to be performed by the items or to which the itemsy contribute;

(b) The postulated initiating events the itemsy have to ~~cope~~ withstand;

(c) The protection against the effects of internal hazards;

(d) The protection against the effects of external hazards;

(e) The safety classification;

(f) Design limits or acceptance criteria;

(g) The engineering design rules ~~applicable to the system~~for the items;

(h) Recommended instrumentation and monitoring;

(i) Provisions against common cause failures;

(j) The ~~E~~environmental conditions ~~for~~ considered in the qualification programme; ~~and~~

(k) Selection of materials.

3.4. The design should define the necessary provisions and devices ~~necessary~~ to facilitate the use of non-permanent equipment for the re-establishment of safe conditions in the fuel storage in the event~~case~~ of multiple failures that~~, which~~ are not accounted for in the design basis. This ~~may~~ include the provision of flanges and sockets for the use of mobile equipment.

DEFENCE IN DEPTH

3.5. ~~Recommendations in p~~Paragraphs~~s~~ 3.6~~3.6~~ –3.8~~3.8~~ provide recommendations~~guidance to fulfill~~ on meeting Requirement 7 of SSR-2/1 (Rev. 1) [1]~~[1]~~:.

3.6. The design of spent fuel storage systems should include multiple means to remove decay heat from irradiated fuel and to maintain subcriticality margin~~s~~ in all the ~~various~~ plant states considered in the design.

3.7. The ~~need for~~application of the concepts of redundancy, diversity and functional independenc~~ey~~ should be defined taking into account para. 3.8~~3.8~~. ~~Implemented~~ The combined application~~ation~~ of redundancy, diversity and independenc~~ey~~ among the various cooling means should be adequate to demonstrate ~~that~~ that the coolant temperature limits and/or fuel cladding temperature limits defined for operational states and for accident conditions are not exceeded and [TC7]~~-~~that the uncovering of the fuel assemblies is prevented with a high level of confidence.

3.8. The ~~risk~~ potential for common cause failures of the means of decay heat removal ~~means~~ should be identified and the consequences of such failures should be assessed. In ~~the~~ cases that ~~may~~ might result in the uncovering the assemblies or an interruption to the removal of decay heat[TC8], the identified vulnerabilities ~~of the decay heat removal means~~ should be removed to the extent possible by the provision ~~implementation~~ of diverse and redundant ~~provisions~~means.

SAFETY FUNCTIONS

3.9. The safety functions performed by the fuel handling and storage systems and the contribution of each major structure and component in the fulfil~~accomplish~~ment of these functions should be described in a level of detail that is sufficient ~~for a~~to enable ~~definition of~~ the design bases of the structures, systems and components to be defined.

POSTULATED INITIATING EVENTS

3.10. ~~Recommendations in P~~paragraphs~~s~~ 3.11~~3.11~~–3.13~~3.13~~ provide ~~guidance~~ recommendations ~~to~~ on ~~fulfill~~ meeting Requirement 16 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

3.11. For spent fuel storage, an adequate coolant inventory in the fuel storage area is essential to the fundamental safety functions of decay heat removal and radiation protection, and can contribute to maintaining subcriticality margins. Therefore, the potential for a significant loss of coolant inventory should be a major consideration in the identification of postulated initiating events.

3.12. Postulated initiating events relevant to the design of fuel storage systems should ~~be~~ include those events that potentially lead to a reduction in subcriticality margin, a reduction in decay heat removal capability, a significant release of radioactive material~~s~~, or a significant direct radiation exposure of operating personnel. Postulated initiating events are caused by equipment failures, ~~operating errors~~ operator errors, external hazards~~,~~ or internal hazards. Typical examples of postulated initiating events are provided in paras 3.50~~3.48~~ and 3.52~~3.50~~.

3.13. Bounding ~~conditions~~ cases ~~caused by~~associated with the postulated initiating events ~~should~~ are ~~required to~~should be determined to define the necessary performance capabilities of the equipment designed to mitigate their consequences: see para. 5.9 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

3.14. ~~Recommendations in p~~Paragraphs~~s~~ 3.15~~3.15~~ –3.33~~3.33~~ provide ~~guidance~~ recommendations on meeting~~to fulfill~~ ~~requirements relevant to "Internal Hazards" of~~ Requirement 17 of SSR-2/1 (Rev. 1) [1]~~[1]~~ in relation to internal hazards.

3.15. Items ~~necessary for maintaining safe conditions~~important to safety ~~should~~ are required to be designed to withstand loads resulting from or be protected against the effects of internal hazards: see para. 5.15A of SSR-2/1 (Rev. 1) [1]~~[1]~~. ~~That protection~~The design should also consider the consequences of the failure of unprotected equipment.

3.16. The redundant elements~~cies~~ of the fuel handling and storage systems should be segregated to the extent possible, or else should be adequately separated, and protected as necessary to prevent the loss of the safety function performed by the systems (i.e. to prevent~~ion of~~ common cause failures initiated by the effects of ~~the~~ internal hazards).

3.17. The effects of a single hazard should not result in the failure of ~~all~~ the entire cooling capability of spent fuel storage systems.

3.18. The storage building should be designed to withstand the ~~hazard~~ loadings generated by hazards occurring within the plant site (e.g.~~,~~ explosions and internally generated missiles).

3.19. The ~~D~~design methods and construction codes used should provide adequate margins to ~~prevent~~ avoid~~the~~ cliff edge effects in the event of a minor increase in the severity of an internal hazard above the design basis.

3.20. The ~~R~~recommendations provided in IAEA Safety Standards Series No. NS-G-1.7, Protection Against Internal Fires and Explosions in the Design of Nuclear Power Plants [12]~~[12]~~, and IAEA Safety Standards Series No. NS-G-1.11, Protection against Internal Hazards other than Fires and Explosions in the Design of Nuclear Power Plants [12]~~[12]~~ should be considered in order to identify the relevant hazards and develop appropriate methods of protecting equipment from ~~the selected internal~~these hazards.

3.21. Typical examples of internal hazards ~~which~~ that influence the design of fuel handling and storage systems are provided in ~~the subsequent~~ paras 3.22–3.33.~~graphs.~~

Heavy load drop

3.22. The potential for falling heavy loads to damage stored fuel or otherwise impact the ~~continued~~ fulfilment ~~implementation~~ of the fundamental safety functions ~~should~~ is required to be considered in the design: see ~~(P~~para. 6.67(d) of SSR-2/1 (Rev. 1) [1]~~)~~. Falling objects are primarily the result of component failures and ~~operator~~ errors by operating personnel during fuel handling.

3.23. ~~Due~~ Owing to the frequency of fuel handling, a drop of a fuel assembly in any area traversed during the handling should be considered. ~~Other potential l~~Load drops in the fuel storage area ~~include~~ could also occur during the movement of water-tight gates, the transfer of tools, and the ~~infrequent~~ installation or removal of fuel storage racks.

3.24. Very heavy objects associated with refuelling operations (e.g.~~,~~ the reactor vessel head and activated ~~reactor~~ internal structures of the reactor) and fuel transfer or storage cask loading operations should be excluded from consideration as hazards in the fuel storage area through prevention, , with a high level of confidence,[TC9]with a high level of confidence, by careful design of the handling equipment~~,~~ and ~~of~~ by means of the layout of the refuelling, fuel storage~~,~~ and cask loading areas.

3.25. The design and layout of fuel handling and storage systems should prevent the movement of ~~these~~ heavy objects over the fuel storage areas through spatial separation, and should prevent indirect effects through structural independence of the fuel storage area and the construction of weirs or other structures to prevent a substantial loss of coolant inventory in the event of heavy load drops that damage structures in nearby areas.

Internal flooding in ~~new fuel~~fresh fuel ~~-~~dry storage areas for fresh fuel

3.26. The design and layout of dry storage areas for ~~new fuel~~fresh fuel ~~dry storage~~ should provide protection against internal flooding~~, for example,~~ by means of, for example, flood barriers, routing of water piping through areas isolated from the fuel storage ~~or~~ and adequate drains, in order to ~~keep~~ maintain the ~~minimum~~ subcriticality margins.

Pipe breaks

3.27. Equipment that performs~~ing the~~ a fundamental safety function~~s~~ should be protected against the effect of high~~-~~ energy and moderate[TC10] ~~-~~energy pipe breaks.

3.28. ~~A~~ The substantial loss of coolant inventory from spent fuel storage systems ~~resulting~~ due to~~from~~ a pipe break~~s~~ should be avoided by ensuring that all liner penetrations in the fuel storage area are above the elevation necessary for adequate shielding in the spent fuel pool area (see para. 6.68 of SSR-2/1 (Rev. 1) [1]).

Fires

3.29. ~~All design relevant~~The recommendations ~~indicated~~ provided in NS-G-1.7 -[12]~~[12]~~ should be implemented to reduce the probability ~~for~~ of a fire ~~to~~ being started, to limit ~~its~~ the propagation of the fire, to protect items important to safety and to prevent the loss of the fundamental safety functions. The following paras 3.30~~3.29~~–3.32~~3.31~~ provide recommendations specific to fuel storage.

3.30. For spent fuel storage, the different cooling capabilities and each redundant division of a cooling system should be implemented in ~~its own~~individual fire compartments, or at least each of these should be in ~~its own~~an individual fire cell if~~, where~~ implementing individual ~~a~~ fire compartments is not achievable.

3.31. To be protected from fire, ~~new fuel~~fresh fuel~~–~~dry storage areas for fresh fuel should be implemented inside a fire compartment.

3.32. The effects of firefighting agents on the subcriticality of ~~new fuel~~fresh fuel in dry storage should be ~~accounted for~~considered.

Explosions

3.33. If hydrogen generation is considered as a hazard, specific design provisions should be implemented to prevent hydrogen generation or to limit hydrogen concentration (e.g.~~,~~ ensuring~~e~~ material compatibility with spent fuel storage pool coolant chemistry or providing~~e~~ ventilation). These provisions should ensure ~~so~~ that the hydrogen concentration is kept at a safe level below the lower flammability limits, including in locations where higher hydrogen concentration ~~may~~ might exist.

EXTERNAL HAZARDS

3.34. ~~Recommendations in p~~Paragraphs 3.35~~3.35~~–3.43~~3.42~~ provide recommendations~~guidance to fulfill~~ on meeting ~~the requirements relevant to “External Hazards” of~~ Requirement 17 of SSR-2/1 (Rev. 1) [1]~~[1]~~, in relation to external hazards.

3.35. The ~~R~~recommendations provided in IAEA Safety Standards Series No. NS-G-1.5, External Events Excluding Earthquakes in the Design of Nuclear Power Plants [14]~~[14]~~ should be considered, in order to understand the general concept ~~for~~ of ~~a complete~~ identifying~~ication of the~~ relevant external hazards and ~~for an adequate~~ protecting~~on of the~~ structures, systems and components against the effects of these ~~selected external~~ hazards.

3.36. For fuel storage, , ~~I~~items important to safety of fuel storage designed to accomplish fundamental safety functions ~~should~~ are required to be protected against, or designed to withstand the effects of the selected external hazards: see para. 5.15A of SSR-2/1 (Rev. 1) [1].

3.37. The protection should primarily rely on an adequate layout and design of the buildings at the site.

~~3.36.~~3.38. For each hazard~~s~~ or likely combinations of hazards, the structures, systems and components whose operability ~~or/~~and/or integrity ~~is required~~needs to be maintained during or after the hazard should be identified and specified. Where the protection ~~of~~ provided by the layout and design of buildings is not sufficient~~effective~~, structures, systems and components should be designed to withstand the loadings generated by the hazard ~~loads and loads~~and ~~from~~ by likely combinations of hazards.

~~3.37.~~3.39. With regard to fuel storage, i~~I~~tems important to safety ~~of fuel storage~~ should be ~~classified and~~ assigned ~~to~~ the appropriate seismic categori~~es~~z~~ations~~es in accordance with the recommendations ~~and guidance given~~provided in IAEA Safety Standards Series No. NS-G-1.6, Seismic Design and Qualification for Nuclear Power Plants [15]~~[15]~~. The structures, systems and components necessary for the ~~accomplishment~~ fulfilment of ~~the~~ the ~~fundamental~~ safety functions should be designed to withstand SL-2 seismic loads and provision~~s~~ should be ~~taken~~ made to protect them against the effects of such loads on~~event their failure caused by~~ other equipment.

~~3.38.~~3.40. The ~~S~~seismic design specifications for items important to safety ~~of fuel storage~~ should be established on the basis of the consequences ~~with regard to~~of potential damage to stored fuel assemblies, the release of radioactive material~~s~~ in the building and the ~~necessity~~ need to operate the storage systems during and after an earthquake~~.~~. The design of the- spent fuel storage ~~analysis~~ for seismic qualification should take into ~~consider~~ account ~~for~~ the potential for a decrease of the ~~water~~ coolant inventory due to sloshing and for a reduction of the subcriticality margins due to the potential displacement of solid neutron absorbers.

~~3.39.~~3.41. For spent fuel storage, in the event of external hazards, short term actions necessary to maintain a sufficient coolant inventory and an adequate cooling of the fuel -should rely on on-site equipment. Only long term actions should rely on off-site equipment or the availability of off-site [TC11]services ~~available~~.

~~3.40.~~3.42. The ~~M~~methods of design, and the construction codes and standards used should ~~should are required to~~ provide adequate margins to prevent cliff edge effects in the event of an increase of the severity of the external hazards.~~: see para. 5.21 of SSR-2/1 (Rev. 1) [1].~~

~~3.41.~~3.43. ~~Margins provided by the design of the structures, systems and components ultimately necessary to avoid high radiation doses and a large radioactive release should be such~~It should ~~that it can~~ be ~~demonstrated~~ ensured that the integrity of the structures, and the operability of ~~those~~ systems and components, would be preserved in case of natural hazards causing loads that exceed~~ing~~ those ~~resulting~~ determined from the hazard evaluation at the site. ~~In this~~With regard to fuel storage~~s~~, criticality and high radiation doses should be prevented, and irradiated fuel cooling capability should be preserved.

PLANT CONDITIONS TO BE TAKEN INTO ACCOUNT IN DESIGN

Fuel storage capacity

~~3.42.~~3.44. The spent fuel storage capacity should be designed in accordance with ~~the~~ a fuel management policy with a specifi~~c~~ed design capacity and specific positions for stored fuel assemblies. ~~That is, a~~Adequate capacity for spent fuel storage should be provided to allow ~~time for~~ sufficient time for radioactive decay ~~time~~ and for removal of residual heat before the spent fuel is remov~~al~~ed from the spent fuel pool. The maximum storage capacity should consider the availability of licensed ‘away-from-reactor’ storage facilities for spent fuel and the minimum ~~decay~~ time ~~required~~ necessary for radioactive decay and for cooling prior to transfer. A~~s~~t a minimum, the storage capacity should allow for storage of all expected discharged fuel assemblies (~~according to~~in accordance with the fuel management policy) plus additional storage locations for unloading one full core. For mixed-oxide fuel, the higher residual heat values that ~~may~~ might further delay the transfer of the spent fuel into storage casks should be taken into account.

Normal operation

~~3.43.~~3.45. During normal operation, the fundamental safety functions should be accomplished without exceeding the limits and bounding conditions established for normal operation with regard to subcriticality margin, coolant temperature and occupational ~~doses~~ exposures (including radiation levels and airborne activity levels in the workplace).

~~3.44.~~3.46. Decay heat should be removed by a dedicated cooling system designed to maintain the coolant temperature below the maxim~~al~~um temperature specified for normal operation.

~~3.45.~~3.47. In the design of storage systems for spent fuel ~~storage systems~~, adequate means should be implemented and available for:

(a) Maintaining coolant activity within the specifications established for normal operation;

(b) Maintaining coolant chemistry within the specifications established for normal operation;

(c) Compensating for water losses by evaporation;

(d) Collecting radioactive gases potentially leaking from defective fuel rods;

(e) Maintaining appropriate clarity of the coolant for fuel handling operations;

(f) Monitoring and controlling coolant temperature;

(g) Monitoring and controlling the coolant water level; and

(h) Monitoring and controlling airborne activity.

3.46.3.48. Ventilation and air conditioning supporting the spent fuel storage system should be designed in accordance with para. 6.48 of SSR-2/1 Rev 1 [1]. Recommendations for the design of ventilation air conditioning systems are provided in IAEA Safety Standard, Design of Auxiliary and Supporting Systems in Nuclear Power Plants [14].

Anticipated operational occurrences

3.47.3.49. Anticipated operational occurrences should be identified and postulatedspecified to define the design provisions necessary to maintain subcriticality margins, cooling conditions and the coolant inventory within the limits established for anticipated operational occurrences.

3.48.3.50. Typical examples[4] of postulated initiating events which that are categorized asresult in anticipated operational occurrences, based on their frequency of occurrence and radiological consequences, include the following:

(a) Loss of off-site power;

(b) Loss of coolant (small leaks) in the cooling and filtration and/or /purification system, or through the seals of gates;

(c) Loss of cooling water flow, or (for pressurized water reactors) dilution of soluble neutron absorbers (only relevant to pressurized water reactors);

(d) Malfunctioning of a normal operation fuel cooling system during normal operation;

(e) Abnormal fuel assembly configurations with involving a single misplaced fuel assembly or a dropped fuel assembly (without cladding damage) in the fuel storage.

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[4] Typical eExamples are design dependent.

Accident conditions

~~3.49.~~3.51. Credible equipment failures that caus~~eing~~ conditions more severe than anticipated operational occurrences (i.e. with regard to the ~~accomplishment of the~~ fundamental safety functions stated in para. 2.2~~2.2~~) should be postulated.

~~3.50.~~3.52. Single equipment failures and multiple equipment failures should be considered, in order to define design basis accident conditions ~~or~~ and design extension conditions, respectively. Typical examples[46] of such failures to be considered include the following:

(a) Design basis accidents:

- Significant loss of coolant (e.g.~~,~~ breaks of piping connected to the spent fuel pool);
- Failure of the ~~normal operation~~ cooling system used in normal operation;
- Abnormal fuel assembly configurations (e.g. a fuel assembly positioning error~~s~~ and a dropped irradiated fuel assembly with cladding damage);
- A ~~S~~significant change of moderation conditions in fuel storage (e.g.~~,~~ large dilution of soluble neutron absorber (pressurized water reactor only) in the wet storage area, or flooding of the dry storage area).

(b) Design extension conditions:

- Multiple failures leading to the ~~long period~~ loss of the forced cooling system for a long period;[TC12]
- Combinations of failures selected on the basis of probabilistic risk assessments (e.g. a c~~C~~ombination of anticipated operational occurrences or postulated accidents with a common cause failure affecting the system designed for mitigating the event of concern).

DESIGN LIMITS

~~3.51.~~3.53. ~~Recommendations in p~~Paragraphs 3.54~~3.52~~–3.58~~3.56~~ provide recommendations on meeting~~guidance to fulfill~~ Requirements 15 and 28 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~3.52.~~3.54. The performance of structures, systems and components for spent fuel storage should meet the acceptance criteria established for ~~the~~ different operational states and accident conditions.

~~3.53.~~3.55. Stresses caused by load combinations should not exceed the stress limits defined by the design codes ~~used~~ for ~~the design of~~ the structures, systems and components.

3.54.3.56. Criticality should is required to be prevented in all operational states and accident conditions with specified margins: see para. 6.66(a) of SSR-2/1 (Rev. 1) [1]. Examples of good practices[5] are:

(a) For dry storage of new fuelfresh fuel, the effective multiplication factor calculated for optimum moderation conditions should not exceed a values specified as perin national regulations, (e.g., 0.95–0.98, including uncertainties included); and

(b) For wet storage of spent fuel, the effective multiplication factor calculated should not exceed 0.95 in normal operation, and should not exceed values specified as perin national regulations (e.g., 0.95–0.98, including uncertainties) in anticipated operational occurrences and in accident conditions (uncertainties included).

3.55.3.57. For wet storage of spent fuel, an adequate coolant inventory should be maintained over the top of the irradiated fuel assemblies for shielding in all operational states and accident conditions, as follows:

(a) For wet storage of spent fuel, the water level in the pools should be sufficient to appropriate forprovide radiationological shielding of for the operating personnel during fuel handling operations (to comply ensure that doses towith the such personnel will be maintained below the dose limits and will be kept as low as reasonably achievable dose rate limitations and objectives) during in normal operation and under in anticipated operational occurrences; and

(b) In accident conditions, a substantial coolant inventory should be maintained for to provide radiationological shielding.

3.56.3.58. For wet storage of spent fuel, decay heat removal should be adequate to maintain the spent fuel pool temperature at acceptable levels for operating personnel and for the normal operation purification system under for all conditions of normal operating conditionsoperation, including high decay heat loads associated with refuelling. For anticipated operational occurrences, the decay heat removal capability should be promptly restored to return the pool temperature to normal operating conditions without reaching boiling[TC13] conditions. In accident conditions, adequate removal of heat should be maintained by relying on inherent safety features, on the operation of active or passive systems, or a combination of safety features and active and passive systemstheir combinations, as followsthat is:

5 Examples are design dependent.

(a) Maintaining forced cooling during in both design basis accidents and in design extension conditions;

(b) Maintaining forced cooling during in design basis accidents, and relying on natural evaporation of coolant supplemented by makeup water to compensate for the loss of coolant inventory for design extension conditions, to provide for acceptable diversity in the removal of heat in accident conditions; or.

(c) For both design basis accidents and [TC14] design extension conditions, relying on natural evaporation of coolant, supplemented by makeup water to compensate for the losst of coolant inventory to provides another alternative for removal of heat in accident conditions.

RELIABILITY

3.57.3.59. Recommendations in pParagraphs 3.603.58–3.803.78 provide recommendations on meeting guidance to fulfill the Requirements 18, 21–through 26, 29, and 30, and 80 of SSR-2/1 (Rev. 1) [1][1].

3.58.3.60. To fulfill meet Requirement 23, the requirements established in para. 5.37 of SSR-2/1 (Rev. 1) [1][1], the design of items important to safety of spent fuel storage should is required to ensure that these items can withstand all conditions specified in be consistent with their design bases with sufficient reliability and effectiveness.

3.59.3.61. To fulfill Requirement 80, As stated in para. 6.68 of SSR-2/1 (Rev. 1) [1][1], the reliability of the design for spent fuel storage systems should is required to be such that "the possibility of conditions arising that could lead to an early radioactive release or a large radioactive release is 'practically eliminated' and so as to avoid high radiation fields on the site."

3.60.3.62. The reliability of the different means designed to operate in different plant states should be commensurate with the safety significance importance of the function to be accomplished.

3.61.3.63. Different factors influence the reliability and each of these factors should be considered in order to achieve the adequate reliability of the different systems necessary to remove decay heat from spent fuel storage and to maintain an adequate coolant inventory in the pool. These factors include:, inter alia:

(a) Safety classification and the associated engineering rules for design and manufacturing of individual structures, systems and components;

(b) Design criteria relevant for the systems (number of redundant trains, seismic qualification, qualification in relation to harsh environmental conditions, power supplies);

(c) Consideration of vVulnerabilities for common cause failures and related design provisions (e.g. by means of , for example, diversity, separation, and independence);

(d) Layout provisions to protect the systems against from the effects of internal and external hazards;

(e) Design provisions for monitoring, inspection, testing and maintenance.

3.62.3.64. For normal operation, anticipated operational occurrences and for accident conditions, the heat removal capacity should be designed taking intowith account taken of the maximumal heat loads and the maximumal heat sink temperature.

3.63.3.65. Methods to ensure the robust design of fuel storage systems should are required to should be specified applied in order to fulfill meet Requirement 18 of SSR-2/1 (Rev. 1) [1][1]. For all safety classes identified, corresponding engineering design rules should be specified and applied. These include:

(a) Use of appropriate codes and standards;

(b) Proven engineering practices;

(c) Conservative safety margins;

(d) Qualification.

Reliability for operational states

3.64.3.66. Gates separating the spent fuel pools from other pools or compartments should be water-tight under in normal operating conditionsoperation and during anticipated operational occurrences. (i.e., Ggates with pneumatic seals should be provided with reliable back-up air supplies to maintain pressure following a loss of off-site power).

3.65.3.67. Provisions should be implemented to detect, locate, collect, isolate and collect locate any leakage of water through the pool metallic liners of the pool. Means should be in place for repairing of small leakages through the pool metallic liners.

3.66.3.68. The cooling system operated in normal operation should be designed to maintain the coolant temperature below the maximumal temperature specified for normal operation despite even when the unavailability of cooling components of the system are unavailable due tofor maintenance purposes.

~~3.67.~~3.69. The cooling system should be designed to maintain the coolant temperature below the maximum~~al~~ temperature specified for anticipated operational occurrences in the event of ~~the~~ a loss of ~~the~~ off-site power.

Reliability for accident conditions

~~3.68.~~3.70. The system(s) ~~required~~ necessary to remove decay heat in design basis accidents should be designed to meet the single failure criterion.

~~3.69.~~3.71. The forced cooling system ~~required~~ necessary to remove decay heat in design basis accidents should be provided with an emergency power supply.~~ied.~~

~~3.70.~~3.72. A single equipment failure or piping break in the forced cooling system should not lead to the total loss of forced cooling.

~~3.71.~~3.73. Means should be implemented (e.g. isolation valves, anti-si~~y~~phoning devices) ~~should be implemented~~ to minimize the loss of coolant in the event of a pipe break.

~~3.72.~~3.74. The system ~~required~~ necessary to remove decay heat in accident conditions should be designed so that it can be restarted in conditions in which the ~~pool water~~ subcooling function of the pool water is lost.

~~3.73.~~3.75. Water storage pools should not be designed with penetrations below the minimum water level ~~required~~ necessary for shielding of stored irradiated fuel in accident conditions.

~~3.74.~~3.76. The volume of the spent fuel pool should be adequate to ensure that, in the event of a loss of forced cooling, a sufficient period of time is available to allow for implementation of corrective measures before the water reaches the coolant temperature limits[TC15].

~~3.75.~~3.77. Design layout provisions should be implemented to prevent ~~from uncovering~~ the top of the spent fuel assemblies from becoming uncovered and to maintain ~~a~~ sufficient radiation~~ological~~ shielding in the ~~case~~ event of inadvertent or accidental leakage through a gate between the spent fuel pool and a drained fuel handling compartment~~(s)~~.

~~3.76.~~3.78. The spent fuel storage racks should be designed to maintain an adequate heat transfer from each irradiated fuel assembly through natural convective flow to prevent nucleate boiling within the fuel assembly.

~~3.77.~~3.79. Design provisions should be implemented to compensate for the loss of coolant by evaporation and for potential leakage associated with postulated accidents. Such provision includes a permanently installed system that provides emergency makeup water to ~~deal with~~restore the ~~water~~coolant -inventory~~coolant losses~~

~~3.78.~~3.80. Additional provisions ~~should are required to~~should be implemented to facilitate the use of non-permanent~~ly or other permanently installed~~ equipment or other permanently installed equipment to recover the coolant inventory and decay heat removal capability: see para. 6.68(c) of SSR-2/1 (Rev. 1) [1]. Such provisions ~~(which can also include the use of other permanently installed systems)~~ should be in an area where access can be ensured. Connecting devices should be provided outside ~~of~~ the spent fuel storage area. Typical provisions ~~can~~ include:

(a) Connection to other permanently installed systems, for example, the service water system and the fire water system;

(b) Installation of piping and fittings to allow connection of a cooling system or the delivery of makeup water using portable equipment in areas away from the spent fuel pool; ~~and~~

(c) Provisions for ventilation of the spent fuel pool area to remove decay heat and steam;~~, or~~

(d) ~~Adequate p~~Provisions to recover forced cooling of the spent fuel pool in the event ~~with~~ of an extended loss of AC power (i.e.~~,~~ station blackout);~~.~~

(e) Means for the temporary repair of small leaks through the metallic ~~pool~~ liners of the pool.[TC16]

STRUCTURAL INTEGRITY

~~3.79.~~3.81. The ~~S~~structural integrity and operability of structures and components designed to ~~accomplish~~ fulfil the fundamental safety functions should be maintained throughout ~~of~~ their ~~own~~ lifetime in all ~~the~~ operational states and accident conditions ~~during~~ in which they are designed to operate. The design should take account of relevant loading conditions (e.g.~~,~~ stress, temperature, corrosive environment and~~,~~ radiation levels), and should consider creep, fatigue, thermal stresses, corrosion, changes in material properties with time (e.g. concrete shrinkage) and the potential for degradation of ~~reinforcement~~reinforcing material. ~~—.~~

~~3.80.~~3.82. Loads and load combinations considered in the design should be identified, justified and documented. Typical examples of design loads~~,~~ load combinations for strength analyses and evaluation of stress analysis results are described in paras 3.83~~3.81~~–3.87~~3.85~~.

~~3.81.~~3.83. Design loads that should be considered in the design of storage racks ~~the~~ for ~~new fuel~~fresh fuel ~~storage racks~~ include the following:

(a) Static loads;

(b) Uplift forces on the racks due to the f~~F~~uel handling machine ~~uplift forces on the racks~~ (with an assumption that the forces are applied to a postulated stuck fuel assembly); ~~and~~

(c) SL-2 ~~S~~seismic loads~~ of the safe shutdown earthquake~~.

~~3.82.~~3.84. Design loads that should be considered in the design of storage racks ~~the~~ for spent fuel ~~storage racks~~ include the following:

(a) ~~Items~~The loads listed in ~~(a), (b) and (c) in~~ para. 3.83~~3.81~~;

(b) Dynamic loads resulting from the dropping of a fuel assembly~~ drop accident~~; ~~and~~

(c) Thermal loads.

~~3.83.~~3.85. Design loads that should be considered in the design of the storage structure for spent fuel ~~storage structure~~ include the following:

(a) SL-2 ~~S~~seismic loads ~~associated with the safe shutdown earthquake~~ and associated hydro-dynamic loads due to water movement in the storage area;

(b) Dynamic loads resulting from the dropping of a spent fuel cask~~ drops~~;

(c) Loads from thermal effects ~~of~~ resulting from an extended loss of cooling event; ~~and~~

(d) Static loads.

~~3.84.~~3.86. Methods for combining ~~the~~ individual loads should be established ~~according to~~in accordance with applicable codes and standards.

~~3.85.~~3.87. The allowable stresses for given loading conditions should comply with ~~the applicable~~ limits ~~of~~ specified in applicable proven codes and standards. If there are no such codes or standards ~~apply~~, justification should be provided for the allowable stress levels selected.

SAFETY CLASSIFICATION

~~3.86.~~3.88. ~~Recommendations in p~~Paragraphs 3.89~~3.87~~–3.93~~3.91~~ provide ~~guidance~~ recommendations ~~to fulfill~~on meeting Requirement 22 of SSR-2/1 (Rev. 1) [1]~~[1]~~. Recommendations on ~~the~~ safety c~~C~~lassification ~~process and guidance for classification is~~are ~~described~~ provided in IAEA Safety Standards Series No. SSG-30, Safety Classification of Structures, Systems and Components in Nuclear Power Plants [16]~~[16]~~.

~~3.87.~~3.89. For the purposes of safety classification, the consequences of the failure of the item in terms of the failure to perform ~~accomplishment of~~ the safety function, the radiation ~~level~~ exposure of workers and the level of the radioactive release should be considered.*]*

~~3.88.~~3.90. The safety classification~~ification~~ should be established in a consistent manner such that all systems necessary for the ~~accomplishment~~ fulfilment of ~~a~~ the same function in a specific plant state are assigned ~~in~~ to the same class, or else a justification for assigning a different class should be provided.

~~3.89.~~3.91. In accordance with Requirement 9 of SSR-2/1 (Rev. 1) [1], p~~P~~ressure retaining equipment should be designed and manufactured according to requirements established by national or international codes appropriate to their safety classification and the applicability of the selected design standard justified (see, for example, Refs. [17–19]). The engineering design and manufacturing rules applicable to each individual component ~~For each individual component, the requirements to be applied~~ should be selected with due account taken of the two effects resulting from its failure (function not ~~accomplished~~ fulfilled and radioactive release)[6]. ~~.~~

~~3.90.~~3.92. Specific structures or components should be designed and manufactured ~~according to~~in accordance with requirements established by national or international codes appropriate to their safety class~~ification; and~~ the applicability of the selected design standard should be justified.

~~3.91.~~3.93. In ~~A~~accordance with~~ing to~~ the recommendations ~~given~~ provided in SSG-30 [16]~~[16]~~:

(a) Structures that ensur~~eing~~ subcriticality margins should be assigned ~~in SSG-30~~to safety class 1;

(b) Systems designed not to exceed the design limits applicable to design basis accidents should be assigned ~~in SSG-30~~to safety class 2, or ~~in SSG-30~~to safety class 1 if they are needed in the short term;

(c) Systems implemented as a back-up of the system designated for design basis accidents should be assigned ~~in SSG-30~~to safety class 3, or ~~in SSG-30~~to safety class 2 if they are needed in the short term;

(d) Systems for heat removal in normal operation should be assigned ~~in SSG-30~~to safety class 3; ~~and~~

[6] ~~As examples, the pressure retaining boundary of components necessary for the accomplishment of decay heat removal in accident conditions are usually designed and manufactured in compliance with The American Society of Mechanical Engineers (ASME) Section III, Division 1, subsection NC (or Design and Construction Rules for Mechanical Components of Pressurized Water reactor Nuclear Islands — Level 2 (RCC-M2), The Japan Society of Mechanical Engineers (JSME) SNC1, Canadian Standards Association (CSA) — N285.0 or similar standards).~~

(e) Systems designed for operational states and whose failure would not lead to radiological consequences exceeding the limit specified for operational states need not be safety classified.

ENVIRONMENTAL QUALIFICATION

~~3.92.~~3.94. ~~Recommendations in p~~Paragraphs 3.95~~3.93~~–3.100~~3.98~~ provide ~~guidance~~ recommendations on meeting ~~to fulfill~~ Requirement 30 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~3.93.~~3.95. Structures, systems and components ~~should are required to~~should be qualified to perform their intended functions in the entire range of environmental conditions that might prevail prior to or during their operation until their mission time ~~be~~ is completed (see Requirement 30 of SSR-2/1 (Rev. 1) [1]~~[1]~~), or should otherwise be adequately protected from those environmental conditions.

~~3.94.~~3.96. The relevant environmental and seismic conditions that ~~may~~ might prevail prior to, during and following an accident, the ageing of structures, systems and components throughout the lifetime of the plant, synergistic effects, and margins should all be taken into consideration in the environmental qualification. ~~Relevant information is described~~Further recommendations are provided in NS-G-1.6 [15]~~[15]~~ and in IAEA Safety Standards Series No. NS-G-2.12, Ageing Management for Nuclear Power Plants [20]~~[20]~~.

~~3.95.~~3.97. Environmental qualification should include the consideration of such factors as temperature, pressure, humidity, radiation levels, radioactive aerosols, vibration, water spray, steam, flooding, electromagnetic influence[TC17], contact with chemical agents, and ~~their~~ combinations of these factors.

~~3.96.~~3.98. Environmental qualification should be carried out by means of testing or~~,~~ by analysis (including~~and~~ the use of engineering expertise), or by a combination of ~~these~~both: see also paras 5.49 and 5.50 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~3.97.~~3.99. For components subject to the effects of ageing by various mechanisms, a design life, a programme of inspection ~~program~~ and a replacement frequency (if appropriate) should be established. In the qualification of such components, samples should be subjected to artificial ageing experiments to simulate the end of their design lives before being tested under design basis accident conditions.

~~3.98.~~3.100. Qualification data and results should be documented and kept available as part of the design documentation.

PREVENTION OF CRITICALITY

~~3.99.~~3.101. When a subcritical margin cannot be maintained by control of geometry, additional means such as fixed neutron absorbers should be applied. If fixed neutron absorbers are used, it should be ensured by proper design and fabrication that the absorbers will not become separated or displaced ~~during~~ in operational states ~~and~~ or ~~during~~in accident conditions, including~~and~~ during or after an earthquake.

~~3.100.~~3.102. When soluble absorbers are used to meet the design limit for accident conditions, it should be demonstrated that pure water will not cause criticality ~~is not reached with pure water~~ in all modes of normal operation. [TC18]

~~3.101.~~3.103. Any geometric deformations of the fuel ~~and~~ or storage equipment that could be caused by any postulated initiating events should be taken into account in the design provisions for the prevention of criticality. Consideration should also be given to routine fuel movements that~~, which~~ could bring the fuel being moved into ~~close~~ proximity with stored fuel or in which fuel could be dropped and fall onto, or next to, stored fuel.

~~3.102.~~3.104. The lattice of the spent fuel storage racks should be designed to prevent any reduction of subcriticality margins due, for ~~instance~~example, to the entrapment of air or steam during fuel handling or storage.

~~3.103.~~3.105. Provision~~s~~ should be made in the design of fuel storage racks to prevent placement of fuel assemblies into inappropriate positions.

~~3.104.~~3.106. In determining the subcriticality, a conservatively calculated value of the effective multiplication factor k_{eff} or, alternatively, the infinite multiplication factor k_{∞} should be used. Recommendations ~~(General guidance for~~ on criticality safety ~~in the handling of fission material is described~~are provided in IAEA Safety Standards Series No. SSG-27, Criticality Safety in the Handling of Fissile Material [21]~~[21]~~.~~)~~ The following recommendations apply in respect of the design of fuel handling and storage systems:

(a) An adequate subcriticality margin under all credible conditions should be demonstrated, with account taken of all the uncertainties in the calculation codes and experimental data.~~;~~

(b) If the enrichment is variable within a fuel assembly, exact modelling should be used or a conservative uniform enrichment of the fuel assembly should be assumed.~~;~~

(c) If the enrichments ~~for~~ of the fuel assemblies differ, the design of the storage racks for ~~new fuel~~fresh fuel ~~storage racks~~ should generally be based on the enrichment value corresponding to that of the fuel assembly with highest enrichment or the most reactive fuel assembly.~~;~~

(d) All spent fuel assemblies should be assumed to have a burnup and enrichment that result in maximal ~~-~~reactivity, unless credit for burnup is assumed on the basis of a justification that includes appropriate measurements confirming the calculated values for fissile content or depletion level prior to storage of the fuel.~~;~~

(e) Where the fuel design is variable and/or there are uncertainties in any data relating to the fuel (in terms of design, geometrical and material specifications, manufacturing tolerances and nuclear data), conservative values should be used in all subcriticality calculations. If necessary, a sensitivity analysis should be performed.~~;~~

(f) The inventory of the fuel storage racks should be assumed to be at the maximum capacity of the design.~~;~~

(g) Credit should not be claimed for neutron absorbing parts or components of fuel storage racks for normal operations [TC19]unless they are permanently installed;~~.~~

(h) The fuel storage racks should be designed so that lateral, axial and bending loads leading to unacceptable dimensional changes of the fuel are prevented. Any geometric deformations of the fuel and the storage racks that could be caused by any postulated initiating event or by the design basis earthquake should be taken into account in the criticality assessment.~~;~~

(i) Appropriate conservative assumptions for moderation should be made.~~;~~

(j) Consideration should be given to the effects of neutron reflection, by taking into account ~~precisely~~ the exact design of the fuel storage racks including materials, dimensions and spacing between the fuel storage racks and between the fuel storage racks and the structures near the racks (e.g.~~,~~ floors and walls).~~;~~

(k) Assumptions ~~of~~ regarding neutronic decoupling for different storage zones, if applicable, should be substantiated by appropriate calculations~~; and~~.

(l) Allowance ~~should be made~~ for the presence of burnable absorbers that are integral parts of fuel assemblies should be made only ~~be made~~ on the basis of a justification that is acceptable to the regulatory body and that includes consideration of the possible reduction of subcriticality margins due to burnout of a burnable absorber.

RADIATION PROTECTION

~~3.105.~~3.107. The design of a spent fuel storage facility should ~~be such as to~~ provide for radiation protection of workers, the public and the environment in accordance with the requirements of national legislation, and ~~account taken of~~ the requirements established in IAEA Safety Standards Series No. ~~GRS~~

GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [22]~~[22]~~. Further~~ and the~~ recommendations are provided ~~presented ~~in IAEA Safety Standards Series No. NS-G-1.13, Radiation Protection Aspects of Design for Nuclear Power Plants [23]~~[23]~~.

~~3.106.~~3.108. In accordance with para. 6.48 and Requirement 81 of SSR-2/1 (Rev. 1) [1]~~[1]~~, ~~S~~suitable ventilation system(s) and shielding ~~should are required to~~should be implemented to maintain the concentrations of airborne radioactive material and the direct radiation exposure of workers ~~to direct radiation ~~as low as reasonably achievable in operational states~~ without exceeding limits defined for the protection of workers~~

~~3.107.~~3.109. Suitable confinement and filtration systems should be implemented to minimize the radiological consequences to the public and the environment and to ~~keep them~~ensure that these consequences are below the limits defined for operational states and accident conditions.

~~3.108.~~3.110. For the design of shielding, bounding ~~conditions ~~cases should be considered for initial fuel composition, ~~-~~burnup and cooling times for gamma and neutron radiation, the inventory of the spent fuel at the maximum design capacity of the spent fuel ~~-~~storage facility, the effects of axial burnup on gamma and neutron sources, the mobility of activated crud and the activation of non-fuel ~~hardware~~components.

~~3.109.~~3.111. Penetrations through shielding barriers (e.g. penetrations associated with cooling systems or penetrations provided for loading and unloading) should be designed to avoid localized high gamma and neutron radiation fields, either directly through ~~from both ~~the penetration ~~and ~~or due to radiation streaming.

~~3.110.~~3.112. ~~In dry storage, new fuel~~Fresh fuel containing fissionable material recovered by reprocessing emits a significant amount of radiation. ~~Its handling and storage should include ~~In dry storage, additional shielding should be provided to limit the exposure of operating personnel from the handling and storage of such fuel. ~~owing to its higher radiation levels~~

MATERIALS

~~3.111.~~3.113. Structural materials and welding methods should be selected on the basis of accepted design codes and standards. Consideration should be given to the potential cumulative effects of radiation on materials likely to be subjected to significant radiation fields. In addition, potential ~~thermal effects on ~~material degradation due to thermal effects should also be considered.

~~3.112.~~3.114. The material used for the pool liner and other structur~~ale~~ materials in contact with the coolant (e.g. racks) should have a low sensitivity to corrosion phenomena taking into account coolant chemistry.

3.115. Materials in direct contact with fuel should be compatible with the materials of the fuel assemblies, and should be such as to minimize chemical and galvanic reactions that~~, which~~ might degrade the integrity of the spent fuel during its storage. Materials in direct contact with spent fuel~~, and~~ should not contaminate the ~~spent~~ spent fuel with substances that might significantly degrade the integrity of the spent fuel during its storage.

~~3.113.~~3.116. Materials used in the construction of fuel storage systems should allow easy decontamination of surfaces.

~~3.114.~~3.117. The ~~C~~compatibility of decontamination materials with the operating environment should be considered.

~~3.115.~~3.118. Materials used in the construction of fuel storage systems should comply with the recommendations in paras 3.29–3.32 with regard to protection against fires.

~~3.116.~~3.119. For storage racks that use fixed solid neutron absorbers, it should be possible throughout the operating lifetime of the storage racks to demonstrate that:

(a) The ~~F~~fixed solid neutron absorbers have not lost their effectiveness; ~~and~~

(b) The ~~F~~fixed solid neutron absorbers are chemically compatible with the other rack components and are chemically stable when immersed in -water.

MONITORING

~~3.117.~~3.120. ~~Recommendations in p~~Paragraphs 3.121~~3.118~~–3.127~~3.124~~ provide recommendations on meeting ~~guidance to fulfill r~~Requirement 80, para. 6.68A and Requirement 82 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~3.118.~~3.121. Adequate and qualified instrumentation ~~should is required to~~should be implemented for monitoring the water level in the spent fuel storage in operational states and in accident conditions: see para. 6.68A (b) of SSR-2/1 (Rev. 1) [1]~~[1]~~.~~.~~ Reliable ~~wide range level~~ instrumentation for monitoring the water level over a wide range should be implemented for monitoring under accident conditions.

~~3.119.~~3.122. Adequate and qualified (as necessary) [TC20]instrumentation ~~should is required to~~should be implemented for monitoring water temperature in the irradiated fuel storage ~~in~~ for operational states and for accident conditions: see para. 6.68A (a) of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~3.120.~~3.123. Adequate and qualified instrumentation ~~should is required to~~should be implemented for monitoring the~~air~~ activity in air in fuel storage and fuel handling areas ~~in~~ for operational states and for relevant accident conditions: see para. 6.68A (c) of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~3.121.~~3.124. Adequate and qualified instrumentation ~~should is required to~~should be implemented for monitoring the activity in water~~ activity~~ in the irradiated fuel storage for~~ selected~~ operational states and for relevant accident conditions: see para. 6.68A (c) of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~3.122.~~3.125. Adequate means ~~should are required to~~should be implemented for monitoring chemical parameters in the spent fuel pool in operational states: see para. 6.68A (d) of SSR-2/1 (Rev. 1) [1]~~[1]~~. This should~~,~~ include~~ing~~ monitoring the concentration of soluble absorbers, as appropriate.

~~3.123.~~3.126. Instrumentation ~~required~~ necessary for monitoring ~~of~~ key parameters that will be used in accident management should be redundant.

~~3.124.~~3.127. Areas in which spent fuel is handled ~~and~~ or stored should be provided with suitable radiation monitoring equipment and alarms for the protection of operating personnel. This should include an adequate number of radiation monitors to ensure the protection ~~for the~~of personnel operat~~or~~ings ~~of~~ fuel handling machines. Provision~~s~~ should be made for continuous air monitoring in any area in which airborne radioactive material ~~may~~ might be released during the handling of irradiated fuel. More detailed recommendations are provided ~~by~~ in IAEA Safety Standards Series No. RS-G-1.8, Environmental and Source Monitoring for Purposes of Radiation Protection [24]~~.~~.

~~3.125.~~3.128. ~~3.125A~~ The design of fuel storage facilities should consider and facilitate the use of remote and robotic technology for monitoring and measurement of potentially very high ~~level~~ dose rates, particularly in ~~case~~ the event of an accident. Design ~~for~~ of ~~spent fuel pool~~ water purification systems for the spent fuel pool.[TC21]

~~3.126.~~3.129. Limits on concentrations of ~~radioactive substances~~radionuclides in spent fuel pool water should be specified~~ for the spent fuel pools~~. Limits should also be established for water quality and for levels of ~~atmospheric~~ radionuclides in the air~~contamination~~.

~~3.127.~~3.130. Systems for purification of the spent fuel pool water ~~purification~~ should be designed to ensure that:

(a) Radioactive, ionic and solid impurities arising from activation products, damaged fuel and other ~~materials~~ sources can be removed from the water so as to ensure that the radiation dose rate due to the ~~shielding~~ water itself can be maintained within the specified limits;

(b) The limits relating to the chemistry of the pool water (e.g.~~for instance,~~ boron concentration, content of chloride, sulphate and fluoride as appropriate, pH value and conductivity) ~~which~~ that are defined for normal operation in relation to maintaining subcriticality and minimizing corrosion can be complied with;

(c) The clarity of water can be maintained at an acceptable level so that fuel handling operations in water can be monitored;

(d) The Ccapacity of purification system is able sufficient to purify the water volume in the spent fuel pool within a specified period of time; and

(e) Provision is made for the control of microbial growth, as appropriate.

3.128.3.131. Systems for purification of spent fuel pool water purification should be designed to be able to remove impurities and suspended particles from the surface of the pool water.

3.129.3.132. The design of systems for the purification of spent fuel pool water purification systems should provide measures means for the local removal of pool water and for routing to the purification system or to local purification equipment, to be prepared forin the event of operations in which the release of radioactive material may might increase or the suspension of particles may might occur, for instanceexample, during fuel reconstitution.

3.130.3.133. The design of systems for the purification of spent fuel pool water purification systems should provide include measures for preventing the spread of airborne radioactive materialsradionuclides, including halogens, from the surface of the pool (e.g.for example, by positioning the ventilation and air conditioning suction inlets near the pool surface).

3.131.3.134. The design of the systems for the purification of spent fuel pool water purification systems should provide measures for preventing the unacceptable buildup of contamination in all fuel storage areas and for permitting facilitating the reduction of contamination to be reduced to acceptable levels if buildup does occur. Piping should be designed with a minimum of flanges and other features (such as traps or loops) in which radioactive material may might accumulate.

3.132.3.135. The maximal coolant temperature in normal operation should not exceed the maximumal permissible temperature of the purification equipment (e.g., ion exchanger).

ILLUMINATION EQUIPMENT

3.133.3.136. Recommendations in pParagraphss 3.1373.134–3.1403.137 provide guidance recommendations on meetingto fulfill Requirement 75 of SSR-2/1 (Rev. 1) [1][1].

~~3.134.~~3.137. Operational areas for spent fuel handling and storage, including the pool area, should be provided with the necessary illumination equipment ~~for illumination~~ (i.e.~~,~~ underwater lighting near work areas and ~~some~~ a means for the replacement of underwater lamps) to permit the satisfactory handling and visual inspection and identification of ~~the~~ fuel assemblies.

~~3.135.~~3.138. Materials used in underwater lighting should be appropriate for the environmental conditions and in particular should not undergo unacceptable corrosion or cause any unacceptable contamination of the water.

~~3.136.~~3.139. Resistance to impact and to thermal shock should be provided to the extent possible.

~~3.137.~~3.140. Lighting technologies with a high temperature spectrum to maximize the ~~depth~~ range of transmission through water should be selected.

4. DESIGN BASIS FOR EQUIPMENT AND COMPONENTS OF FUEL HANDLING SYSTEMS

~~4.1.~~ Fuel handling systems are mainly used to unload and reload the reactor core.

~~4.2.~~4.1. Fuel handling systems used in light water reactors include the following:~~:~~

(a) A ~~R~~refuelling machine to handle the new or spent fuel assemblies for loading and unloading the core and to move the assemblies between the core and either the fuel transfer system (for pressurized water reactors) or directly to the storage location (for boiling water reactors);

(b) A ~~S~~system to transfer fuel assemblies between the reactor pool and the spent fuel pool through the fuel transfer channel (for typical [TC22]pressurized water reactors); ~~and~~

(c) Systems to move and locate fuel assemblies ~~at~~ in fuel storage areas (e.g.~~,~~ auxiliary crane or hoist, ~~new fuel~~fresh fuel elevator and fuel handling machine);~~.~~

(d) Fuel handling tools (e.g.~~,~~ unlatching tools for the control rod drive shaft ~~unlatching tool~~, ~~new fuel~~fresh fuel assembly handling tools, spent fuel assembly handling tools).

~~4.3.~~4.2. Fuel handling systems used in pressurized heavy water reactors (channel type) include the following:

(a) A ~~S~~system to transport ~~new fuel~~fresh fuel assemblies to a fuelling machine (i.e.~~,~~ a ~~new fuel~~fresh fuel transfer mechanism);

(b) A ~~S~~system to load ~~new fuel~~fresh fuels into the core and to discharge spent fuels from the core (i.e.~~,~~ the fuelling machine);

(c) A ~~S~~system to transfer the spent fuel assemblies discharged from the fuelling machine into the storage pool water (e.g.~~,~~ elevator and ladder); ~~and~~

(d) Auxiliary crane or hoist in the fuel building; ~~and~~

(e) Fuel handling tools (e.g.~~,~~ a fuel bundle grappler).

GENERAL

~~4.4.~~4.3. To meet Requirement 14 of SSR-2/1 (Rev. 1) [1]~~[1]~~, a~~A~~ design basis should be defined for every component and equipment of fuel handling systems, and should specify the items listed in para. 3.3~~3.3~~, as applicable.

~~4.5.~~4.4. In ~~normal~~ operational states and in accident conditions, load~~ing~~s should be ~~appropriately~~ limited to ensure that neither fuel damage nor inadvertent criticality is caused and that no damage is caused to the structure of the spent fuel storage pool or the fuel handling equipment.

~~4.6.~~4.5. Provision~~s~~ should be made in the design of fuel handling systems to avoid dropping, sticking or jamming of fuel assemblies during handling and transfer operations.

~~4.7.~~4.6. Provision~~s~~ should be made in the design of fuel handling systems to avoid dropping of fuel handling tools during handling operations.

SAFETY FUNCTIONS

~~4.8.~~4.7. In accordance with Requirement 80 of SSR-2/1 (Rev. 1) [1]~~[1]~~, ~~F~~fuel handling systems ~~should are required to~~ should be designed to maintain subcriticality margins~~,~~ and to avoid fuel damage, ~~occupational doses~~high radiation fields~~,~~ and releases of radioactive material exceeding ~~the~~ specified limits during fuel handling operations. The contribution of major components and equipment to the fundamental safety functions ~~of major components and equipment~~ should be described in a level of detail sufficient for a definition of their design bases.

POSTULATED INITIATING EVENTS

~~4.9.~~4.8. ~~Recommendations in~~ ~~P~~paragraphs 4.9~~4.9~~–4.13~~4.13~~ provide ~~guidance to fulfill~~recommendations on meeting Requirement 16 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~4.10.~~4.9. Postulated initiating events relevant for the design of fuel handling systems ~~should~~ include equipment failures and~~,~~ ~~operating errors~~ operator errors that potentially lead~~ing~~ to reduction of the subcriticality margin, or to a significant release of radioactive material~~s~~, or to a significant direct radiation exposure of operating personnel. All Ssuch postulated initiating events should are required to be considered in the selected to design to establish the preventiveon measures and protective measures that are necessary to ensure that the required safety functions will be performed: (see para. 5.7 of SSR-2/1 (Rev. 1) [1][1]).

4.11.4.10. Where fuel handling constraints are essential for maintaining an adequate margin of subcriticality, operational operating errors operator errors such as misplacement of fuel assemblies and uncontrolled drops of fuel assemblies should be considered as postulated initiating events.

4.12.4.11. The Ppotential dropping of handled a fuel assemblyies should be considered as a postulated initiating event. A Ppotential release of radioactive material should be considered with regarding to the protection of workers, the public and to the environment.

4.13.4.12. Fuel misplacement during fuel movement activities should be prevented [TC23]in fuel movement activities by implementing interlocks of suitable reliability and quality.

4.14.4.13. Mechanical damage caused by excessive handling system forces or by dropping of heavy objects should be considered among internal events unless these can be prevented[TC24] by reliable interlocks. Examples of Ppossible handling system forces actions that may could cause damage include: fuel assembly hang-up, translation while hoisting or lowering, or and opening the grapple under load. Mechanical damage resulting from excessive motion (e.g., continued lowering after seating of the fuel assembly or upward motion into a hard stop) or and over excessive speed should also be considered.

INTERNAL HAZARDS

4.15.4.14. To fulfill meet Requirement 17 the requirements relevant to "Internal Hazards" of Requirement 17 of SSR-2/1 (Rev. 1) [1][1] in relation to internal hazards, protection of fuel handling systems should be primarily assured ensured by the layout of the building in which they are installed.

EXTERNAL HAZARDS

4.16.4.15. Recommendations in pParagraphs 4.164.16–4.184.18 provide recommendationsguidance to fulfill the on meeting requirements relevant to "External Hazards" of Requirement 17 of SSR-2/1 (Rev. 1) [1][1] in relation to external hazards.

4.17.4.16. Equipment and components of fuel handling systems should are required to be designed to withstand the effects of external hazards or to be protected against the effects of external hazards and their combinations of these hazards: (see para. 5.15A of SSR-2/1 (Rev. 1) [1][1]).

~~4.18.~~4.17. Protection of fuel handling systems against the effects of external hazards should be primarily ~~assured~~ ensured by the appropriate design of the building in which they are installed. When the protection is not effective (e.g.~~,~~ as might be the case in the event of an earthquake), handling equipment should be designed to keep its integrity and ~~not~~ to not drop ~~the~~ loads (e.g. in the event of ~~the safe shutdown earthquake~~SL-2 seismic loadings).

~~4.19. Handling and lifting operation during an earthquake should not result in the dropping of loads.~~

~~4.20.~~4.18. Seismic design specifications for fuel handling systems should be established on the basis of the consequences ~~with regard to~~in terms of potential damage to fuel assemblies (stored or ~~in~~ being handled~~ing~~), the release of radioactive material~~s~~ into the building, and the ~~necessity~~ need to operate the equipment during and after an earthquake.

DESIGN LIMITS

~~4.21.~~4.19. ~~Recommendations in p~~Paragraphs 4.20~~4.20~~–4.21~~4.21~~ provide recommendations on meeting ~~guidance to fulfill~~ Requirements 15 and 28 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~4.22.~~4.20. The design should ensure that ~~S~~stresses caused by design load combinations ~~should~~ remain below allowable limits established for fuel and for the~~,~~ individual components and equipment of fuel handling systems.

~~4.23.~~4.21. Limits and conditions for the operation of handling equipment (e.g.~~,~~ limits on lifting capacity and on speed ~~for~~ of lifting, lowering, rotating and traversing ~~movement~~, as well as restrictions on the~~ed~~ movements of handling equipment~~, limitation on lifting capacity to restrict the reduction in shield in thickness, etc.~~) should be defined and ~~not be exceeded by provision of~~ interlocks should be provided to ensure that these limits and conditions are not exceeded.

RELIABILITY

~~4.24.~~4.22. ~~Recommendations in p~~Paragraphs 4.23~~4.23, 4.25, 4.27~~–4.47~~4.47~~ provide ~~guidance~~ recommendations ~~to fulfill the~~on meeting Requirements 22, 23, 25, 26, 29 and 30 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~4.25.~~4.23. ~~Required~~ The necessary reliability for individual items of fuel handling equipment should be defined. This reliability should be specified ~~taking into~~with account taken of the consequences of the failure of the equipment. The following factors contribute to achieving the necessary reliability:

(a) The ~~S~~safety classification~~ification~~ and the associated engineering rules for design and manufacturing of individual structures, systems and components;

(a) Design provisions for monitoring, inspection, testing and maintenance.~~;~~

(b) The design of command, control and monitoring devices as well as identification markings, actuating elements and connecting elements to safely perform and monitor the fuel handling process;

(c) Devices for communication between fuel fuel pool, the fuel handling machines and the control room.[TC25]

~~4.26.~~4.24. The design of load bearing parts of ~~F~~fuel handling systems should ~~be designed by means of~~ conservative ~~methods for load bearing parts~~.

~~4.27.~~4.25. A ~~R~~reliability assessment should be conducted to verify whether the reliability target has been achieved.

~~STRUCTURAL DESIGN~~STRENGTH ANALYSES FOR ITEMS IMPORTANT TO SAFETY

~~4.28. Recommendations in paras 4.27–4.29 provide guidance on strength analyses performed for items important to safety of fuel handling.~~

~~4.29.~~4.26. ~~In the s~~Strength analyses should be undertaken to~~, it should be~~ demonstrate~~d~~ that the stresses caused by load combinations ~~meet~~ are within the design limits established for the individual structures and equipment of fuel handling systems. Typical examples of loads that should be considered in the strength analyses include:

(a) Static loads;

(b) Dynamic loads derived from the normal operation of equipment (e.g.~~,~~ loads from handling equipment at acceleration);

(c) Dynamic loads derived from abnormal operation of equipment (e.g.~~,~~ accidental drop of a fuel assembly ~~with~~ from a maximum~~al~~ height) and from non-symmetrical loads;

(d) Seismic loads defined ~~according to~~in accordance with the seismic categorization in NS-G-1.6 [15]~~[15]~~;

(e) Temperature loads.

~~4.30.~~4.27. Methods for assessing load combinations~~ing the individual loads~~ should be established in accordance with ~~according to~~ applicable design codes and standards.

~~4.31.~~4.28. The strength analyse~~i~~s should ~~take~~ credit ~~for~~ any equipment that is provided to limit loads (~~through devices such as~~e.g. dampers or shock absorbers), and failure modes for this equipment should also be considered.

SPECIFIC DESIGN RECOMMENDATIONS

~~4.32.~~4.29. For light water reactors, systems for lifting fuel assemblies should be designed so that abnormal handling and lifting operations cannot result in unacceptable loads ~~for~~ on the fuel assembly. This should be ensured~~,~~ by means of physical limitations or by automatic protective~~on~~ actions (either passive or actuated by instrumentation and control~~I&C~~ systems). Methods that ~~may~~ ~~might~~could be used include the following:

(a) Restriction of the power of the hoist motor;

(b) The ~~P~~provision of slipping clutches within ~~the~~ drive mechanisms;

(c) Automatic and continuous load sensing and registering devices linked to the hoist motor or cable; ~~and~~

(d) A specified speed limitation.

~~4.33.~~4.30. Provision~~s~~ should be made in the design for the use of manually operated~~ing~~ equipment that is capable of placing fuel assemblies into a safe location in the event of the failure of the normal operating mode of the fuel handling system.

~~4.34.~~4.31. Handling equipment should be designed to prevent ~~from~~ the leakage and escape of lubricants and other fluids or substances ~~which~~ that could degrade the purity of the pool water. Such substances either should be prevented from entering wet storage systems or, preferably, should be fully compatible with the fuel and the~~,~~ equipment and storage structures.

~~4.35.~~4.32. Handling equipment should be designed to prevent the inadvertent emplacement of fuel or~~and~~ core components into a position that is already occupied or into an otherwise inappropriate position.

~~4.36.~~4.33. The design of fuel handling and refuelling machines can include ~~computerized operational management~~instrumentation and control systems to manage and monitor fuel handling conducted in the reactor building and in the fuel building. The ~~computerized operational management~~instrumentation and control systems can be used to help prevent incorrect movements of the fuel assembly and the ~~inadvertent~~ emplacement of a fuel assembly into an inappropriate position ~~and incorrect movements of the fuel assembly~~. The reliability of this system should be ~~appropriate~~ commensurate with the safety significance~~to conduct~~ of fuel loading and unloading operations. The consequences of malfunctioning of such ~~this computerized operational management~~ instrumentation and control systems should be considered.

~~4.37.~~4.34. For light water reactors, when the fuel assembly is tilted, loads arising in the fuel assembly structure should be limited by means of supports to ensure that no damage will occur.

~~4.38.~~4.35. For light water reactors, measures should be provided in the design of fuel handling systems to limit the risk of incorrect positioning of a fuel assembly in the vessel during core refuelling operations.

~~4.39.~~4.36. For light water reactors, electrical interlocks to prevent ~~travel~~ movement of the refuelling machine while the fuel is in an incorrect position should be provided.

Specific design aspects for the refuelling machine

Light water reactors

~~4.40.~~4.37. The hoist gripper of the refuelling machine should be designed to grasp securely and to transport fuel assemblies or other assemblies safely. Consequently, the following safety features and safety systems should be provided:

(a) Before lifting is commenced, ~~A~~ a positive indication that the hoist gripper is correctly located on the fuel ~~—~~ assembly ~~before lifting is commenced~~ should be obtained. This should be implemented by the provision of automatic interlocks where feasible. If this is not feasible, strictly controlled administrative procedures should be applied.~~;~~

(b) The gripper should remain latched ~~upon~~ in the event of loss of power.~~;~~

(c) The gripper should not be capable of decoupling from ~~the~~ a fuel assembly while the fuel handling machine is exerting a force on the fuel assembly. This should be implemented by using mechanical interlocks.~~;~~

(d) The gripper should ~~only~~ decouple from a fuel assembly only at specified elevations, even when no load is applied. This should be implemented by the provision of automatic interlocks where feasible. If this is not feasible, strictly controlled administrative procedures should be applied.~~;~~ ~~and~~

(e) The gripper should have an ~~inherent~~ integral safety device that prevents the fuel ~~—~~assembly from becoming unlocked.

~~Recommendation (c) should be fulfilled by using mechanical interlocks.~~

Recommendations (a) and (d) should be fulfilled by the provision of automatic interlocks where feasible. If this is not feasible, strictly controlled administrative procedures should be applied.

4.41.4.38. Protection devices should be provided to ensure that fuel handling equipment cannot perform horizontal movements during the lifting or lowering of fuel or core components when this could result in the forcing of fuel into position.

4.42.4.39. Protection devices (electrical and/or mechanical interlocks) supplemented by administrative measures should be provided to limit the movement of fuel handling machines in order to prevent fuel damage (for instance,e.g. overload protection devices to prevent fuel damage, supplemented by the observation of load cell readings to verify there is no overload).

4.43. (deleted the following statement)[TC26] The design of electromechanical and electrical protection devices applied to major components of cranes (e.g., hooks, cables) should comply with the single failure criterion in order to prevent damage to fuel assemblies.

Pressurized heavy water reactors

4.44.4.40. Design provisions should be implemented to provide continuous cooling of the fuel in the event that irradiated fuel bundles become stuck in the fuelling machine and stay for an extended period of time until appropriate action is taken. These provisions should be designed toin order to prevent significant damage of to the irradiated fuel bundles or the failure of the fuel elements due to insufficient air cooling. to the air, when the irradiated fuel bundles are stuck in the fueling machine and stay for an extended period of time until appropriate action is taken.

4.45.4.41. In designs nuclear power plants with on-loadpower power refuelling, the designs of the fuelling machine and the interfacing equipment designs should protect the integrity and function of the reactor coolant circuit, specifically but not limited toin particular to maintaining the pressure boundary and the fuel cooling functions.

4.46.4.42. Conditions or failures that could result in a fuelling machine becoming stuck during the refuelling cycle should be anticipated and provisions should be put in place to prevent such an event or else to mitigate the consequences. Manual pProvision should be made available to manually release the fuel handling machine from a sticking position in which it has become stuck. For designs with on-power load fuelling, particular attention should be paid to situations where a fuelling machine could become stuck on channel in a configuration that could result in local flow blockages.

~~4.47.~~4.43. The design of the fuelling machine ~~design~~ should prevent ~~excessive~~ the mechanical loads on ~~new fuel~~fresh fuel, in-core interfacing fuel, interfacing equipment and ~~on~~ spent fuel from exceeding design limits.

~~4.48.~~4.44. The fuelling machine should be designed to withstand loads caused by interfacing systems in operational states.

~~4.49.~~4.45. The fuelling machine should be designed such that contamination of the fuelling machine ~~by~~ from the ~~transporting~~ handling of ~~defect~~ damaged fuel is minimized, and should also be designed so as to facilitate decontamination afterwards.

Specific design aspects for ~~the~~ nuclear power plants with a fuel transfer system (pressurized water reactors)

~~4.50.~~4.46. ~~In a nuclear power plant with a fuel transfer system~~ T~~t~~he fuel transfer system should be designed to ensure adequate cooling of the fuel even during a malfunction of the fuel transfer operation.

~~4.51.~~4.47. When the spent fuel pool is outside of the containment, design provisions should be implemented to meet the requirements for isolation of the containment ~~isolation requirements~~: see Requirement 56 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~4.52.~~4.48. ~~In case the fuel assembly is jammed due to the failure (or malfunction) of the fuel transfer system,~~ T~~t~~he design of the fuel transfer system should allow access for safe retrieval of the assembly in a timely manner ~~.~~ in the event that the fuel assembly is jammed due to the failure (or malfunction) of the fuel transfer system.

SAFETY CLASSIFICATION

~~4.53.~~4.49. The equipment and components of fuel handling systems ~~need~~ are required to be classified ~~taking into account~~on the basis of their function and safety significance: see ~~in order to fulfill~~ Requirement 22 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~4.54.~~4.50. ~~According to SSR-2/1 (Rev. 1) [1],~~ T~~t~~he safety classification of handling equipment can be directly derived from the severity of the consequences of equipment failure during handling operations (fuel damage, radiation exposure or release of radioactive material~~s~~).

~~4.55.~~4.51. Safety classified equipment should be designed and manufactured in accordance with ~~according to requirements established by~~ national or international codes that are appropriate to their safety class. ~~ification and t~~The applic~~ationability~~ of the selected design standards should be justified.

ENVIRONMENTAL QUALIFICATION

~~4.56.~~4.52. Any ~~operating~~ prevailing environmental conditions ~~for~~ in which the system ~~provides~~ performs a safety function~~s~~ ~~should are required to~~should be considered in the qualification of fuel handling systems: see Requirement 30 of SSR-2/1 (Rev. 1) [1]. The ~~R~~recommendations provided in paras 3.9~~3~~5–3.100~~98~~ should be taken into account. [TC27]

RADIATION PROTECTION

~~4.57.~~4.53. Lifting equipment for underwater spent fuel assemblies ~~under water~~ should be designed so that the lift is controlled within limits ~~so as~~ to maintain the minimum ~~required~~ depth of water shielding that is necessary.

~~4.58.~~4.54. Hollow handling tools used under water should be designed so that they fill with water on submersion (to maintain water shielding) and drain on removal.

~~4.59.~~4.55. In handling ~~new fuel~~fresh fuel (including mixed-oxide fuel) ~~that~~ containings~~s~~ fissionable material recovered by reprocessing, and which ~~may~~ emits significant amounts of radiation, consideration should be given to providing additional shielding to limit the exposure of operating personnel, owing to the higher radiation levels associated with the ~~new fuel~~fresh fuel.

MATERIALS

~~4.60.~~4.56. Structural materials should be selected on the basis of accepted design codes and standards. Consideration should be given to the potential cumulative effects of radiation on materials likely to be subjected to significant radiation fields.

~~4.61.~~4.57. Materials in direct contact with fuel should be compatible with the materials of the fuel assemblies, and should be such as to minimize chemical and galvanic reactions that~~, which~~ might degrade the integrity of the spent fuel during its handling.

~~4.62.~~4.58. Materials used in the construction of fuel handling systems should allow easy decontamination of surfaces.

5. DESIGN BASIS FOR EQUIPMENT USED FOR INSPECTION AND REPAIR OF [TC28]IRRADIATED FUEL INSPECTION AND REPAIR, HANDLING AND OF DAMAGED FUEL HANDLING, AND DESIGN BASIS FOR HANDLING AND STORAGE OF IRRADIATED CORE COMPONENTS

EQUIPMENT USED FOR INSPECTION AND REPAIR OF SPENT FUEL INSPECTION AND REPAIR, AND HANDLING OF DAMAGED FUEL HANDLING

5.1. Recommendations Safety measures for handling equipment used for inspection and, repair (dismantling and reconstitution) of spent fuel, and for handling damaged fuel, handling should be established implemented considering theose recommendations provided in Section 4 and applying a graded approach taking intowith account taken of the consequences of should equipment failures.

5.2.5.1. Specific considerations to for typical handling equipment are described in subsequent paragraphs: 5.2–5.11.

Inspection equipment

5.3.5.2. Equipment should be provided for the inspection of fuel assemblies and other core components by visual or other methods.

5.4.5.3. Inspection equipment should be designed so as to minimize the effects of irradiation and to prevent overheating of the fuel.

Dismantling and reconstitution equipment

5.5.5.4. Appropriate dismantling equipment should be provided if it is necessary to dismantle fuel in order to retain reusable parts such as fuel channels, and if the dismantling of the fuel is necessary before storage.

5.6.5.5. Dismantling and reconstitution equipment should be designed so as to minimize the effects of irradiation and to prevent overheating of the fuel.

5.7.5.6. The dismantling and reconstitution equipment should be designed to preserve the integrity of the fuel rods. The design should prevent possible fuel damage by loads caused by the lifting of dismantled fuel assemblies or fuel rods, by other handling operations such as tilting or by changes to the fuel cladding.

~~5.8.~~5.7. In the design of dismantling and reconstitution equipment, reliable means should be provided for removing residual heat from the irradiated fuel and from the ~~cleaning~~ equipment used to clean ~~of~~ the irradiated fuel.

~~Damaged fuel~~ ~~H~~Handling equipment for damaged fuel

~~5.9.~~5.8. ~~Detection e~~Equipment for the detection of damage to~~d~~ fuel assemblies should be capable of detecting the failure of irradiated fuel assemblies without further impairing the structural integrity of the fuel.

~~5.10.~~5.9. ~~Given a potential source of contamination, p~~Provisions should be available to place leaking fuel in appropriate special containers. The containers should be designed to withstand the temperatures and pressures resulting from the residual heat of the irradiated fuel and from chemical reactions between the fuel or its cladding and the surrounding water.

~~5.11.~~5.10. In the design, consideration should be given to the procedures to be adopted for the removal of damaged fuel assemblies ~~or other irradiated core components~~. The ~~design of~~ special tools for the manipulation of damaged fuel should be designed to ensure an adequate margin of subcriticality, adequate decay heat removal and shielding against radiation. ~~—~~ Procedures to permit the use of non-standard equipment should be specified and strict administrative control should be observed.

~~5.12.~~5.11. The ~~D~~design of ~~canisters~~ the containers used for encapsulating damaged fuel should be compatible with interim storage.~~,~~ The design should also be compatible with long-term storage, or else the containers should be capable of being safely unloaded and the fuel transferred to suitable long-term storage containers after the interim storage period.

HANDLING AND STORAGE SYSTEMS FOR IRRADIATED CORE COMPONENTS

~~5.13.~~5.12. ~~A number of miscellaneous~~ Sometimes irradiated core components that do not contain fuel ~~will~~~~might be~~are stored in the spent fuel storage and handled ~~with use of~~using the same handling systems designed for spent fuel. Irradiated core components include components such as reactivity control devices or shutdown devices, in-core instrumentation, neutron sources, flow restrictors, fuel channels, burnable absorbers and samples of reactor vessel material.

~~5.14.~~5.13. In general, the recommendations on fuel storage and handling systems provided in Sections 3 and 4 should be followed. Specific considerations ~~to~~ for different types of irradiated core component~~s~~ are described in ~~subsequent~~ para~~graph~~s 5.14–5.21~~0~~~~:~~

Irradiated core components

~~5.15.~~5.14. For irradiated core components, particular attention should be paid to the following:

(a) Adequate shielding of irradiated core components should be ~~ensured~~provided.~~;~~

(b) Where the inspection of irradiated core components is necessary, interlocks and other ~~-~~measures should be provided, as appropriate, to ensure the protection of ~~the~~ operating personnel~~ors from exposure~~.~~;~~

(c) Means of transferring irradiated core components into a suitable shipping container should be provided, where necessary.~~;~~

(d) Specified storage and disposal systems should be provided, together with inspection systems, where necessary.~~;~~

(e) Appropriate care should be taken ~~in~~ when handling irradiated core components to protect stored fuel and to limit the possible spread of contamination.~~; and~~

(f) Irradiated core components should not be stored in the storage area for unirradiated fuel. If necessary, provision should be made for the temporary storage of such items in the storage facility for irradiated fuel.

5.15. Consideration should be given to the procedures to be adopted for the removal of irradiated core components. The special tools for the manipulation of irradiated core components should be designed to ensure an adequate margin of subcriticality, adequate decay heat removal and shielding against radiation. Procedures to permit the use of non-standard equipment should be specified and strict administrative control should be observed.

Neutron sources

5.16. Sufficient shielding and monitoring equipment should be provided to protect operating personnel ~~against~~ from ~~ionizing~~ exposure to radiation from neutron sources. ~~The design of the spent fuel pool should indicate that~~ U~~u~~pon the receipt of transport containers containing neutron sources, contamination checks ~~are~~ should be performed, and ~~that~~ the transport containers for neutron sources ~~are~~ should be clearly marked in accordance with ~~according to~~ the requirements of the regulatory body.

5.17. Neutron sources should be kept separate~~d~~ from the area for spent fuel handling and storage and ~~in~~ at a sufficient distance ~~enough~~ to ensure neutronic decoupling, unless a suitable safety case is provided to ensure adequate shielding or decoupling between source and assemblies.

5.18. Arrangements should be made for the clear identification of all sources and administrative controls should be in place for controlling these sources~~m~~.

Reusable reactor items

5.19. In most reactor types, there are some core components and fuel assembly items that can be reused (such as fuel channels in boiling water reactors or flow restrictor assemblies in pressurized water reactors). These items ~~may~~ might be highly activated. If such items are brought to the assembling areas for reuse, the spread of contamination and the radiation exposure of operating personnel should be minimized.

5.20. Reusable components should be capable of being inspected, as necessary, to ensure their dimensional stability and the absence of any ~~possible~~ damage resulting from operation or handling. Where reusable components contain replaceable items (~~such as~~e.g. seals), it should be possible to inspect the replaceable components.

5.21. The design of the area for storage reusable reactor items ~~storage~~ should be such as to prevent reusable components from being contaminated with materials that ~~may~~ might affect the integrity of reactor components after the reusable components are reinserted.

6. HANDLING OF FUEL CASKS

6.1. The equipment for handling ~~the~~ fuel casks should be designed to be compatible with ~~that~~ the equipment for lifting fuel and components~~-~~, and should include the following:

(a) Vehicles for moving casks;

(b) Cranes and associated lifting devices for casks, cask lids ~~or~~ and cask internals;

(c) Decontamination equipment;

(d) Radiation monitoring equipment;

(e) Cask draining, flushing, purging and vacuum-drying systems;

(f) Tools for disconnection of cask lids;

(g) Cask testing equipment;

(h) Means and devices for preventing the ~~radioactive~~ contamination of the external surfaces of casks;

(i) Means for identifying leaking fuel~~s~~ in casks; ~~and~~

(j) Illumination equipment.

Operating aspects of handling fuel casks are described in the Annex~~ I~~.

DESIGN FOR FACILITATING THE HANDLING OF CASKS FOR SPENT FUEL

6.2. General The recommendations provided in Section 4paras 4.49–4.58 regarding safety classification, environmental qualification, radiation protection and materials should be applied, as appropriate, to the design of handling equipment of for spent fuel casks.

6.3. The spent fuel storage area should be designed to facilitate the handling of spent fuel casks that are to be transported off the site. Consideration of Recommendations on the design of the spent fuel casks is outside the scope of this Safety Guide; for detailed information seeare provided in SSG-15 [2][2].

6.4. The design of the spent fuel storage area should include systems for decontaminating the casks prior to transport or transfer to storage outside the spent fuel storage area. [TC29]Provisions should be made, and to perform leakage tests, surface contamination tests and other necessary tests on the cask. Provision should also be made for draining the fluids liquids used in decontamination or in flushing the cask coolant system (where relevant) and transferring these liquids to the radioactive waste system.

6.5. The transport route inside the plant should be along a designated safe load path[TC30], consistent with. Passage over stored fuel should be prevented. Stored fuel, the spent fuel pool liner, and cooling systems and reactor systems essential to reactor safety should be adequately protected from the dropping or tilting of a fuel cask. [TC31]

6.6. In accordance with Requirement 80para. 6.67(d) of SSR-2/1 (Rev. 1) [1][1], fuel handling systems are required to be designed to prevent the dropping of heavy objects, including fuel casks. The possibility of aA cask drop accident should be prevented with a high level of confidence by means of an appropriate crane design, and appropriate procedures for the inspection, testing and maintenance of the crane and the associated lifting gear, and also by means of adequate operator training of operating personnel. [TC32]If the cask lifting system is such that failure of a single component could result in an unacceptable dropped load, damping devices should be used together with restrictions on the lifting height in order to be able to mitigate the potential consequences.

6.7. Spent fuel cask handling systems should be designed such as to prevent the dropping of heavy loads during transfer and during loading operations and, during and following after a design basis earthquake.

6.8. The layout of the area for irradiated fuel cask handling should be designed so as to provide adequate space around the cask for inspection, radiation monitoring and decontamination tests. The necessary storage area for casks and associated equipment (such as shock absorbers) should be provided.

6.9. Administrative means should be ~~developed~~ implemented to ensure that there is no loading of fuel that has been cooled for an insufficient period of time or of a combination of fuel assemblies that is not permitted in the cask.

EXTERNAL HAZARDS

6.10. The ~~P~~protection of handling equipment ~~of~~ for spent fuel casks against external hazards should be primarily assured by the appropriate design of the building in which they are installed. Seismic design specifications for handling equipment ~~of~~ for spent fuel cask should be established on the basis of the consequences ~~with regard to~~in terms of the potential damage to fuel assemblies inside the cask and the ~~necessity~~ need to operate the handling equipment during and after an earthquake. ~~(Design provisions for fuel storage systems are addressed in paras 3.36–3.40.)~~

VEHICLES AND CRANES USED IN THE TRANSFER OF FUEL CASKS

6.11. Requirements for overhead lifting equipment are established in Requirement 76 of SSR-2/1 (Rev. 1) [1]~~[1]~~.

~~6.11.~~6.12. In accordance with Requirement 80 of SSR-2/1 (Rev. 1) [1]~~[1]~~, t~~T~~he vehicles or cranes used in the transfer of casks ~~should are required to~~should be designed to limit the possibility of dropping or inadvertently tilting the casks. Vehicles and cranes should be provided with a reliable braking system to ensure that they are not moved unintentionally. Consideration should be given to increasing the reliability of the lifting and transport equipment such that dropping of ~~the~~ a load can be treated as a low-frequency event, for example, by the use of single failure proof cranes. Suitabl~~e~~y ~~diverse~~ speed limitations on the horizontal and vertical movement~~s~~ of the cranes should be provided so as to ensure the safe handling of ~~the~~ casks.[TC33]

~~6.12.~~6.13. ~~To meet the~~The requirements for the transport of fuel are established ~~transport regulations~~ in IAEA Safety Standards Series No. SSR-6 (Rev. 1), Regulations for the Safe Transport of Radioactive Material, 2018 Edition [25]~~[25]~~. To help ensure compliance with these requirements~~, guidance is provided as follows~~:

(1) The ~~design~~ facility should include radiation monitoring equipment that is capable of measuring gamma radiation, ~~as well as~~ fast neutrons and thermal neutrons from the cask, ~~where relevant~~as appropriate;~~.~~

(2) Provision should be made to measure surface contamination on the external surfaces of the cask to ensure that the ~~transport regulations~~requirements of SSR-6 (Rev. 1) [25]~~[25]~~ are met before the cask leaves the nuclear power plant.

~~6.13.~~6.14. If fuel is transported back to the pool from dry storage, adequate cooling of the cask and the fuel should be provided.

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ANNEX ~~I~~: OPERATING ASPECTS OF HANDLING SPENT FUEL CASKS

AI~~ .~~1. The handling of the spent fuel cask has different aspects depending on which of the following unloading strategies is used:

- Unloading ~~by~~ with immersion of the cask in the unloading pit;
- ~~, and~~
- Unloading with connection of the cask under the unloading pit.

~~I.2 The main actions for each unloading strategy are as follows:~~

AI~~ .~~2.~~1~~ Unloading ~~by~~ with immersion of the cask involves the following actions:

- The cask is introduced inside the fuel building on the ground floor by truck or by train~~.~~;
- The shock absorbers of the cask are removed;
- The cask is tilted to the vertical using the reception hall crane;
- ~~It~~ The cask is transferred to the pool floor (~~for example~~e.g. 20 met~~e~~res above the pool floor) to be put into the preparation pit;
- After ~~its~~ preparation (filling, cooling~~,~~, precautions against contamination~~ protection, etc.~~), the cask is handled to the unloading pit;
- The cask is immersed by ~~the~~ filling ~~of~~ the unloading pit with pool water;
- The~~ biologic~~ lid is removed to start the unloading of the fuel assemblies;
- When the filling of the cask with fuel assemblies is finished, the ~~inverse~~ above process is reversed~~ done~~.

AI~~ ~~3.~~2.2~~ Unloading with connection of the cask under the unloading pit involves the following actions:

- The cask is introduced inside the preparation building;
- ~~Its~~ The shock absorbers of the cask are removed;
- The cask is tilted to the vertical using the preparation building crane;
- The cask is transferred to the cask wagon;
- The wagon is transferred to the fuel building;
- After ~~its~~ preparation (removal of the lid, filling, cooling~~, removing of the lid, …~~) the cask is connected under the unloading pit;
- After the connection of the cask, the gate at the bottom of the unloading pit is opened to start the unloading of the fuel;
- After the unloading of the fuel is completed, the ~~inverse~~ above process is reversed~~done~~.

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