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for protecting people and the environment

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Storage of Spent Fuel

DRAFT SPECIFIC SAFETY GUIDE DS371

Draft Specific Safety Guide

IAEA
International Atomic Energy Agency

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IAEA SAFETY STANDARDS

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STORAGE OF SPENT FUEL

~~The following States are Members of the International Atomic Energy Agency:~~

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FOREWORD

~~by Mohamed ElBaradei~~
~~Director General~~

The IAEA's Statute authorizes the Agency to establish safety standards to protect health and minimize danger to life and property — standards which the IAEA must use in its own operations, and which a State can apply by means of its regulatory provisions for nuclear and radiation safety. A comprehensive body of safety standards under regular review, together with the IAEA's assistance in their application, has become a key element in a global safety regime.

In the mid-1990s, a major overhaul of the IAEA's safety standards programme was initiated, with a revised oversight committee structure and a systematic approach to updating the entire corpus of standards. The new standards that have resulted are of a high calibre and reflect best practices in Member States. With the assistance of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its safety standards.

Safety standards are only effective, however, if they are properly applied in practice. The IAEA's safety services — which range in scope from engineering safety, operational safety, and radiation, transport and waste safety to regulatory matters and safety culture in organizations — assist Member States in applying the standards and appraise their effectiveness. These safety services enable valuable insights to be shared and I continue to urge all Member States to make use of them.

Regulating nuclear and radiation safety is a national responsibility, and many Member States have decided to adopt the IAEA's safety standards for use in their national regulations. For the Contracting Parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by designers, manufacturers and operators around the world to enhance nuclear and radiation safety in power generation, medicine, industry, agriculture, research and education.

The IAEA takes seriously the enduring challenge for users and regulators everywhere: that of ensuring a high level of safety in the use of nuclear materials and radiation sources around the world. Their continuing utilization for the benefit of humankind must be managed in a safe manner, and the IAEA safety standards are designed to facilitate the achievement of that goal.

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1. INTRODUCTION

BACKGROUND

1.1. Spent nuclear fuel is generated from the operation of nuclear reactors of all types and needs to be safely managed following its removal from the reactor core. Spent fuel is considered as a waste in some circumstances or as a potential future energy resource ~~-~~in others and as such, management options may involve direct disposal (as part of what is generally known as the 'once through fuel cycle') or reprocessing (as part of what is generally known as the 'closed fuel cycle').~~"~~ Either management ~~process~~ option will involve a number of steps, which will necessarily include storage of the spent fuel for some period of time. This time period for storage can ~~vary~~differ, depending on the management strategy adopted, ~~and can vary~~ from a few months to several decades. The time period for storage will be a significant factor in determining the storage arrangements adopted. The final management option may not have been determined at the time of design~~ing~~ of the storage facility, leading to some uncertainty in the storage period that will be necessary, a factor that needs to be considered in the adoption of a storage option and the design of the facility. Storage options include wet storage in some form of storage pool or dry storage in a facility or storage casks built for this purpose. Storage casks can be located in a designated area on a site or in a designated storage building. A number of different designs for both wet and dry storage have been developed and used in different ~~countries~~States.

1.2. ~~Whatever~~ Irrespective of the ~~circumstances~~ consideration of ~~storage~~spent fuel ~~are~~ (either as a waste or an energy resource), the safety aspects for storage remain the same, as indicated in the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [1]. As such, this ~~document~~ Safety Guide does not differentiate between ~~the~~ spent fuel stored as waste or spent fuel stored for later use as a resource material.

1.3. The safety of a spent fuel storage facility, and the spent fuel stored within it, is ensured by: appropriate containment of the radionuclides involved, criticality safety, heat removal, radiation shielding~~,~~ and retrievability. These functions are ensured by the proper siting, design, construction and commissioning of the storage facility, its proper management and safe operation. At the design stage, ~~D~~due consideration ~~is~~ also need~~sed for~~ to be given to the future decommissioning of the facility ~~during the design stage~~.

1.4. Spent fuel is generated continually by operating nuclear reactors. It is stored in the reactor fuel storage pool for a period of time for cooling and then may be transferred to a designated wet or dry spent fuel storage facility, ~~waiting for~~where it will await reprocessing or disposal (if it is considered to be radioactive waste). ~~Some reactor~~The spent fuel storage pools of some reactors have sufficient capacity for all the spent fuel that will be ~~produced~~ generated during the lifetime of the reactor.

1.5. The basic safety aspects for storage of spent fuel are applicable for the storage of spent fuel from research reactors as well as from power reactors. An approach should be adopted that takes account~~s for~~ of the differences between the fuel types (e.g. lower heat generation, higher enrichment and cladding materials that are less corrosion resistant) when considering containment, heat removal, criticality control, radiation shielding and retrievability~~ (e.g. lower heat generation, higher enrichment and less corrosion resistant cladding materials~~.

1.6. Many spent fuel storage facilities at reactors were intended to serve for a limited period of time (a few years) as a place to keep spent fuel between unloading from the reactor and its subsequent reprocessing or disposal. In view of the time being taken to develop disposal facilities and the limited reprocessing programmes that have been developed, storage periods are being extended from years to decades. This conceptual change in the management of spent fuel has been accompanied by other developments, e.g. increase in enrichment, increase of burnup, use of advanced fuel design and mixed oxide (MOX) fuel, re-racking, use of burnup credit and in some cases extension of storage periods beyond the original ~~design life~~design lifetime of the storage facility. Nevertheless, storage ~~can not~~cannot be considered as the ultimate solution for the management of spent fuel, which requires a defined end_point such as reprocessing or disposal in order to ensure safety. The design lifetime of nuclear installations is generally of the order up to decades and experience with the storage of spent fuel of up to around fifty years has accrued. Whil~~est~~ design lifetimes of up to one hundred years have been considered and adopted for certain spent fuel storage facilities, in view of the rate of industrial and institutional change, periods beyond around fifty years are deemed to be '~~"~~long~~er~~ term'~~"~~ in the context of this ~~document~~ Safety Guide (~~S~~see also Annex I~~1~~).[pls note: you call it long term in the Annex!]

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1.7. This Safety Guide supersedes the publications Safety Series No. 116, 117 and 118, which were published in 1994 and covered the design, operation and safety assessment of spent fuel storage facilities respectively. It ~~combines the contents of the three earlier Safety Series publications and also~~additionally incorporates recommendations addressing the impact of the new developments ~~identified~~described ~~above~~in para. 1.6. It complements the Safety Guide on storage of radioactive waste [2].

OBJECTIVE

1.8. The objective of this Safety Guide is to provide up-to-date guidance and recommendations on the design, safe operation and assessment of safety for the different types of spent fuel storage facilities (wet and dry), considering different types of spent fuel from nuclear reactors, including research reactors, and different storage periods, including storage going beyond the original design lifetime of the storage facility. The Safety Guide presents guidance and recommendations on how to ~~fulfil~~ meet the requirements established in the following IAEA Safety Requirements publications: Safety of Nuclear Fuel Cycle Facilities [3], Predisposal Management of Radioactive Waste ~~Management~~ [4], Safety

Assessment ~~and Verification of~~for ~~Nuclear~~ Facilities and Activities [5], and The Management System for Facilities and Activities [6].

SCOPE

1.9. This Safety Guide covers spent fuel storage facilities that may be either co-located with other nuclear facilities (such as a nuclear power plant, research reactor or reprocessing plant) or on their own sites. However, it is not specifically intended to cover the storage of spent fuel as long as it ~~is~~ remains a part of the operational activities of a nuclear reactor or a spent fuel reprocessing facility, which is addressed in Ref. [3]~~)~~.

1.10. The scope of this Safety Guide includes the storage of spent fuel from water moderated reactors and can, with due consideration, also be applied to the storage of other types of fuel ~~types~~, such as those from gas cooled reactors and research reactors and also to the storage of spent fuel assembly components and degraded or failed fuel[1] that may be placed in canisters.

1.11. The Safety Guide does not provide comprehensive and detailed recommendations on physical protection of nuclear material and nuclear facilities. Recommendations and guidelines on physical protection arrangements at nuclear facilities, including risk assessment, threat definition, designing, maintaining and operation of physical protection systems, evaluation of effectiveness and inspection of physical protection system, ~~can be found~~are provided in Refs [7, 8] and in publications in the IAEA Nuclear Security Series. The Safety Guide considers physical protection and accounting and control of nuclear material ~~safeguards arrangements~~ only to highlight their potential implications ~~on~~ for safety.

STRUCTURE

1.12. ~~Chapter two~~Section 2 of this publication addresses the application of the fundamental safety objective~~s~~ and principles and criteria ~~applicable~~ to the storage of spent fuel. The roles and responsibilities of the organizations involved in the storage of spent fuel are set out in ~~chapter three~~Section 3 and ~~chapter four~~Section 4 provides ~~guidance~~ recommendations on the management systems necessary to provide assurance of safety. ~~Chapter five~~Section 5 provides ~~guidance~~ recommendations on safety assessment and ~~chapter six~~Section 6 ~~the~~ provides recommendations on ~~general~~ safety considerations in respect of design, construction, operation and decommissioning of spent fuel storage facilities, including considerations for long term~~s~~ storage. ~~Chapter seven~~Appendix I addresses considerations specific to wet and dry storage of spent fuel and ~~chapter eight~~Appendix II addresses considerations in respect of spent fuel with particular characteristics. Annex I provides explanations of the concepts of long term and short term storage. Annex II summarize~~s~~d safety considerations for wet and dry spent fuel storage facilities. Annex III provides an example of the sections that may be included in the operating procedures for a spent fuel storage facility. Annex IV

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[1] The terms degraded fuel or failed fuel can cover a broad range of conditions ranging from minor pinholes to cracked cladding to broken fuel pins. The nature and extent of failure is an important consideration.

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provides an overview of related IAEA Safety Standards. Annexes V to VII provide listings of events for consideration in a safety assessment for a spent fuel storage facility.

2. PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

2.1. National requirements for radiation protection ~~requirements~~ are required ~~[?requirement in BSS, GSR Part 1?~~ to be established keeping in view the fundamental safety objective and fundamental safety principles set out in Ref. [9] and in compliance with the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [10]. In particular, ~~the radiation protection of~~~~doses to any person who is~~ exposures to persons ~~ed~~ as a consequence of the storage of spent fuel ~~is~~ are required to be kept within specified dose limits and radiation protection is required to be optimized within dose constraints.

2.2. If several nuclear installations (e.~~-~~g. ~~NPPs~~nuclear power plants, spent fuel storage facilities, reprocessing facilities~~ etc.~~) are located at the same site, the dose constraints for public exposure should take into account ~~potential~~ all sources of exposure~~s~~ ~~that could arise from~~ that could be associated with activities at the site, leaving an appropriate margin for foreseeable future activities at the site that may also give rise to exposure. Particularly in ~~this~~ such cases the regulatory body should require the operating organization(s) of the nuclear installation(s) on the site to develop constraints, subject to regulatory approval;~~,~~ ~~or~~ alternatively, the regulatory body may establish the dose constraint(s). Requirements on dose constraints are ~~provided~~ established in Ref. [10] and ~~guidance~~ recommendations are provided in Ref. [11].

2.3. The design of a spent fuel storage facility and the storage of spent fuel must be ~~carried out in~~ such ~~a way~~ that workers, the public and the environment, present and future, will be protected ~~against~~ from~~the~~ harmful effects of radiation from all sources of exposure~~s~~ ~~that could arise from~~associated with current activities with spent fuel at the site with ~~, leaving, if appropriate,~~ sufficient margins. ~~for sources of exposure that could arise from foreseeable future activities[?]~~ [9, 10].

2.4. Discharges to the environment from spent fuel storage facilities should be controlled in accordance with the conditions imposed by the national regulatory body and should be included when estimating doses to workers and the public.

2.5. The adequacy of control measures taken to limit the radiation exposure of ~~the~~ workers and the public should be verified by ~~the~~ monitoring and surveillance both inside and outside ~~of~~ the facility.

2.6. In the generation and storage of spent fuel, as well as in subsequent management steps, a safety culture ~~should be fostered and maintained to~~that encourages a questioning and learning attitude to ~~‘~~protection~~’~~ and ~~‘~~safety~~’~~ and ~~to~~ that discourages complacency should be fostered and maintained [3, 10, 12, 13].

3. ROLES AND RESPONSIBILITIES

GENERAL

Requirement 1 (GSR Part 5, Ref. [4]): Legal and regulatory framework

The government shall provide for an appropriate national legal and regulatory framework within which radioactive waste management activities can be planned and safely carried out. This shall include the clear and unequivocal allocation of responsibilities, the securing of financial and other resources, and the provision of independent regulatory functions. Protection shall also be provided beyond national borders as appropriate and necessary for neighbouring States that may be affected.

Requirement 6 (GSR Part 5, Ref. [4]): Interdependences

Interdependences among all steps in the predisposal management of radioactive waste, as well as the impact of the anticipated disposal option, shall be appropriately taken into account.

3.1. Storage of spent fuel should be undertaken within an appropriate national legal and regulatory framework that provides for a clear allocation of responsibilities [14], including responsibilities for meeting international obligations and for verifying compliance with these obligations ~~[?]~~, and which ensures the effective regulatory control of the facilities and activities concerned [3, 4]. The national legal framework should also ensure compliance with other relevant national and international legal instruments, such as the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [1].

3.2. The management of spent fuel may entail the transfer of spent fuel from one operating organization to another~~;~~ and various interdependencies exist between ~~among~~ the various steps in the management of spent fuel. The legal framework should include provisions to ensure a clear allocation of responsibility for safety throughout the entire process, in particular~~,~~ with respect to storage of spent fuel and ~~, including the~~ its transfer between operating organizations. ~~The c~~Continuity of responsibility for safety should be ensured by means of a system ~~for granting~~ of authorization~~s~~ by the regulatory body. For transfers between ~~Member~~ States, authorizations from the respective national regulatory bodies ~~should~~ are required ~~to be obtained~~ [1, 15].

3.3. The responsibilities of the regulatory body[2], the operating organization and, when appropriate, the spent fuel owner in respect of spent fuel management should be clearly specified and functionally separate~~d~~.

[2] The regulatory body may be one or a number of regulatory authorities with responsibility for the facility or activity.

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3.4. A mechanism for providing adequate financial resources should be established to cover any future costs, in particular, the costs ~~of~~ associated with the spent fuel ~~after~~ storage, decommissioning of the storage facility and also the costs of managing radioactive waste. The financial mechanism should be established before licensing and eventual operation, and should be updated~~,~~ as necessary. Consideration~~s~~ should also be given to provision of ~~to providing how~~ the necessary financial resources ~~would be provided~~ in the event of premature shutdown of the spent fuel storage facility.

RESPONSIBILITIES OF THE GOVERNMENT

Requirement 2 (GSR Part 5, Ref. [4]): National policy and strategy on radioactive waste management

To ~~assure~~ ensure the effective management and control of radioactive waste, the government shall ensure that a national policy and a strategy for radioactive waste management are established. The policy and strategy shall be appropriate for the nature and the amount of the radioactive waste in the State, shall indicate the regulatory control required, and shall consider relevant societal factors. The policy and strategy shall be compatible with the ~~F~~fundamental s~~S~~afety p~~P~~rinciples [9~~2~~] and with international instruments, conventions and codes that have been ratified by the State. The national policy and strategy shall form the basis for decision making with respect to the management of radioactive waste.

3.5. The government is responsible for establishing a national policy and corresponding strategies for the management of spent fuel and for providing the legal and regulatory framework necessary to implement the policies and strategies. These policies and strategies should ~~address~~ cover all types of spent fuel and spent fuel storage facilit~~y~~ies in the ~~Member~~ State, ~~taking into~~with account taken of the interdependencies between the various stages of spent fuel management, the time periods involved and the options available.

3.6. The government is responsible for establishing a regulatory body independent from the owners of the spent fuel ~~owners and~~ or the ~~spent fuel management~~ operating organizations managing the spent fuel~~of the spent fuel storage facilities~~, with adequate authority, power, staffing and financial resources to discharge its assigned responsibilities [14].

3.7. The government should consult interested parties (i.e. those who are involved in or are affected by spent fuel management activities) on matters relating to the development of policies and strategies that affect the management of spent fuel.

3.8. In the event that circumstances change and require storage is required beyond the storage period originally envisaged in the national strategy, a re-evaluation of the national storage strategy should be initiated.

RESPONSIBILITIES OF THE REGULATORY BODY

Requirement 3 (GSR Part 5, Ref. [4]): Responsibilities of the regulatory body
The regulatory body shall establish the requirements for the development of radioactive waste management facilities and activities and shall set out procedures for meeting the requirements for the various stages of the licensing process. The regulatory body shall review and assess the safety case and the environmental impact assessment for radioactive waste management facilities and activities, as prepared by the operator both prior to authorization and periodically during operation. The regulatory body shall provide for the issuing, amending, suspension or revoking of licences, subject to any necessary conditions. The regulatory body shall carry out activities to verify that the operator meets these conditions. Enforcement actions shall be taken as necessary by the regulatory body in the event of deviations from, or non-compliance with, requirements and conditions.

3.9. Regulatory responsibilities may include contributing to the technical input for the definingestablishment of policies, safety principles and associated criteria, and for establishing regulations or conditions to serve as the basis for regulatory activities. The regulatory body should also provide guidance to operating organizations on how to meet requirements relating to the safe storage of spent fuel.

3.10. Since spent fuel may be stored for long periods of time prior to its retrieval for reprocessing or disposal, the regulatory body should verify that the operating organization is providing the necessary personnel, technical and financial resources for the lifetime of the spent fuel storage facility, to the extent that such confirmation is within its the statutory obligations of the regulatory body.

3.11. The regulatory review of the decommissioning plans for spent fuel storage facilities should follow a graded approach, particularly considering the phases in the lifetime of the storage facility lifetime. The initial decommissioning plan should be conceptual and should be reviewed by the regulatory body for its overall completeness rather than for specific decommissioning arrangements, but should include specifically how financial and human resources and the availability of the necessary information from the design, construction and operational phases will be asensured for when the decommissioning takes place. The decommissioning plan should be regularly updated regularly by the licensee and updates should be reviewed by the regulatory body. If a facility is shut down and no longer to be used for its intended purpose, a final decommissioning plan should be submitted to the regulatory body for both review and approval.

3.12. General recommendations for regulatory inspection and enforcement actions relatinge~~d~~ to spent fuel storage facilities are provided in Ref. [16]. The regulatory body should periodically verify that the key aspects of the operation of the storage facility meet the requirements of the national legal system and facility license conditions, such as those relating to the keeping of records on inventories and material transfers, compliance with acceptance criteria for storage, maintenance, inspection, testing and surveillance, operational limits and conditions, physical protection of nuclear material and ~~emergency~~ arrangements for emergency preparedness and response. ~~This~~ Such verification may be carried out, for example, by routine inspections of the spent fuel storage facility and audits of the operating organization. The regulatory body should ~~confirm~~ verify that the necessary records are prepared and that they are maintained for an appropriate period of time. A suggested list of records is included in Ref. [17].

3.13. The regulatory body should set up appropriate means of informing interested parties, such as persons living in the vicinity, the general public, information media and others about the safety aspects (including health and environmental aspects) of the spent fuel storage facility~~ies~~ and about regulatory processes and should consult these parties, as appropriate, in an open and inclusive manner. ~~Demands~~ The need for confidentiality, e.g. for security reasons, should be respected.

3.14. The regulatory body should consider the licensing strategy to be adopted, for example:

(a) A ~~L~~licence issued for the entire lifetime of the storage system and/or facility, which ~~that~~ encompasses the whole anticipated operating period, ~~with~~ including periodic~~al~~ review~~s~~ of safety assessments, as elaborated in S~~s~~ection 5;~~,~~ or

(b) A ~~L~~licence issued for a specified time period with the possibility ~~of~~ for its renewal after expiration.

3.15. If the regulatory body consists of more than one authority, effective arrangements should be made to ensure that regulatory responsibilities and functions are clearly defined and co-ordinated, in order to avoid any omissions or unnecessary duplication and to prevent conflicting requirements being placed on the operating organization. The main regulatory functions of review and assessment and inspection and enforcement should be organized in such a way as to achieve consistency and to enable the necessary feedback and exchange of information.

RESPONSIBILITIES OF THE ~~OPERATOR~~OPERATING ORGANIZATION[3]

Requirement 4 (GSR Part 5, Ref. [4]): Responsibilities of the operator

[3] The ~~operator~~operating organization is assumed to be ~~a~~ the licensee. If the facility is operated under contract, the interface between responsibilities of the licensee and those of the contracted operational management ~~-~~ should be clearly defined, agreed on and documented.

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Operators shall be responsible for the safety of predisposal radioactive waste[4] management facilities or activities. The operator shall carry out safety assessments and shall develop a safety case, and shall ensure that the necessary activities for siting, design, construction, commissioning, operation, shutdown and decommissioning are carried out in compliance with legal and regulatory requirements.

3.16. The ~~operator~~operating organization is responsible for the safety of all activities associated with the storage of spent fuel (including activities undertaken by contractors), and for the identification and implementation of the programmes and procedures necessary to ensure safety. The ~~operator~~operating organization should maintain a high level of safety culture and demonstrate safety. In some instances the ~~operator~~operating organization may ~~own the~~be the owner of fuel and in other cases the owner may be a separate organiz~~s~~ation. In the latter instance, consideration should be given to ~~the~~ interdependencies, including any activity carried out prior to receipt of the spent fuel at a storage facility, such as its characterization or packaging, or subsequent transport of the spent fuel from the facility, ~~should be considered~~ to ensure that conditions for safety will be met.

3.17. The responsibilities of the operating organization of a spent fuel storage facility ~~would~~ typically include:

(a) Appl~~ying~~ication to the regulatory body for permission to site, design, construct, commission, operate, modify or decommission a spent fuel storage facility;

(b) Conduct~~ing~~ of appropriate safety and environmental assessments ~~to~~ in support of the application for a licence;

(c) Operat~~ing~~ion of the spent fuel storage facility in accordance with the requirements of the safety case, the licence conditions and the applicable regulations;

(d) Develop~~ing~~ment and appl~~ying~~ication of acceptance criteria for the storage of spent fuel as approved by the regulatory body; ~~and~~

(e) Providing periodic reports as required by the regulatory body (e.g. information on the actual inventory of spent fuel, any transfers of spent fuel into and out of the facility and any ~~reportable significant [reportable is unclear, but perhaps significant doesn't implies the same level of significance as reportable....]~~ events that occur at the facility and which have to be reported to the regulatory body) and communicating with relevant ~~stakeholders~~ interested parties and the general public.

[4] As indicated in the introduction (para 1.1), no ~~difference~~ distinction is made in respect of safety between spent fuel considered as waste or as a resource material ~~in respect of safety~~.

3.18. Prior to ~~the~~ authorization of a spent fuel storage facility, the operating organization should provide the regulatory body with a safety case[5] that demonstrates the safety of the proposed activities and demonstrates that the proposed activities ~~are~~ will be in compliance with the safety requirements and criteria set out in national laws and regulations. The operating organization should use the safety assessment to establish specific operational limits and conditions. The operating organization may wish to set an operational target level below these specified limits to assist in avoiding any breach of approved limits and conditions (see para. 6.106).

3.19. At an early stage in the lifetime of a spent fuel storage facility, the operating organization should prepare preliminary plans for its eventual decommissioning. For new facilities, features that will facilitat~~eing~~ decommissioning should be taken into consideration at the design stage; such features ~~and~~ should be ~~compiled into a~~ included in the decommissioning plan together with information on arrangements for how the availability of the necessary human and financial resources and information will be assured, for presentation in the safety case. ~~Requirements on decommissioning are provided in Ref. [19] and guidance in Ref. [19].~~

3.20. For existing facilities without a decommissioning plan, ~~plans~~ ~~this~~such a plan should be prepared as soon as possible. Requirements on decommissioning are ~~provided~~ established in Ref. [18~~9~~] and ~~guidance~~ recommendations are provided in Ref. [19].

3.21. The operating organization should establish the requirements for training and qualification ~~requirements for~~ of its staff and contractors, including for initial and periodic refresher training. The operating organization should ensure that all concerned staff members understand the nature of the spent fuel, its potential hazards and the relevant operating and safety procedures. Supervisory staff should be competent to perform their activities and should therefore be selected, trained, qualified and authorized for that purpose. A radiation protection officer should be appointed to oversee the application of radiation protection requirements.

3.22. The operating organization should carry out pre-operational tests and commissioning tests to demonstrate compliance of the storage facility and storage activities with the requirements of the safety assessment and with the safety requirements established by the regulatory body.

3.23. The operating organization should ensure that discharges of radioactive and other potentially hazardous materials to the environment are in accordance with the conditions of licence. Discharges should be documented.

[5] The safety case is a ~~A~~ collection of arguments and evidence in support of the safety of a facility or activity. This collection of argument and evidence may be known by different names (such as ~~a~~ safety report, ~~a~~ safety dossier, ~~a~~ safety file) ~~etc~~ in different ~~countries~~ States and may be presented in a single document or a series of documents~~.~~ (~~s~~See Section 5).

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3.24. The operating organization should prepare plans and implement programmes for personnel monitoring, area monitoring, environmental monitoring, and for emergency preparedness and response (see para~~.~~ 6.44).

3.25. The operating organization should establish a process on how to authorize and make modifications to the spent fuel storage facility, storage conditions, or the spent fuel to be stored, ~~that~~ which is ~~appropriate given~~commensurate with the significance of the modifications. As part of ~~T~~the process ~~should evaluate~~ the potential consequences of ~~the~~ such modifications should be evaluated, including consequences ~~on~~ for the safety of other facilities and also ~~on~~ for the retrieval, reprocessing or disposal of spent fuel.

3.26. The operating organization ~~should~~ is required to put in place appropriate mechanisms ~~to~~ for ensur~~e~~ing that sufficient financial resources are available to undertake all necessary tasks throughout the lifetime of the facility, including its decommissioning [14].

3.27. The operating organization should develop and maintain a records system on spent fuel data and on the storage system, which should include~~s~~ the radioactive inventory, location and characteristics of the spent fuel, information on ownership and~~,~~ origin and information about its characterization. ~~There should be an~~An unequivocal identification ~~with a marking~~ system should be established, with markings that will last for the duration of the storage period. ~~These~~ Such records should be preserved and updated, to enable the implementation of the spent fuel management strategy; whether disposal or reprocessing.

3.28. The ~~operator~~operating organization should draw up emergency plans on the basis~~ed~~ o~~n~~f the potential radiological impacts of accidents [20, 21] and should be prepared to respond to accidents at all times as indicated in the emergency plans (~~S~~see paras 6.73~~7~~ and 6.74).

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RESPONSIBILITIES OF THE SPENT FUEL OWNER

> **Requirement 6 (GSR Part 5, Ref. [4]): Interdependences**
>
> **Interdependences among all steps in the predisposal management of radioactive waste, as well as the impact of the anticipated disposal option, shall be appropriately taken into account.**

3.29. There should be clear and unequivocal ownership of the spent fuel stored in the facility. The interface between the responsibilities of the ~~operator~~operating organization and the spent fuel owner, if they differ, should be clearly defined, agreed upon and documented. The spent fuel owner, i.e. a body having legal title to the spent fuel, including financial liabilities, (usually the spent fuel producer)~~,~~ should be responsible for the overall strategy for the management of its spent fuel.~~,~~ In determining the overall strategy, the owner should takeing into account interdependencies between all stages of spent fuel management, the options available and the overall national spent fuel management strategy. The owner should analyse the available options, justify the reasons for the approach chosen and provide the regulatory body with plans for the management of the spent fuel beyond the anticipated storage period (which should be in line with approved national policy), together with justification for the plans. These plans should be periodically updated, as needed necessary and specifically before the end of the storage period.

3.30. Information about changes of in ownership of the spent fuel ownership or about changes in the relationship between the owner and the operatoroperating organization of a spent fuel storage facility should be provided to the regulatory body.

ACCOUNTING AND CONTROL OF NUCLEAR MATERIAL AND PHYSICAL PROTECTION SYSTEMS

Requirement 21 (GSR Part 5, Ref. [4]): System of accounting for and control of nuclear material

For facilities subject to agreements on nuclear material accountings, in the design and operation of predisposal radioactive waste management facilities the system of accounting for and control of nuclear material shall be implemented in such a way so as not to compromise the safety of the facility.

Requirement 5 (GSR Part 5, Ref. [4]): Requirements in respect of security measures

Measures shall be implemented to ensure an integrated approach to safety and security in the predisposal management of radioactive waste.

3.31. The operating organization will be required to establish, maintain and implement a system for nuclear material accounting and control as an integrated part of the State Ssystem of Aaccounting for and cControl (SSAC)[6] of nuclear material. In addition, physical protection systems to for deterrence and detection and deter of the intrusion of unauthorized persons and prevent against sabotage from inside within and outside the facility will be designed and installed during the construction and operation of the spent fuel storage facility. The implications of these such systems and arrangements on the safety of the facility should be assessed and it should be ensured that no safety functions will would be compromised

6 NPT sSafeguards agreements between the IAEA and non-nuclear-weapon States party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) contain the obligation of the State to establish and maintain a "State's national system of accountancy for and control of nuclear material". The Agency IAEA document describing the structure and content of such NPT safeguards agreements, INFCIRC/153(Corr.), also known as the '"Blue Book'", lays downsets out the basic requirements for a State''s system of accounting for and control of nuclear material — SSAC for short.

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nor ~~that~~ would the overall level of safety at the facility ~~will~~ be significantly reduced on account of ~~these~~ such systems and arrangements.

4. MANAGEMENT SYSTEM

Requirement 7 (GSR Part 5, Ref. [4]): Management systems
Management systems shall be applied for all steps and elements of the predisposal management of radioactive waste.

4.1. The requirements on management systems for all ~~each~~ stages in the lifetime of a spent fuel storage facility are established in Ref. [6]. ~~The safety guide~~Recommendations on ~~for~~ ~~the~~ management systems related to ~~for~~ the storage of spent fuel ~~storage is~~ are ~~published~~ provided in Ref. [22].

4.2. A management system is required to be established, implemented, assessed and continually improved by the operating organization [6], and should be applied to all stages of the storage of spent fuel that have a bearing on safety. It should be aligned with the goals of the operating organization and should contribute to ~~its~~ their achievement. The ~~scope of the~~ management system should make provision for ~~includes~~ siting, design, commissioning, operation, maintenance and decommissioning of the spent fuel storage facility. The management system should be designed to ensure that the safety of the spent fuel and of the spent fuel storage facility is maintained, and that the quality of the records and of subsidiary information of spent fuel inventories is preserved, with account taken of the length of the storage period and the consecutive management steps, for example reprocessing or disposal. The~~A~~ management system should also contain provisions to ensure that the ~~achievement~~ fulfilment of its goals can be demonstrated.

4.3 The long term nature of spent fuel management operations means that particular ~~attention~~ consideration should be ~~paid~~ given to establishing and maintaining confidence that the performance of the spent fuel storage facilities and activities will meet the safety requirements ~~for the lifetime of the facility~~ through the lifetime of the facility to the end of its decommissioning (e.g. by creati~~ng the~~on of the funding arrangements that will be necessary to manage the spent fuel in the long term).

SPENT FUEL MANAGEMENT

4.4 National and international policies and principles for spent fuel management that currently constitute an accepted management arrangement can evolve over the lifetime of the facility. Policy decisions (e.g. regarding spent fuel reprocessing) and technological innovations and advances (e.g. in partitioning and transmutation) can lead to fundamental changes in the overall spent fuel management strategy. However, the operating organization ~~management will~~ retains its responsibility for all activities at all times, and continuous commitment by the organization ~~management will~~ remains a prerequisite to ensuring safety and the protection of human health and the environment.

4.5 For the plans, goals and objectives that define the strategy for achieving an integrated approach to safety, interactions with all interested parties should be considered, as well as long term aspects such as:

(a) Provisionding of adequate resources (the adequacy of resources for maintenance of facilites and equipment safety may need to be periodically reviewed over operational periods that may extend over decades);

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(b) Preservationing of technology and knowledge and transfer raling it of such knowledge to people joining the programme or the organization in the future;

(c) Retaining Retention or transferring transferral of ownership of spent fuel and spent fuel management facilities;

(d) Succession planning for the programme's or the organization's technical and managerial human resources;

(e) Continuationing of arrangements for interacting with interested parties.

RESOURCE MANAGEMENT

4.54.6 Spent fuel management activities will require financial and human resources, and the necessary infrastructure within at the site where the -spent fuel storage facility is located. Senior management should be responsible for making arrangements to provide adequate resources for spent fuel management activities, to satisfy the demands imposed by the safety, health, environmental, security, quality and economic aspects associated withof the full range of activities involved in the management of spent fuel and the potentially long duration of the such activities.

4.64.7 Funding aArrangements for funding of future spent fuel management activities should be specified, and responsibilities, mechanisms and schedules for providing the funds should be established in due time. The generator of the spent fuel should establish an appropriate funding mechanism.

4.8 Management systems for spent fuel management activities should include provisions to deal with several funding challenges:

(a) For various reasons (e.g. bankruptcy, cessation of business), it may not be feasible to obtain the necessary funds from the spent fuel generator, especially if funds were not set aside at the time the benefits were received from the activity, or if ownership of the spent fuel has been transferred to other parties.

(b) If funds are to come from public sources, this will compete with other demands for public funding, and it may be difficult to gain access to adequate funds on a timely basis.

(c) It may be difficult to make realistic estimates of costs for spent fuel management activities that are still in the planning stage and for which no experience has been accumulated.

(d) It may be difficult to estimate anticipated costs for activities that will only begin in the long term, because they will depend strongly on assumptions made about future inflation rates, ~~bank~~ interest rates and technological developments.

(e) It may be difficult to ~~set~~ determine appropriate risk and contingency factors to be built into estimates of future costs, owing to the uncertaint~~y~~ies associated with ~~unforeseeable~~ future changes in societal demands, political imperatives, public opinion and the nature of unplanned events that may require resources for dealing with them.

(f) If several organizations are involved in ~~the~~ spent fuel management activities, the necessary financial arrangements may be complex and may vary~~iable~~ over the lifetime of the facility. ~~The~~ It may be problematic to establish~~ment of~~ an adequate degree of confidence in all the arrangements so that the necessary continuity of funding throughout the entire series of activities is ensured~~ may be problematic~~.

~~4.7~~4.9 Accumulated experience, including lessons learned from incidents and events should be reviewed periodically and should be used in revising training programmes and in future decision making.

~~4.8~~4.10 In the design~~ing~~ of facilities for long term spent fuel management~~ activities~~, consideration should be given to the incorporation~~ng~~ of measures ~~for~~ that will ease~~ of~~ operation, maintenance of equipment and eventual decommissioning of the facility. For long term spent fuel management activities, future infrastructural requirements should be specified and plans should be made to ensure that these will be met. In such planning, consideration should be given to the continuing need for support services, ~~for~~ spare parts for equipment that may eventually no longer be manufactured and~~,~~ ~~for~~ equipment upgrades to meet new regulations and operational improvements, and ~~for~~ to the evolution and inevitable obsolescence of software. Consideration should also be given to the need to develop monitoring programmes and inspection techniques for use during extended periods of storage.

PROCESS IMPLEMENTATION

~~4.9~~4.11 Consideration should be given to the possible need to relocate spent fuel casks if problems arise after they have been placed in storage (e.g. threats to the integrity of casks or problems associated with criticality or decay heat). The availability of any specialized equipment that may be ~~required~~ necessary over a long time period while spent fuel is in storage or that may be required necessary in the future should be assessed.

4.104.12 Records concerning about of the spent fuel and its storage that need to be retained for an extended period should be stored in a manner that minimizes the likelihood and consequences of loss, damage or deterioration due to unpredictable events such as fire, flooding or other natural or human initiated occurrences. Storage arrangements for records should meet the requirements prescribed by the national authorities or the regulatory body and the status of the records should be periodically reassessed. When unpredictable events lead to the inadvertent destruction of If records are inadvertently destroyed, the status of surviving records should be examined and the importance of their retention and their necessary retention periods should be re-evaluated.

4.114.13 Management systems should be reassessed whenever the relationship between the owner of the spent fuel/ and the operatoroperating organization of the facility structure changes (e.g. public organizations are privatized, new organizations are created, existing organizations are combined or restructured, responsibilities are transferred between organizations, or operating organizations undergo internal reorganization of the management structure, or the reallocation of resources are reallocated).

5. SAFETY CASE AND SAFETY ASSESSMENT

Requirement 13 (GSR Part 5, Ref. [4]): Preparation of the safety case and supporting safety assessment

The operator shall prepare a safety case and a supporting safety assessment. In the case of a step by step development, or in the event of the modification of the facility or activity, the safety case and its supporting safety assessment shall be reviewed and updated as necessary.

Requirement 14 (GSR Part 5, Ref. [4]): Scope of the safety case and supporting safety assessment

The safety case for a predisposal radioactive waste management facility shall include a description of how all the safety aspects of the site, the design, operation, shutdown and decommissioning of the facility, and the managerial controls satisfy the regulatory requirements. The safety case and its supporting safety assessment shall demonstrate the level of protection provided and shall provide assurance to the regulatory body that safety requirements will be met.

Requirement 22 (GSR Part 5, Ref. [4]): Existing facilities

The safety at existing facilities shall be reviewed to verify compliance with requirements. Safety related upgrades shall be made by the operator in line with national policies and as required by the regulatory body

5.1. In demonstrating the safety of the spent fuel storage facility and related activities, a safety case should be developed ~~together with the~~as development of the facility progresses, and the supporting safety assessment should be carried out in a structured and systematic manner. Proposed facilities, process, operations, activities, etc., should be examined to determine if they can be implemented safely and meet all requirements regarding safety [21]. If storage casks ~~-~~are to be used, there may be one or separate safety cases and/~~-~~or safety assessment(s) for the storage casks, the storage building or facility and subsequent transport arrangement if the cask will be used eventually for transport as well as for storage. This will depend on the national regulatory approach;~~,~~ however, ~~whatever~~ irrespective of the approach is taken, the interdependencies should be taken into consideration such to ensure that an integrated approach to safety is adopted and safety is optimized. The safety case and supporting safety assessment should provide the primary input to the licensing documentation required to demonstrate compliance with regulatory requirements [5].

5.2. The ~~different~~ various stages in the ~~life time~~lifetime of the spent fuel storage facility (i.e. siting, design, construction, commissioning, operation and decommissioning) should be taken into account in the safety case.~~assessment~~. The safety case~~assessment~~ should be periodically reviewed in accordance with regulatory requirements and should be revised as necessary.

5.3. The Fundamental Safety Principles [9] place tThe prime responsibility for safety throughout the lifetime of a facility on lies with the operating organization [9]. This includes the responsibility for both ensuring and demonstrating the safety of a facility in the safety case. , an important aspect of which. is Tthe safety assessment is an important aspect to ensure and demonstrate the safety of nuclear facilities.

5.4. Comprehensive guidance recommendations on development of a safety case and supporting safety assessment, together with their review by the regulatory body is are provided in reference Ref. [21]. Guidance Recommendations areis provided on the objectives of the safety case, and development of the safety case and the approach to structuring and carrying out safety assessment. Reference [21] also provides recommendations on Sspecific issues are addressed, in particular the evolution of the safety case with the development of the facility, assessment of measures to provide defence in depth and aspects relatinged to longer term storage.

5.5. Longer term storage (see para. 1.6 and Annex I), may involve a period of time which that exceeds the normal design lifetime of civil structures including short term storage facilities, and this will have implications for the choice selection of construction materials, operating methods, and quality assurance and quality control requirements, etc. Specific issues that should be given special particular consideration in the safety case for a facility for longer term storage of spent fuel include the assumed anticipated lifetime of the facility lifetime, the importance of passive safety features, retrievability and management systems. Consideration should also be given to the provision of supporting services when the lifetime of the spent fuel storage facility is longerremains in operation after than other facilities on at the site have been closed, in particular for storage facilities at reactor sites.

5.6. The rationale for selectionng of the assessment time frame should be explained and justified. Depending on the purposes of the assessment (for design studies, licensing etc)for longer term storage, for ease of modelling or presentation it might be convenient to divide the overall time frame of the safety assessment into shorter time windows with different various end points for modelling or presentational reasons.

5.7. In determining Tthe assessment time frame should be defined by taking account should be taken of the characteristics of the particular storage facility or activity, the site, and the spent fuel to be stored. Other factors that should be considered when deciding on assessment time frames include the following:

- For most longer term storage systems (including storage casks, engineered constructions and the surrounding environment), potential health and environmental impacts may rise increase for a period of time after commissioning of the facility. In the longer term, depending on the nature of the facility, potential impacts may decrease, in particular through decay of the radioactive radionuclide inventory of the spent fuel. The safety assessment calculations should consider the maximum, or peak, dose or risk associated with the facility or activity.

- ~~Another~~ A further consideration ~~which~~ that may influence decisions on assessment time frames is the return period of natural external hazards, such as extreme meteorological events or earthquakes.

- Several factors that can significantly affect the results of the safety assessment ~~results~~ may change with time, such as: ~~the nature of;~~ external hazards from ~~anthropogenic~~ human activities such as the construction of ~~nearby~~ other facilities nearby;~~,~~ natural events such as ~~the~~ changes in water levels; ~~or~~ and changes ~~to~~ in the availability of support~~ing~~ facilities and infrastructure due to shutdown and decommissioning of co located facilities. ~~The~~Potential changes such as these should be considered in the safety assessment ~~should consider these changes~~. As a means to assess the possible evolution of the long~~er~~ term storage, ~~assessments may consider~~ one or more scenarios to reflect different evolution paths may be considered in the safety assessment. Assessment time windows may be defined, as appropriate, to reflect ~~the~~ potential changes at the storage facility.

- The location, habits and characteristics of the ~~radiation dose receptor~~ ~~critical~~ reference person in radiological impacts assessment ~~group, as well as the conditions in which they are located,~~ may be changed over time. Consequently, the reference person ~~such receptors~~~~the critical group~~ should be considered as hypothetical, but ~~receptors~~ individuals and populations in the future should be afforded at least the same level of protection as is required at the present day. The habits and characteristics assumed for the reference person ~~critical group~~ should be chosen on the basis of reasonably conservative and plausible assumptions, considering current lifestyles as well as the available site or regional environmental conditions.

5.8. The ~~operator~~operating organization should demonstrate as soon as possible that, to the extent possible, passive safety features are applied. In ~~T~~the assessment of long~~er~~ term safety ~~should account for~~ the degradation of passive barriers over time should be taken into account.

5.9. The complementary performance of the different elements providing ~~various systems and components that provide~~ safety functions should be evaluated. Each element ~~such system or component~~~~safety function~~ should be ~~as~~ independent ~~as possible~~ from the others to the extent possible, to ensure that they are complementary and cannot fail through a single failure mode. The safety case should explain and justify the functions provided by each element ~~barrier~~ and should ~~specify~~identify the time periods over which they are expected to perform their various safety functions and also the alternative or additional safety functions that operate if a barrier does not fully perform.

5.10. ~~Similar to~~As in the case of disposal ~~situations~~of radioactive waste, the environment may also offer additional protective functions ~~barriers~~ (e.g. underlying clay layers which would provide a

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sorption capacity for contaminants in the event~~cases~~ of any leakages from the facility). Such aspects should be taken into account during the siting of the facility and should be considered in the safety case.

5.11. Storage is by definition an interim measure, but it can last for several decades. The intention in storing spent fuel is that it can be retrieved for reprocessing or processing and/or disposal at a later time. In t~~T~~he safety case ~~should consider~~ a plan for safe handling of the spent fuel following the period of storage should be considered and ~~assess~~ the potential effects of degradation of the spent fuel and/~~-~~or any elements of the containment on the ability to retrieve and handle the spent fuel should be assessed (see also ~~s~~Section 6).

5.12. The possibility of inadvertent human intrusion normally would not be considered relevant when assessing the safety of a storage facility because the facility will require continued surveillance and maintenance not only during but also after the spent fuel emplacement phase. ~~The p~~Prevention of intentional human intrusion requires adequate security arrangements and these should be addressed in the safety case. ~~and cConfidence in their long term effectiveness needs toshould be built in their long term effectiveness among interested parties [?the public?].~~

5.13. Because storage is an interim measure, the safety case should describe the provisions for the regular monitoring, inspection and maintenance of the storage facility to ensure its continued integrity over the anticipated lifetime of the facility.

5.14. Because of the long time frames potentially involved, ~~in the safety case should also consider~~ a plan for adequate record keeping over the expected time frame for storage should be considered in the safety case.

5.15. Periodically, the safety case should be reviewed to ~~consider~~ assess the continuing adequacy of the storage capacity;~~, with~~ account should be taken of the predicted spent fuel arising, ~~both for normal operation and for possible incidents~~the expected lifetime of the storage facility and the availability of reprocessing or disposal options.

5.16. It may be ~~required~~ necessary to reassess the anticipated impacts of decommissioning after operational experience has been gained.

5.17. The requirement to perform ~~a~~ safety assessment ~~comes~~ derives from national programme requirements and the realization that the safety assessment can contribute directly to safety as through this~~by identifying~~ appropriate measures are identified that can be put in place to protect ~~the~~ workers, the public and the environment. Safety assessment is undertaken in conjunction with the planning and design of a proposed facility or activity, rather than its being a separate activity. The results of the safety assessment can be used to determine any necessary changes in the plans or design~~s~~ so that compliance with all requirements is ~~as~~ensured. The~~y~~ results are also used to establish controls and limitations on the design, construction and operation of the facility.

5.18. Safety assessment is typically an iterative process used to ensure that a spent fuel storage facility can be operated safely and should be ~~used~~ commenced~~arried~~ out early in the design process. Generally, in the control of radiation hazards, reliance should be placed principally on design features rather than on ~~operational~~ operating procedures ~~in the control of radiation hazards~~.

5.19. ~~The p~~Postulated initiating events that may influence the design of the spent fuel storage facility and the integrity and safety of the spent fuel should be identified. The primary causes of postulated initiating events may be credible equipment failures and operator errors or human induced or natural events (both within and external to the facility). In identifying the relevant postulated initiating events, generic lists should be consulted (See Annexes III ~~3~~,~~4~~ IV and ~~5~~V). ~~They~~ Such lists should not be ~~solely~~ relied on solely, since site specific environmental conditions and phenomena and the design and operation of the facility will also influence the decision as to which postulated initiating events ~~should~~ need to be evaluated in the safety assessment.~~.~~

5.20. ~~The s~~Safety assessment should cover the storage facility and the type of spent fuel to be stored and storage arrangements. In this regard, the types, quantities, initial enrichment, burnup, ~~fuel~~ integrity, heat production, storage mode (wet or dry storage) and physical and chemical characteristics of the spent fuel represent basic elements that need to be ~~available~~ included in the safety assessment of spent fuel storage facilities.

5.21. ~~The s~~Safety assessment for ~~of~~ a spent fuel storage facility should ~~encompass~~ cover the expected operational period of the facility. The storage of spent fuel for long periods of time would require events of lower likelihood to be evaluated in the safety assessment than that for a shorter duration of storage. Similarly, ~~P~~processes that may not be relevant for a shorter duration of storage may become significant for a longer duration of storage (e.g. generation of gas, general corrosion, stress corrosion, radiation or hydride induced embrittlement of cladding material, natural processes such as vermin infestation and possible change of nuclear reactivity over a long time).

5.22. A facility specific safety case and supporting assessment ~~would~~ should generally include aspects such as:

(a) A ~~D~~description of the site and facility (including the maximum expected inventory of spent fuel and its acceptance criteria, the storage facility and its characteristics, structures, systems and components, including the characteristics of ~~the~~ items important to the safety of the spent fuel storage facility, in accordance with the requirements of ~~the~~ its licence) and a specification of ~~the~~ applicable regulations and guidance~~.~~;

(b) A ~~D~~description of spent fuel handling and storage activities and any other ~~type of~~ operations at the facility;

(c) Systematic identification of hazards and scenarios associated with operational states and accident conditions and external events (e.g. fires, handling accidents and seismic events~~).~~);

(d) An evaluation of hazards and scenarios ~~to~~ including~~e~~ screening of their combinations that may result in ~~the~~ a release of radioactive material, to eliminate those of ~~insufficient~~ low likelihood or low potential consequences~~.~~;

(e) Assessment of the probabilities and potential consequences of the release(s) of radioactive material identified in the hazard evaluation by quantitative analysis and comparison of the results of the~~at~~ assessment with regulatory limitations~~.~~;

(f) Establishment of operational limits, conditions and administrative controls based on the safety assessment. If necessary, the design of the spent fuel storage facility should~~has to~~ be modified and the safety assessment ~~has to~~ should be updated. ~~This~~ Such controls should include acceptance criteria for spent fuel casks, including canisters containing failed fuel~~.~~;

(g) Documentation~~ing~~ of safety analyses and the safety assessment for inclusion in the documentation supporting the licensing of the facility~~.~~;

(h) The ~~C~~commissioning programme~~.~~;

(i) ~~The o~~Organizational control of ~~the~~ operations~~.~~;

(j) Procedures and operational manuals for activities with significant safety implications~~.~~;

(k) A programme for periodic maintenance, inspection~~s~~ and testing~~.~~;

(l) The expected values for sub~~-~~criticality, heat removal capacity and calculated radiation doses inside and at the boundary of the spent fuel storage facility~~.~~;

(m) Monitoring programmes, including a programme for shielding verification, a programme for surveillance of the condition of stored spent fuel and a programme ~~of~~ for surveillance of ~~the~~ stored spent fuel assemblies, if appropriate~~.~~;

(n) A~~n~~ programme for feedback of operational ~~feedback programme~~experience~~.~~;

(o) The training programme for staff~~.~~;

(p) Safety implications of ~~safeguards~~ aspects of accounting and control for nuclear material~~.~~;

(q) Physical protection arrangements for ~~radioactive materials~~the facility~~.~~;

(r) The ~~E~~emergency preparedness and response plan~~.~~;

(s) The management system~~.~~;

(t) Provisions for occupational radiation protection ~~and~~

(u) Provisions for the management of radioactive waste and for decommissioning.

5.23. In ~~T~~the safety assessment ~~should identify the~~ key hazards should be identified, so that the required safety functions and safety systems ~~are~~ can be identified and ~~so that~~ a level of confidence can be established in the parameters supporting the safety assessment ~~can be established~~ that is commensurate with their significance (e.g. by sensitivity analysis).

5.24. The safety assessment should include an assessment of hazards ~~during~~ in operational states and ~~under~~ accident conditions. It should provide an assessment of doses at the site boundary and of the potential for exposure~~s~~ in areas within the site ~~where~~ to which there is to be unrestricted access. ~~Under~~ In normal operation, for spent fuel storage facilities ~~have~~there should be nothing that will cause ~~is no sources~~ a fast increase ~~of~~in the nuclear reactivity in the stored ~~of the~~ fuel and as such there are relatively few credible mechanisms for such a sudden excursion followed by a release of radioactive material.

5.25. As appropriate, limitations on authorized discharge~~s~~ should be established for the spent fuel storage facility, ~~following~~ in accordance with the ~~guidance~~ recommendations provided in Ref. [23].

5.26. ~~An~~ If the initial safety assessment ~~that~~ yields results that are close to or that exceed the limiting performance objectives ~~would suggest the need for~~ it may be necessary to carry out a more rigorous evaluation of the suitability of any generic data sources that may have been used, and/or an inventory reduction or additional safety systems and controls may be necessary.

Requirement 16 (GSR Part 5, Ref. [4]): Periodic safety reviews

The operator shall carry out periodic safety reviews and shall implement any safety upgrades required by the regulatory body following this review. The results of the periodic safety review shall be reflected in the updated version of the safety case for the facility.

5.27. The safety case and supporting safety assessment~~s~~, including the management systems used for their implement~~at~~i~~o~~ng ~~management systems,~~ should be periodically reviewed in accordance with regulatory requirements. The review of management systems should include aspects of safety culture. In addition, ~~they~~ the safety case and supporting safety assessment~~s~~ should be reviewed and updated:

(a) When there is any significant change to the ~~installation~~ facility or its radionuclide inventory that may affect~~s~~ safety;

(b) When changes occur in the site characteristics that may impact on the storage facility, e.g. industrial development or~~,~~ changes in the ~~nearby~~ surrounding population;

(c) When significant changes in knowledge and understanding occur (such as from research data or from feedback of operatingo~~nal~~ experience ~~feedback~~);

(d) When there is an emerging safety issue due to a regulatory concern or an incident; and

(e) Periodically at predefined periods as specified by the regulatory body. Some ~~Member~~ States specify that a periodic safety review be carried out not less than once in ten years.

5.28. Safety should be reassessed in the case of significant, unexpected deviations in ~~the~~ storage conditions, e.g. if ~~safety relevant~~ properties of the spent fuel that are relevant to safety ~~properties change and~~ begin to deviate from those taken as a basis in the safety assessment.

5.29. For storage beyond the original design lifetime, a re-evaluation of the initial design (and of the ~~existing~~ current design if it is significantly ~~changed~~different), ~~the~~ operations, maintenance, ageing management, ~~the~~ safety assessment and any other aspect of the spent fuel storage facility relating to safety should be performed. If during the design lifetime ~~it is foreseen that~~ an extension to the storage period ~~may be required~~is foreseen, ~~then~~ a precautionary approach should be applied, in particular through validationi~~ng~~ of the adequacy of the design assumptions for the extended period~~s~~ envisaged.

DOCUMENTATION OF THE SAFETY CASE

Requirement 15 (GSR Part 5, Ref. [4]): Documentation of the safety case and supporting safety assessment
The safety case and its supporting safety assessment shall be documented at a level of detail and to a quality sufficient to demonstrate safety, to support the decision at each stage and to allow for the independent review and approval of the safety case and safety assessment. The documentation shall be clearly written and shall include arguments justifying the approaches taken in the safety case on the basis of information that is traceable.

5.30. In documenting the safety case particular ~~attention~~ consideration should be given to ensuring that the level of detail and the supporting assessment ~~is~~ are commensurate with the importance to safety of ~~a~~the particular system or component and ~~their~~ its complexity, and that an independent reviewer will be able to ~~come to~~reach a conclusion on the adequacy of the assessment and ~~safety~~ the arguments employed, both in their extent and their depth. Assumptions used in the safety case must be justified in the documentation as must the use of generic information.

6. GENERAL SAFETY CONSIDERATIONS FOR STORAGE OF SPENT FUEL

GENERAL

Requirement 11 (GSR Part 5, Ref. [4]): Storage of radioactive waste

Waste shall be stored in such a manner that it can be inspected, monitored, retrieved and preserved in a condition suitable for its subsequent management. Due account shall be taken of the expected period of storage, and to the extent possible passive safety features shall be applied. For long term storage[7] in particular, measures shall be taken to prevent the degradation of the waste containment.

Requirement 5 (GSR Part 5, Ref. [4]): Requirements in respect of security measures

Measures shall be implemented to ensure an integrated approach to safety and security in the predisposal management of radioactive waste.

Requirement 21 (GSR Part 5, Ref. [4]): System of accounting for and control of nuclear material

For facilities subject to agreements on nuclear material accounting~~,~~, in the design and operation of predisposal radioactive waste management facilities the system of accounting for and control of nuclear material shall be implemented in such a way so as not to compromise the safety of the facility.

6.1. Spent fuel storage facilities~~,~~ should provide for the safe, stable and secure storage of spent fuel before it is reprocessed or disposed of. The design features and the operation of the facility ~~operations~~ should be such as to provide containment of radioactive~~nuclides~~ material, to ensure that radiation protection of workers, members of the public and the environment is optimized within the dose constraints in accordance~~ing~~ with~~to~~ the requirements established in ~~the~~ Ref. [10], to maintain subcriticality, to ensure removal of decay heat and to ensure retrievability of the spent fuel. These safety functions should be maintained during all operational states and accident conditions.

6.2. Various types of wet and dry spent fuel storage facilities are currently in operation or under consideration in various States. Spent fuel is stored in essentially one of three different modes:

(a) Wet storage in pools at~~,~~ or remote from a reactor site. The spent fuel is stored in standard storage racks or in compact storage racks ~~with~~ in which closer spacing of the fuel assemblies or fuel elements is allowed, to increase the capacity of storage.~~;~~

(b) Dry storage in either storage or dual purpose~~,~~ (i.e. storage and transport) casks at or remote from a reactor site. Casks are modular in nature. ~~These~~ Such systems are sealed systems designed to

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[7] See para. 1.6.

prevent the release of radioactive material during storage. They provide shielding and containment of the spent fuel by physical barriers, which may include ~~the~~ a metal or concrete body and metal liner or metal canister and lids. They are usually cylindrical in shape, circular in cross-section, with the long axis ~~being~~ arranged either vertically or horizontally. The fuel position is maintained by means of a storage basket which may or may not be an integral part of the cask. Heat is removed from the stored fuel by conduction, radiation and forced or natural convection to the surrounding environment. Casks may be enclosed in buildings or stored in an open area.~~; and~~

(c) Dry storage in vault type storage facilities: a vault is a massive, radiation shielded facility ~~where~~ in which spent fuel is stored. A vault can be either above or below ground level; it may be a reinforced concrete structure containing an array of storage cavities. The spent fuel is appropriately contained in order to prevent unacceptable releases of radioactive material. Shielding is provided by the structure surrounding the stored material. Primary heat removal is by forced or natural air convection over the exterior of the storage cavities. This heat is released to the atmosphere either directly or via appropriate filtration, depending ~~up~~on the system design. Some systems also use a secondary cooling circuit. However, if natural convection is to be used, the need for active components, e.g. pumps and ventilators, should be minimized ~~with~~ through higher operational reliability of the system and corresponding cost reduction~~ and higher operational reliability of the system~~.

6.3. Although designs of spent fuel storage facilities may differ, in general they should consist of relatively simple, preferably passive inherently safe systems~~, which are~~ intended to provide adequate safety over the ~~design life~~design lifetime of the facility, ~~this~~ which may span several decades. The lifetime of ~~the~~ a spent fuel storage facility should be appropriate for the envisaged storage period. The design should also contain features to ensure that associated handling and storage operations are relatively straightforward.

6.4. In general the storage facility should be designed to fulfill the main safety functions, i.e. ~~control of~~maintaining subcriticality, removal of heat, containment of ~~the~~ radioactive material~~, retrievability~~ and shielding ~~of~~ from radiation, and in addition retrievability of the fuel . The design features should at least, if possible, include the following:

(a) If possible, systems for ~~heat~~ removal of heat from the spent fuel should be driven by the energy generated by the spent fuel itself (e.g. natural convection);

(b) A multi-barrier approach should be adopted in ensuring containment, with ~~taking~~ account taken of all elements including the fuel matrix, the fuel cladding, the storage casks, the storage vaults and~~,~~ any building structures ~~etc as may~~that can be demonstrated to be reliable and competent;

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(c) Safety systems should be designed to achieve their safety functions with ~~a~~ minimum ~~reliance on~~need for monitoring;

(d) Safety systems should be designed to function with minimum human intervention;

(e) The storage building, or the cask in the case of dry storage, should be resistant to the hazards taken into consideration in the s~~S~~afety a~~A~~ssessment;

(f) Access should be provided for response to incidents;

(g) The spent fuel storage facility should ~~enable~~ be such that retrieval of the spent fuel or spent fuel package for inspection or reworking is possible~~enabled~~;

(h) The spent fuel and the storage system should be sufficiently resistant to degradation;

(i) The storage environment should not adversely affect the properties of the spent fuel, ~~any~~ spent fuel package ~~and~~ or the storage system;

(j) The spent fuel storage system should allow for inspections;

(k) The spent fuel storage system should be designed to avoid or minimiz~~s~~e the generation of secondary waste streams.

~~6.3.~~6.5. Security and access controls are required at spent fuel storage facilities to prevent ~~the~~ unauthorized access ~~of~~ by individuals and the unauthorized removal of radioactive material~~s~~, and such controls should be compatible with the safety measures applied ~~of~~ at the facility.

DESIGN OF SPENT FUEL STORAGE FACILITIES

Design process

6.6. In the design process, appropriate analytical methods, procedures and tools should be used in conjunction with suitably selected input data and assumptions covering all operational states and ~~credible~~ accident conditions that are credible, with account tak~~e~~ing ~~also~~of natural phenomena ~~into account~~. Only verified and validated methods should be used for predicting the safety of operational states ~~and~~ or the consequences of accidents. The input data ~~should be~~ selected ~~so as to~~should be conservative, albeit realistic. ~~Where~~ If possible, the degree of conservatism should be quantified. Where uncertainties in input data, analyses or predictions are unavoidable, appropriate allowances should be made to compensate for such uncertainties. The sensitivity of the assessment results to uncertainties should be evaluated.

6.7. As part of the overall process leading to an acceptable design, ~~its~~ the design evolution and the supporting rationale should be clearly and adequately documented and kept readily available for future reference. The supporting documentation should be presented as a safety case~~.~~ [5].

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6.8. It should be demonstrated in the safety case that in the design~~,~~ all credible hazards and scenarios have been adequately analysed and appropriately addressed. The safety case should describe the performance assessment models and methodologies used and the ~~resulting~~ conclusions reached. Thus, for any design proposed, it should be demonstrated in the safety case that the spent fuel storage facility can, within the bounds of existing technolog~~y~~ies, be safely constructed, commissioned, operated and decommissioned in accordance with the design specifications and the requirements of the regulatory body.

6.9. ~~The p~~Procedures relat~~inged~~ to the control of design modifications ~~during~~ in subsequent stages of the lifetime of the facility should also be defined. Such modifications might be ~~required~~ necessary to take into account the findings of ~~results of~~ the safety case. ~~The i~~Items important to safety, including ~~their~~ structures, systems and components, should be identified and classified according to their relative importance.

6.10. For storage beyond the original design lifetime of the facility, testing, examination and/or an evaluation may be necessary to assess the integrity of the spent fuel ~~–~~or the storage cask. Careful consideration ~~is needed of~~should be given to the approach to be adopted to prevent unnecessary ~~worker~~ occupational exposure and to prevent accidental release of radioactiv~~ity~~e material. Potential problems with the integrity of the spent fuel or ~~the~~ of storage casks should be considered in advance of the need ~~arising~~ for physical actions, such as placing the spent fuel into new casks. In some cases~~,~~ rather than placing the fuel into a new cask, it may be necessary to move the storage casks to another storage facility ~~where~~ for which the building or structures within the building provide the necessary containment and isolation~~, rather than replacing the storage cask~~. ~~In the case of considering~~If an extensio~~n~~ding to the storage period~~s~~ in dry storage casks is under consideration, assessment of the integrity of the casks and the spent fuel ~~integrity~~, including survey of the casks for leak tightness may be sufficient to demonstrate that ~~the spent fuel~~ the storage period may be extended. In such cases it may be possible that the need for an immediate inspection of the content of the casks may be excluded. In considering an extensio~~n~~ding of the storage period beyond the design lifetime, all factors should be taken into consideration, in particular the radiation dose and potential accidents that could occur ~~in~~ on opening the cask and removing the contents or inspecting them in situ. ~~In the event that~~If it is concluded that the storage period cannot be extended without undertaking an inspection of the fuel, all the necessary precautions should be taken in planning and undertaking the work.

6.11. For storage beyond the original design lifetime, consideration should be given to mitigation of the consequences of potential changes in the storage facility and the stored spent fuel. Changes ~~of~~ in the storage facility may be caused by radiation, heat generation, chemical or galvanic reactions. Changes in the stored spent fuel and storage cask may include:

(a) ~~The g~~Generation of gases ~~which~~ that may cause hazards, by chemical and radiolytic effects (e.g. the generation of hydrogen gas by radiolysis) and ~~the~~ build-up of overpressure;

(b) ~~The g~~Generation of combustible or corrosive substances;

(c) ~~The c~~Corrosion of metals; ~~and~~

(d) Degradation of the spent fuel containment system.

~~These~~ Such considerations are especially important for storage beyond the original design lifetime ~~for which~~ as small effects may accumulate over long periods of time.

~~CONSIDERATIONS FOR DESIGN OF SPENT FUEL STORAGE FACILITIES~~

> **Requirement 10 (GSR Part 5, Ref. [4]): Processing of radioactive waste**
>
> **… The processing of radioactive waste shall be based on appropriate consideration of the characteristics of the waste and of the demands imposed by the different steps in its management (pretreatment, treatment, conditioning, transport, storage and disposal). Waste packages shall be designed and produced so that the radioactive material is appropriately contained ~~during~~ both during normal operation and in accident conditions that could occur in the handling, storage, transport and disposal of waste.**

> **Requirement 17 (GSR Part 5, Ref. [4]): Location and design of facilities**
>
> **Predisposal radioactive waste management facilities shall be located and designed so as to ensure safety for the expected operating lifetime under both normal and possible accident conditions, and for their decommissioning.**

> **DEFENCE IN DEPTH (NS-R-5, Ref. [3])**
>
> **2.4. The concept of defence in depth shall be applied at the facility for the prevention and mitigation of accidents (Principle 8 of Ref. [9~~1~~]).**

Siting

6.12. The Safety Requirements publication on Site Evaluation for Nuclear Installations [24] and the associated Safety Guides ~~on the siting of nuclear power plants~~ [25-31] contain criteria and methods that could be used in a graded approach in the siting of spent fuel storage facilities.

Defence in depth

6.13. The concept of defence in depth should be applied to all safety activities, whether organizational, behavioural or design related, to ensure~~ing~~ that if a failure were to occur, it would be detected and compensated for or corrected by appropriate measures [34]. Defence in depth should be

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applied ~~during~~ in the siting of a spent fuel storage facility and in its design, as well when considering subcriticality, heat removal and containment and radiation protection issues. ~~The concept of defence in depth should be applied to all safety activities, organizational, behavioural or design related, ensuring that if an accident were to occur, it would be detected and compensated for or corrected by appropriate measures [34]~~

6.14. Application of the concept of defence in depth in the design of spent fuel storage should entail ~~providing~~ provision of a series of levels of defence (inherent features, equipment and procedures) aimed at preventing accidents and ensuring appropriate protection and mitigation of consequences in the event that prevention fails [34].

6.15. ~~It is recommended that t~~The facility should have a reserve storage capacity~~: this~~, which should be included in the design or ~~is~~ should be otherwise available, e.g. to allow for reshuffling of spent fuel casks or unpackaged spent fuel elements for inspection, retrieval or maintenance work. The reserve capacity should ~~provide for~~be such that the largest type of storage cask ~~to~~ can be unloaded or, in the case of a modular storage facility, ~~for~~ that at least one module ~~to~~ can be unloaded.

Structural integrity

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6.16. In order ~~F~~for ~~the~~ safety systems and safety related items to perform properly, the components of the spent fuel storage facility should maintain their structural integrity ~~under~~ in all operational states and accident conditions. Therefore, the integrity of the components and their related systems should be demonstrated by a structural evaluation. This should take account of relevant loading conditions (stress, temperature, corrosive environment, radiation levels, etc.), and should consider creep, fatigue, thermal stresses, corrosion and changes in material propert~~y~~ies~~y changes~~ with time (e.g. concrete shrinkage).

6.17. To prevent deviations from normal operation, and to prevent system failures, careful attention should be paid to the selection of appropriate design codes and materials, and to ~~the~~ control of fabrication of components and of construction of the spent fuel storage ~~construction~~facility. In order to detect and intercept deviations from normal operational states, specific systems should be provided as determined in the safety case.

6.18. The integrity of the spent fuel and the geometries required to maintain subcriticality and heat removal, and its related containment barriers, should be maintained ~~during~~ throughout the lifetime of the facility and should be verified using appropriate methods including both prospective analysis and ~~through~~ ongoing surveillance

6.19. The allowable stresses for given loading conditions should comply with the applicable codes and standards. If no such standards apply, justification should be provided ~~of~~ for the ~~resulting~~ allowable stress levels selected ~~should be given~~.

6.20. ~~The selection of s~~Structural materials and welding methods should be ~~based~~ selected on the basis of~~upon~~ accepted 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, ~~the~~ potential thermal effects on material degradation should also be considered.

6.21. The materials of items important to safety, including those structures and components in direct contact with the spent fuel, should be compatible with the spent fuel, ~~and~~ should be such as to minimize chemical and galvanic reactions, which might degrade the integrity of the spent fuel during its storage, and should not contaminate the spent fuel with substances ~~which~~ that might significantly degrade the integrity of the spent fuel during its storage.

6.22. Detailed consideration should be given to the effects of the storage environment on the spent fuel and the items important to safety, i.e. structures, systems and components. In particular, the potential for ~~the~~ oxidation of exposed UO_2 to U_3O_8, with ~~the~~ consequent increase in volume ~~increase~~ and particulate formation, should be considered. In addition, any effects of changes in the storage environment~~s~~ (e.g. wet to -dry or dry to -wet [?]) should be assessed.

~~I.1.~~ 6.23. As determined during the design stage, attaining ~~an~~ adequate reliability might require the use of durable construction materials, redundancy of key components, ~~specifying~~ a specific level ~~ation~~ of ~~the~~ reliability of supporting services (e.g. electrical power supply), ~~incorporating~~ effective monitoring plans and efficient maintenance programmes (i.e. programmes compatible with normal facility operations).

6.24. The ~~materials of~~ construction materials should allow for easy decontamination of surfaces. Compatibility of decontamination materials ~~and~~ with the operating environment~~s~~ should be considered for all operational states and accident conditions. The integrity of systems that are connected to spent fuel storage system, such as heat removal system, is also important. Tube failures and leaks in the spent fuel storage system should ~~not~~ be ~~able~~ prevented, as these~~to~~ could provide a path for chemical species detrimental to either fuel or containment integrity, such as chloride ions, to enter a spent fuel storage pond.

Structural and mechanical loads

6.25. A full description of the structural and mechanical aspects of the design of ~~the~~ a storage facility should be provided in sufficient detail to justify the basic design. Typical items in the evaluation include:

(a) Determination of structural and mechanical loads due to the fuel, fuel storage casks and various components of the spent fuel storage facility under operational states and accident conditions;

(b) Evaluation of the ~~F~~foundations ~~evaluation~~;

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(c) A ~~F~~full structural evaluation of the safety systems of the spent fuel storage facility; ~~and~~

(d) Evaluations of supporting features such as cranes, transfer vehicles and protective buildings.

In evaluating the structural integrity of the facility building and the structures inside, justification should be provided for the structural and mechanical loads evaluated for both normal anticipated conditions and for ~~from for off-normal and accident conditions~~postulated accident initiating events, such as storms, wind-driven missiles and~~,~~ earthquakes~~ etc.~~ and the acceptability criteria adopted for the responses to ~~these~~ such loads. Consideration should be given to the storage conditions that may prevail following postulated initiating events, including external events~~, i.e.~~ such as earthquakes, tornadoes and~~,~~ floods, ~~etc.,~~ and the~~ir~~ acceptability of such conditions should be ensured by the design.

6.26. ~~Care~~ It should be ~~taken~~ ensured that~~to~~ consideration is given all situations ~~where~~ in which handling mechanisms ~~might~~ could malfunction, thereby leaving fuel elements or casks inadequately shielded or irrecoverable. Consideration should also be given to the possibility of ~~the~~ casks becoming ~~jamming~~wedged and immovable within the spent fuel storage facility. In addition to the issue of shielding ~~issue~~in such circumstances, consideration should be given to whether ~~the~~ handling equipment and systems can enable recovery from such situations ~~that~~ or could be ~~endangered~~ damaged by the application of excessive stresses.

Thermal loads and processes

6.27. ~~Considering~~ In view of the decay heat ~~of the~~from spent fuel, all thermal loads and processes should be given appropriate consideration in the design. Typical items for consideration include:

(a) Thermally induced stresses;
(b) Internally and externally generated pressures;
(c) Heat transfer requirements;
(d) Evaporation/water make-up requirements;
(e) The ~~E~~effect of temperature on subcriticality.

Time dependent material processes

6.28. The anticipated lifetime of the storage facility will be a determining factor for ~~topics~~ aspects such as corrosion, creep, fatigue, shrinkage, radiation induced changes and associated radiations fields. In the design of the storage facility ~~C~~consideration should be given to~~ of~~ the impact of ~~these~~ such processes.~~ in the design of the storage facility should be provided~~

Subcriticality

6.29. A fundamental safety ~~objective~~ requirement on~~f~~ all designs for spent fuel storage facilities is to ~~ensure~~ maintain subcriticality of the entire system under all credible circumstances [3].

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6.30. The subcriticality of spent fuel may be ensured or influenced by a number of design factors and precautions. The physical layout and arrangement of the spent fuel storage facility should be designed in such a way as to ensure, through geometrically safe configurations, that subcriticality will be maintained ~~during~~ in all operational states and for credible accident conditions.

6.31. Where spent fuel cannot be maintained subcritical ~~through~~ by means of safe geometrical~~ly~~ ~~safe~~ configurations alone, additional means such as fixed neutron absorbers and/or the use of a burnup credit (see Appendix II, paras ~~.~~II.7 – ~~-~~II.10~~1~~) could be ~~used~~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 operational states and accident conditions. Consideration should also be given to ~~T~~the effects of ageing, corrosion and handling on the fixed neutron absorbers~~ should also be taken into consideration~~.

6.32. Subcriticality can be influenced by internal and external hazards ~~which~~ that have the potential to reconfigure the pre-existing spent fuel assembly array in such a way as to increase the potential for criticality. ~~There is also a need to c~~Consideration should also be given to routine fuel movements, which could bring the fuel being moved into close proximity ~~to~~ with stored fuel or ~~where during movement~~in which~~, the~~ fuel ~~if it was~~could be dropped ~~could~~ and fall onto stored fuel. For operational states and accident conditions, the sequences of events leading to such abnormal fuel configurations should be evaluated. The possible consequences of such occurrences should be evaluated using reliable data and verified and validated methodologies. If warranted, appropriate mitigating measures should be ~~provided~~ put in place to ensure that subcriticality will be maintained under all such conditions.

6.33. An adequate margin of subcriticality ~~margin on~~ in the effective neutron multiplication factor k_{eff} ~~which~~ that is acceptable to the regulatory body should be maintained for operational states and credible accident conditions.[8]~~.~~ For a dry spent fuel storage facility, the minimum margin should be ~~ensured~~ maintained even ~~under the situation of~~in the event of water flooding of the locations where the spent fuel is stored~~age locations,~~ unless flooding is precluded by location or design. The potential for re arrangement or compaction of fuel pins should also be considered in demonstrating the required subcriticality margin.

6.34. The most appropriate approach to estimatinge the required multiplication factors will depend on a number of factors including the ~~type of reactor and~~ spent fuel properties as well as the circumstances being addressed e.g. normal operation or accident conditions. In determining subcriticality, a~~A~~ conservative estimate should be made of ~~subcriticality~~the ~~(K_{eff}~~ effective neutron multiplication factor.~~)~~ ~~taking into~~with account taken of the following:

[8] ~~A 5% margin, a~~After inclusion of ~~the~~ uncertainties in the calculations and data, a margin~~and~~ of 5% or less is ~~being~~ applied in many ~~Member~~ States.

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~~(f)~~(a) If the initial enrichment ~~(~~of fissile material~~s)~~ within a fuel assembly and/or between fuel assemblies is variable, appropriate consideration of this variability in the modelling should be used. Alternatively the highest enrichment may be used to provide a conservative~~ly~~ characteri~~s~~zeation of the the fuel assembly.

~~(g)~~(b) Where uncertainties exist in any data relating to the fuel (in terms of design, geometries, nuclear data, etc.), conservative values for the data should be determined and should be used in all subcriticality calculations. If necessary, a sensitivity analysis should be performed to quantify the effects of such uncertainties.

~~(h)~~(c) ~~Those~~ Any geometric deformations ~~to~~ of the fuel and storage equipment ~~which~~ that ~~might~~ could be caused by any postulated initiating events should be taken into account.

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~~(i)~~(d) Optimum moderation and reflection should be assumed for operational states and accident conditions to provide a pessimistic assessment of criticality. It is important to ensure that the system ~~is~~ will remain subcritical for all credible water densities. The highest nuclear reactivity may be reached at some intermediate density, for example, if water in the pool begins to boil due to failure of the heat removal system or during drying of a cask. Flooding should be assumed in dry storage situations, unless precluded by location or design features.

~~(j)~~(e) For certain accident conditions such as boron dilution, limited credit for soluble boron ~~could~~ may be allowed ~~considering~~ in view of the double contingency principle[9]. ~~By virtue of this principle, two unlikely independent and concurrent incidents are beyond the scope of required analysis.~~.

~~(k)~~(f) The inventory of the spent fuel storage facility should be assumed to be at the maximum ~~design~~ capacity of the design.

~~(l)~~(g) Credit should not be claimed for neutron absorbing parts or components of the spent fuel storage facility unless they are ~~fixed~~permanently installed, their neutron absorbing capabilities can be determined~~,~~ and ~~they~~it ~~are~~ has been demonstrated that they will not ~~to~~ be degraded by any postulated initiating events.~~.~~

~~(m)~~(h) Consideration of ~~the~~ reactivity changes of the fuel assembly may be included, although no allowance for the presence of burnable absorbers should be made unless on the basis of a justification acceptable to the regulatory body, which should include consideration of the reduction of neutron absorption capability with burnup. If burnable absorbers are taken into account, the representative fuel should be assumed to correspond to the highest nuclear reactivity.

~~(n)~~(i) All fuel should be assumed to be at a burnup and enrichment value resulting in maximum nuclear reactivity, unless credit for burnup is assumed on the basis of an adequate justification. Such

[9] By virtue of this principle, two unlikely independent and concurrent incidents are beyond the scope of the required analysis.

justification should include an appropriate measurement or evaluation ~~which~~ that directly or indirectly confirms the calculated values for ~~fissile~~ the content of fissile material or depletion level. For application of burnup credit ~~application~~ in long term storage, ~~the~~ possible changes ~~of~~ in the nuclide composition of the spent fuel with storage time ~~has to~~should be taken into account.

~~(o)~~(j) Assumptions of neutronic decoupling ~~of~~ for different storage areas should be substantiated by appropriate calculations.

6.35. The infinite multiplication factor[10] may be used as a conservative estimate~~ion~~ of k_{eff}.

6.36. The ~~estimation~~ determination of subcriticality for other kinds of fuel may require special considerations. The composition of spent fuel may vary over a large range and it may not be easy to ~~define~~ specify appropriate conservative conditions. For example, ~~-~~BWR fuel with burnable poison may have ~~higher~~ increased reactivity by burning of poison.~~:~~ Also, uranium thorium mixed oxide fuel or fuel from research reactors may have very ~~complicated~~ specific properties that need to be considered.

Heat removal

6.37. Spent fuel storage facilities should be designed with heat removal systems that are capable of reliably cooling the stored spent fuel when the~~at~~ fuel is initially ~~loaded into~~received at the facility. The heat removal capability should be such that the temperature of all spent fuel, including that of the spent fuel cladding, does not exceed the maximum allowable temperature. In addition, the temperature of ~~the~~ other safety related components in the facility should also not exceed their maximum allowable temperatures. Active heat removal systems ~~when~~ performing a safety function should be designed to withstand conditions in all operational states and accident conditions and should satisfy the deterministic single failure criterion.

6.38. In the design of heat removal systems for a spent fuel storage facility, appropriate provision should be ~~included~~ made ~~to~~ for maintaining fuel temperatures within acceptable limits during handling and transfer of spent fuel.

6.39. The heat removal system should be designed for adequate removal of the heat likely to be generated by the maximum inventory of spent fuel anticipated during operation. In determining the necessary heat removal capability for the facility, the post-irradiation cooling interval and the burnup of the fuel to be stored should be taken into consideration. Heat removal systems should be designed to include an additional margin of heat removal capability to take account ~~for~~ of any processes foreseen to degrade or impair the system over time. In the design of the heat removal system, consideration should also be given to the maximum heat capacity of the ~~installation~~facility.

[10] The infinite multiplication factor is the ratio of the number of neutrons produced by fission in one generation to the number of neutrons lost through absorption in the preceding generation.

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6.40. In the case of modular facilities such as vaults, the fact that the heat produced from the decay of spent fuel fission products decreases with time can be taken into account in the design. For example, ~~if forced cooling is initially provided,~~ later in ~~the~~ a facility'~~ie~~s lifetime~~,~~ natural cooling may be adequate, even if initially forced cooling was necessary. An analysis should be performed to determine how long forced cooling ~~is~~ will be required, with due consideration given to maintaining ~~its~~ operability of the forced cooling system and the potential effect(s) of its failure.

6.41. The use of ~~R~~redundant and/or diverse heat removal systems ~~might~~ may be appropriate, depending on the type of storage system used and the potential for fuel overheating over an extended period of time.

Containment of radioactive material~~s~~

6.42. In the design of spent fuel storage and handling systems, adequate and appropriate measures should be provided for containing radioactive material~~s~~ so as to prevent an uncontrolled release of radionuclides to the environment. The spent fuel cladding should be protected during storage against degradation ~~during~~ in normal operational states, accident conditions, and, later, retrieval of the spent fuel.~~,~~ ~~c~~Containment should be ensured by at least two independent static barriers. As ~~needed~~necessary and as far as possible, the effectiveness of the spent fuel storage containment system~~s~~ should be ~~provided with~~ monitored~~ing~~ to determine ~~when~~ if corrective action is ~~needed~~necessary to maintain safe storage conditions.

6.43. Ventilation and off-gas systems should be provided where necessary to ensure collection of airborne radioactive particulate material~~s~~ ~~during~~ in operational states and accident conditions. In the design of the air supply system for the facility, consideration should be given to the potential for the presence of corrosive gases such as chlorine~~,~~ or sulphur dioxide ~~etc.,~~ in the ~~outside~~ external environment, which could be detrimental to the integrity of the spent fuel cladding or ~~any~~ another safety related component.

Radiation protection

6.44. The design of a spent fuel storage facility should be such as to provide for radiation protection of ~~the~~ workers, the public and the environment in accordance with the requirements of national legislation, the requirements established in Ref. [10] and the recommendations presented in Ref.~~s~~ [~~10,~~ 31].

6.45. ~~Adherence to the above~~In order to meet these requirements and recommendations ~~during~~ in the design of spent fuel handling systems in a storage facility ~~requires that~~:

(a) Appropriate ventilation, including efficient, appropriately qualified and designed air filtration systems and provision for their periodic check~~s~~ings, should, as necessary, be included in the

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(b) Provision~~s~~ should be made for the monitoring of radioactive effluents;

(c) Measures for ~~S~~spent fuel handling should be designed to avoid ~~the~~ a build-up of contamination to unacceptable levels and to provide for remedial measures should such ~~contamination~~ a build-up occur;

(d) Handling of spent fuel and casks should be carried out in an environment in which important parameters (e.g. temperature, concentration of impurities, intensity of radiation) are controlled;

(e) Areas ~~where~~ in which spent fuel and casks are to be handled or stored ~~are~~ should be provided with suitable radiation monitoring systems for the protection of workers;

(f) The storage facility should not contain any operation room ~~with~~ to which access is solely through the storage area; ~~and~~

(g) Water monitoring and filtration should be provided for wet storage facilities.

6.46. Shielding should be provided to meet the recommendations in Ref. [31]. To meet these recommendations, the following provisions should be included:

(a) In determining ~~T~~the source term for analysis for shielding design ~~analysis,~~ ~~should~~ consideration should be given to the bounding conditions ~~of~~ for enrichment, burnup and cooling times for gamma and neutron radiation, ~~an~~ the inventory at the maximum design capacity of the spent fuel storage facility, the effects of axial burnup ~~effects~~ on gamma and neutron sources and the activation of non~~-~~-fuel hardware;

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(b) Suitable shielding should be provided for normal operation and accident conditions;

(c) 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 from both the penetration and radiation streaming;

(d) In analysis for shielding design, ~~E~~equipment for handling spent fuel should be assumed to contain the maximum amount of spent fuel;

(e) Handling equipment should be designed to prevent inadvertent placing or lifting of spent fuel into insufficiently shielded positions; ~~and~~

(f) Consideration should be given to ~~T~~the radiological impact of deposits of activation products ~~should be considered~~.

Layout

6.47. Design aspects associated with the layout of a spent fuel storage facility are ~~as follows~~set out in the following:

(a) Handling and storage areas for spent fuel should be secured against unauthorized access ~~or~~ and unauthorized removal of fuel;

(b) The area used for storage should not be part of an access route to other operating areas;

(c) ~~The t~~Transport routes for handling spent fuel on the facility site and within the facility should be arranged to be as direct and short as practical so as to avoid the need for complex or unnecessary moving and handling operations;

(d) The need ~~for~~ to mov~~e~~ing heavy objects above stored spent fuel and items important to safety should be minimized by the layout;

(e) The layout should be ~~carried out in~~ such ~~a way as to reflect application of optimization regarding~~ that all spent fuel handling operations, the storage of spent fuel and the required personnel access are optimized;

(f) The layout should be ~~carried out in~~ such ~~a way~~ as to provide for decontamination of ~~deposits of activation products on~~ surfaces of spent fuel elements (removal of deposits of radioactive material) and appropriate maintenance and repair of spent fuel handling equipment and storage casks;

(g) Sufficient ~~S~~space should be provided to permit ~~the~~ inspection of spent fuel and inspection and maintenance of components, including spent fuel handling equipment;

(h) The layout should ~~be designed to~~ facilitate access to any stored fuel without the need to mov~~e~~ing or handl~~e~~ing other stored fuel;

(i) ~~A d~~Division of the storage area into sectors should be ~~privileged in order~~such as to ~~make easier the~~facilitate access to any stored fuel and to avoid application of the ~~concept~~ FILO (first in last out) concept to enable different storage configurations;

(j) Retrieval of spent fuel or spent fuel packages as well as the possible need~~s~~ for spent fuel encapsulation or conditioning should be addressed in the layout of the facility;

(k) Sufficient s~~S~~pace should be provided to allow movement of the spent fuel and storage casks and the transfer of these ~~between~~ from one item of~~different~~ handling equipment to another;

(l) Sufficient s~~S~~pace should be provided for the safe handling of ~~a~~ shipping and/or storage casks. This may be achieved by using a separate cask loading~~/~~ and unloading area or by including a dedicated space within the spent fuel storage facility;

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(m) Sufficient s~~S~~pace should be provided for the storage and use of the tools and equipment necessary for the repair and testing of storage components. Space for the receipt of other radioactive parts of fuel assemblies may also be required;

(n) Appropriate arrangements for containment measures and the safe storage of degraded or failed fuel should be provided;

(o) The ~~facility should be laid out in such a way as to~~layout should provide for an easy exit ~~for~~ by personnel in an emergency;

~~(o)~~(p) Penetrations should be designed in such a way as to prevent the ingress of foreign material (e.g.~~,~~ rain, inorganic solutions, organic materials~~, etc.~~) ~~which~~ that could reduce subcriticality margins, impair heat transfer or increase corrosion and degradation of the storage facilit~~ies~~y in ways that might reduce the effectiveness of the ~~primary~~ main safety functions or prevent inspection or repair; ~~and~~

~~(r)~~(q) The floor area ~~where~~ on which any transport vehicle with a heavy spent fuel cask ~~could~~ may move or be parked should be designed with adequate floor loading margins. Such areas should be clearly marked to avoid the overloading a floor area designed to a lower floor loading.

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Handling

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6.48. Spent fuel handling and transfer equipment and systems ~~might~~ include:

~~(q)~~(a) Fuel handling machines;

~~(r)~~(b) Fuel transfer equipment;

~~(s)~~(c) Fuel lifting devices;

~~(t)~~(d) Fuel assembly dismantling devices;

~~(u)~~(e) Handling devices for all operations associated with transport of casks or inspection of spent fuel or casks; ~~and~~

~~(v)~~(f) Provision for the safe handling of degraded or failed fuel or casks.

6.49. Handling equipment should be designed to minimize the probability and consequence of ~~incidents and~~ accidents and other incidents, and to minimize the potential for damaging spent fuel, spent fuel assemblies, and storage or transport casks. Consideration should be given to ~~T~~the following ~~should be considered~~:

(a) Equipment should not contain sharp edges or corners ~~which~~ that could damage the surfaces of spent fuel assemblies;

(b) Equipment should be provided with positive latching mechanisms to prevent accidental release;

(c) Equipment should be designed to take account of radiation protection aspects and ~~easy~~ to facilitate maintenance;

(d) ~~Moving equipment should have defined s~~Speed limitations should be specified for equipment for moving spent fuel;

(e) Systems should be designed so that spent fuel cannot be dropped ~~as a result~~ in the event of loss of power. Consideration should be given to the consequences of a single failure and, where appropriate, redundant load paths should be provided;

(f) Where it is necessary to ensure that spent fuel assemblies can be readily placed in a safe location, fuel handling equipment should be designed ~~for~~to permit ~~emergency~~ manual operation in an emergency;

(g) Equipment should be designed to ensure that the magnitude and direction of any forces that are applied to spent fuel assemblies are within acceptable limits; ~~and~~

(h) Equipment should be provided with suitable interlocks or physical limitations to prevent dangerous or incompatible operations,~~.~~ ~~Such interlocks or limitations should~~ such as to prevent ~~travel~~ movement in some circumstances (e.g. to avoid incorrect placement of spent fuel or, in the case of wet storage, where the machine is too close to the pool walls), and also to prevent the lifting of spent fuel assemblies or other components over spent fuel, the accidental release of loads or the application of incorrect forces;~~.~~

(i) Controls and tools should be ergonomically designed and user-friendly;~~.~~

(j) The possibility for tools to be mistaken should be avoided by design;~~.~~

(k) ~~The e~~Environmental conditions (noise, brightness) in working areas should provide for optimal conditions of work.

6.50. Where ~~the~~ operating personnel will require information on the non-visible state of the equipment or components in order to ~~ensure~~ verify the safety of a~~n~~ planned operation, as stated in the safety case, ~~the design should be such as to include~~ provision~~s~~ should be made in the design for~~to~~ effectively transmitting such information to the operating personnel, through appropriately located indicator systems or by ~~any other~~ alternative means.

6.51. In the design of spent fuel handling equipment, provision~~s~~ should be ~~included~~ made for the related use of portable manual or power operated tools, provided that the planned use of such tools is consistent with the design objectives and that such use does not compromise the safety of the spent fuel handling operations.

6.52. To minimize the probability of an accidental drop of any load, ~~the~~ equipment for transferring spent fuel to a spent fuel storage facility should be designed to ensure that the equipment is capable of withstanding conditions of normal operation,~~, off-normal~~ anticipated operational occurrences ~~states~~ and accident conditions. Equipment should be design such that, ~~I~~in the event of an accidental drop of a load, ~~the equipment should not damage~~ the containment or the shielding of fuel casks will not be damaged in a~~ny~~ manner that ~~may~~ could result in unacceptable radiation exposure ~~to~~ of workers or the public. In addition, the design should be such that an accidental drop ~~should~~ will ~~not~~ neither prevent fuel retrieval ~~or~~nor cause significant damage to the spent fuel or spent fuel storage facility.

6.53. Assumptions made that are critical to operational safety should be documented at the design stage to facilitate the subsequent development of ~~operational~~ operating procedures. Justification should be provided, through detailed analyses using appropriate techniques, in support of ~~T~~these assumptions and conclusions concerning the operational safety of the spent fuel storage facility ~~should be justified through detailed analyses using appropriate techniques~~.

6.54. In order to ensure safe operation, spent fuel handling and storage systems should include the following:

(a) Measures to limit radioactive releases and ~~radioactive~~ radiation exposure~~s~~ of workers and the public ~~during~~ in operational states and accident conditions in accordance with the ~~philosophy~~ principle of ~~dose~~ optimization of protection ~~required~~ established in~~by~~ Ref. [9] or ~~those~~ limits established by the regulatory body, with particular consideration being given to the use of remote techniques in areas of high radiation to reduce ~~worker~~ occupational exposure~~s~~;

(b) Measures to ~~limit~~ prevent anticipated operational occurrences and design basis accidents from developing into severe accident~~s~~ ~~conditions~~;

(c) Provision for ease of operation and maintenance of essential equipment (in particular, items important to safety); ~~and~~

(d) Provision ~~through equipment and procedures~~ for ready retrieval of spent fuel from storage through equipment and procedures.

6.55. ~~The operating organization should c~~Consideration should be given to categories of dropped loads such as casks or lids, spent fuel and spent fuel storage racks in the design and assessment of lifting and handling equipment.

6.56. A Drop~~ping~~ of spent fuel during transfer from the cask to the storage rack (or vice versa in the case of cask loading for dry storage) ~~might~~ could result in impacts that should be avoided, such as:

(a) Partial defects in the spent fuel cladding, leading to leaks and resulting ~~fission product~~ contamination of the pool by fission products;

(b) ~~Spent fuel d~~Deformation (e.g. bending) or damage of the spent fuel, which ~~may~~ could lead to difficulties in its subsequent ~~spent fuel~~ handling;

(c) An increased potential ~~of~~ for a criticality accident if spent fuel with low burnup were to ~~fall~~ land alongside a storage basket or other spent fuel in the storage racks; ~~and~~

(d) ~~Personnel r~~Radiation exposure of workers due to the release of fission products.

Ventilation systems

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6.57. Ventilation systems should be designed to maintain a safe and comfortable working environment and should be operated in such a way as to limit the potential for release of ~~radionuclides~~radioactive material.

6.58. Ventilation systems should be operated in such a way as to control the accumulation of flammable and/or explosive gases (e.g. ~~H2~~ H_2 formed by radiolysis). Consideration should also be given to ~~T~~the potential for drawing in of hazardous gases from external sources ~~should also be considered~~.

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6.59. Ventilation systems should be designed to satisfy the recommendations ~~of~~ provided in Ref. [33]. Their operation should be compatible with requirements for fire protection ~~requirements~~.

Communications

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6.60. Adequate means of communications ~~means~~ should be provided by design to ~~satisfy~~ meet the requirements for operation~~al~~ ~~and emergency requirements~~ of the spent fuel storage facility and for emergency preparedness and response.

Instrumentation and ~~C~~control ~~and instrumentation~~

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6.61. When~~ever~~ practicable, control and protection functions should be designed to be mutually independent. If this is not feasible, ~~a~~ detailed justification should be provided for the use of shared and interrelated systems~~ should be provided~~. Account should be taken of ~~E~~ergonomic factors ~~should be implemented~~ in the design of alarms and indications to the operating personnel. Control and monitoring equipment should be calibrated for ~~the~~ its intended~~type of~~ use.

Fire protection

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6.62. The operation of the fuel handling and storage areas should be carried out in accordance with the fire protection recommendations ~~of~~ provided in Ref. [33]. Fire protection measures should be ~~operated~~ implemented in such a way as to limit ~~the~~ risks to personnel and the risk of damage ~~due to fires to personnel,~~to items important to safety, spent fuel storage areas, spent fuel handling systems and support~~ing~~ systems.

6.63. Fire protection systems of appropriate capacity and capability should be provided.

6.64. Fire protection ~~precautions~~ measures should include the limitation and control of amounts of combustible materials in fuel handling and storage areas (e.g. combustible packing materials, piping systems carrying combustible materials~~ etc~~). The spent fuel storage area should be operated in such a way as to ensure that the use of fire suppression measures cannot cause ~~inadvertent~~ unintended criticality.

Radioactive waste management

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6.65. The systems of the spent fuel storage facility should be designed and operated so as to:

(a) Avoid or minimize the potential for generating radioactive waste; ~~and~~

(b) Provide safe and adequate means for handling radioactive waste~~.~~ [4].

6.66. The methods employed for ~~P~~processing ~~methods for~~ such waste should be compatible with the requirements of the receiving waste facility.

Lighting

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6.67. Provision should be made for adequate and reliable ~~illumination~~ lighting in support of operation and to facilitate ~~the~~ inspection and/or physical protection of spent fuel storage areas.

6.68. For wet storage in pools, the pool area should be provided with the necessary ~~illumination~~ lighting equipment, including underwater lighting near work areas and provision~~s~~ for replacement of underwater lamps.

6.69. Materials used in underwater lighting should be compatible with the environment in which they are used and, in particular, should not undergo unacceptable corrosion or cause any unacceptable contamination of the pool water.

~~Area m~~Monitoring

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6.70. Area monitoring should include measurements of radiation dose rates and airborne radionuclides. In controlled areas, fixed, continuously operating instruments with local alarms and unambiguous readouts should be installed to ~~give~~ provide information on ~~the~~ radiation dose rates. Any such instruments should have characteristics and ranges ~~adequate~~ that are sufficient to cover ~~the~~ potential radiation levels in the area.

6.71. Instrumentation ~~to~~ for detecting external contamination ~~of~~ on workers should be provided at exits from locations ~~with a significant probability~~where there is a potential for ~~of~~ such contamination. Instruments for area monitoring and personnel monitoring should be demonstrated to be fit for purpose and should comply with appropriate manufacturing standards.

6.72. Provision~~s~~ for the decontamination of personnel, equipment and components should be made available.

Emergency preparedness

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6.73. The potential radiological impacts of accidents should be assessed by the operating organization and reviewed by the regulatory body [21]. Provision~~s~~ should be made to ensure that there is an effective capability to respond to ~~them~~accidents. Considerations should include the development of scenarios of anticipated sequences of events (see Section 5) and the establishment of emergency procedures and emergency plan to deal with each of the scenarios, including checklists and lists of persons and organizations to be alerted.

6.74. Emergency response procedures should be documented, made available to the personnel concerned and kept up to date. Exercises should be held periodically to test the emergency response plan and the degree of preparedness of ~~the~~ personnel. Inspections should be performed regularly to ascertain whether ~~the~~ equipment and other resources ~~needed~~necessary in the event of an emergency are available and in working order.

Support systems

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6.75. In addition to the ~~above~~ design ~~items~~features of a spent fuel storage facility considered above, a number of other support systems may be ~~required~~ necessary to ensure the operation and safety of spent fuel storage facilities, e.g. emergency electrical power. It should be ensured that such support systems ~~should be~~are available.

6.76. Where the safety of spent fuel storage is dependent upon the supply of utilities (e.g. systems for compressed air or water), adequate sources should be reliably available.

COMMISSIONING OF SPENT FUEL STORAGE FACILITIES

Requirement 18 (GSR Part 5, Ref. [4]): Construction and commissioning of the facilities

Predisposal radioactive waste management facilities shall be constructed in accordance with the design as described in the safety case and approved by the regulatory body. Commissioning of the facility shall be carried out to verify that the equipment, structures, systems components, and the facility as a whole, perform as planned.

General

6.77. Commissioning involves a logical progression of tasks intended to demonstrate the correct functioning of features specifically incorporated into the design to provide for safe storage of spent fuel. In addition, in commissioning operating~~onal~~ procedures are ~~confirmed~~ verified and the readiness of staff to operate the spent fuel storage facility is demonstrated. The operating procedures should cover both operational states and accident conditions.

6.78. The basis for commissioning should be established at an early stage ~~of~~ in the design process as an intrinsic part of the project to facilitate its effective implementation. Commissioning plans should be reviewed and, where appropriate, made subject to ~~the~~ approval ~~of~~ by the regulatory body. The responsibilities of the ~~different~~ various groups typically involved in commissioning should be clearly established. Arrangements should be established to cover:

(a) Specification of tests to be carried out (test objectives, safety criteria to be met);
(b) ~~Documentation p~~Provision and approval of documentation;
(c) Responsibilities;
(d) Safety during testing ;
(e) Control of test work;
(f) Recording and review of test results; ~~and~~
(g) ~~Regulatory i~~Interaction with the regulatory body;~~.~~
(h) Management of equipment~~s~~ ~~for~~ providing temporary commissioning aids and ~~their~~ its removal before commencement of ~~facility~~ operation (and after ~~tests~~ completion of tests).

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6.79. ~~Testing a~~Arrangements for testing should include the following:

(a) Regulatory requirements;

(b) Progression through the stages of commissioning;

(c) Reporting of results and approval for operation;

(d) Retention of records.

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6.80. For modular storage systems, most of the commissioning ~~is~~ will have been completed ~~with the~~on loading of the first storage module. However, some of the commissioning processes may become a part of regular operation as new modules are brought into service. . However, a change in module design may require some of the commissioning steps to be repeated for the new design.

6.81. Some commissioning steps may continue into the ~~spent fuel storage facility~~ operation stage of spent fuel storage facility. For example, it may not be justified to test and verify the heat removal capacity of a storage pool ~~may not be tested and verified with justifiable efforts~~ until the facility has received spent fuel. Some large storage facilities use transport casks and spent fuel of various designs. Some commissioning steps may need to be repeated when new casks or new spent fuel designs are first used.

Commissioning stages

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6.82. Commissioning will usually be completed in several stages:

(a) ~~Construction c~~Completion of construction;

(b) Equipment testing;

(c) ~~Performance d~~Demonstration of performance;

(d) Non-~~In~~active commissioning; ~~and~~

(e) Active commissioning.

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6.83. ~~During~~ In the ~~construction completion~~ stage of completion of construction, the spent fuel storage facility should ~~be~~ undergo detailed physical~~ly~~ inspection~~ed in detail~~ to confirm compliance with the detailed design. Factors such as physical dimensions and ~~initial~~ levels of ~~radiation~~ background ~~conditions~~ radiation should be ~~established~~determined. A systematic check against ~~the~~ design drawings and project documentation should be carried out to establish the as-built status of the facility. (In addition to providing information to facilitate operation of the ~~plant~~facility, this check can also be important when considering possible future modifications and ultimate decommissioning of the ~~installation~~facility.)

6.84. ~~During~~ In the equipment testing stage, the ~~spent fuel storage facility~~ equipment and systems of the spent fuel storage facility should be energized and the various controls, directions of rotation ~~direction~~, directions of flow ~~directions~~, currents, interlocks, etc., tested. Activities such as load testing of casks and spent fuel assembly lifting equipment should also be carried out and the safe control of equipment should be demonstrated during these tests. If necessary it should also be demonstrated that the physical interaction between items of equipment is limited~~items should also be demonstrated~~.

6.85. ~~During~~ In the performance ~~testing~~ demonstration stage, after ~~the~~ individual items of equipment ~~items~~ have been tested, a range of tests should be performed to demonstrate the safe interaction of all equipment and the overall operational capability and capacity of the spent fuel storage facility. At this stage, the safety and effectiveness of all instructions and procedures should be demonstrated. This should include demonstration of satisfactory training of operating personnel for both normal operation and anticipated operational occurrences. The ability of personnel to conduct maintenance work safely and effectively should also be demonstrated.

6.86. The non-~~in~~active commissioning stage should provide a formal demonstration that the ~~plant~~facility personnel, equipment and procedures function in the manner intended, especially those identified~~,~~, in the safety case, as important to the safety of ~~plant~~facility operation~~, usually derived from the safety case~~. All safety features that can be tested without the presence of spent fuel ~~present~~ should be checked before the spent fuel storage facility is put into operation.

6.87. Once ~~the~~ non-~~in~~active commissioning has been satisfactorily accomplished, the active commissioning stage ~~begins~~ is commenced with the introduction of radioactive material into the spent fuel storage facility. ~~It is highly recommend that a~~All tests and any resulting amendments should be completed before ~~introducing~~ the introduction of radioactive material. The~~is~~ introduction of radioactive material effectively marks the start of the operation of the facility and, hence, from this stage, the relevant safety requirements for ~~plant~~facility operation ~~should~~ apply [3, 4]. Active commissioning should involve a range of tests to demonstrate that the design criteria for ~~radiological~~ radiation protection have been met.

6.88. Upon completion of commissioning, a final commissioning report should be prepared. This should detail all testing carried out and should provide evidence of its successful completion. The ~~is aim of this~~ report should demonstrate to the regulatory body that its requirements have been ~~satisfied~~ met and may provide the basis for the subsequent licensing of the spent fuel storage facility for full operation. Additionally, any changes to the ~~plant~~facility or to procedures implemented during commissioning should be documented in an appropriate way in the final commissioning report.

OPERATION OF SPENT FUEL STORAGE FACILITIES

Requirement 9 (GSR Part 5, Ref. [4]): Characterization and classification of radioactive waste
At various steps in the predisposal management of radioactive waste, the radioactive waste shall be characterized and classified in accordance with requirements established or approved by the regulatory body.

Requirement 19 (GSR Part 5, Ref. [4]): Facility operation
Predisposal radioactive waste management facilities shall be operated in accordance with national regulations and with the conditions imposed by the regulatory body. Operations shall be based on documented procedures. Due consideration shall be given to the maintenance of the facility to ensure its safe performance. Emergency preparedness and response plans, if developed by the operator, are subject to the approval of the regulatory body.

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General

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6.89. ~~All spent fuel storage facility operations~~ Spent fuel storage facilities should be ~~performed~~ operated in accordance with written procedures prepared by the operating organization. These documents and their updates should be prepared in co-operation with the organizations responsible for the design of the spent fuel storage facility. However, the operating organization is responsible for ensuring that the procedures are prepared, reviewed, approved and issued appropriately. These procedures should, as a minimum, be such as to ensure compliance with the operational limits and conditions for the spent fuel storage facility and, more generally, with the safety assessment.

6.90. Instructions and procedures should be ~~developed~~ prepared for normal operations of the spent fuel storage facility, anticipated operational occurrences and design basis accident conditions. Instructions and procedures should be prepared so that the designated responsible person can readily perform each action ~~can be readily performed~~ in the proper sequence ~~by the designated responsible person~~. Responsibilities for approval of any ~~required~~ deviations from operating procedures that may be necessary for operational reasons should be clearly ~~defined~~specified.

6.91. Adequate arrangements should be made for the review and approval of operating procedures, ~~a~~ the systematic evaluation of operating experience, ~~also~~ including that of other facilities, and the taking of corrective actions in a timely and appropriate manner to prevent and counteract developments adverse to safety. Provision~~s~~ should be made for ~~implementing a~~ controll~~ing~~ed the distribution of ~~operational~~ operating procedures, in order to guarantee that operating personnel have access to only the ~~last~~ latest approved edition.

6.92. The maintenance and modification of any item of equipment, process or document of the spent fuel storage facility should be subject to ~~specific~~ specified procedures. These procedures ~~will require~~should be subject to authorization before they are implemented. The procedures should ~~involve~~ describe the categorization of the modification in accordance with its safety significance. Depending upon the safety categorization, each modification will be subject to varying ~~degrees~~ levels of review and ~~endorsement~~ approval by management of the facility and the regulatory body. ~~.~~

6.93. ~~All~~ The maintenance ~~and~~ or modification of any item of equipment should be appropriately recorded and documented ~~including~~ along with its~~their~~ commissioning test results. The documents should be revised immediately after completion of the maintenance or modification.

Operational aspects

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6.94. The operating organization should ensure that operating procedures relating to the maintaining of subcriticality are subjected to rigorous review and compared with the safety requirements of the design~~,~~. This may include confirmatory analysis and review by the regulatory body. Some of the factors ~~to~~ that should be considered in this review include:

(a) The types of ~~S~~spent fuel ~~types~~to be stored;

(b) ~~Subcritical s~~Spent fuel geometries necessary to ensure subcriticality;

(c) Spent fuel container types (if used);

(d) ~~Spent fuel H~~handling operations for the spent fuel;

(e) The ~~P~~potential for abnormal operation;

(f) Spent fuel parameters (e.g. initial enrichment, final enrichment, burnup); ~~and~~

(g) Dependence of subcriticality on neutron absorbers.

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6.95. Cladding failure can result in the release of isotopes such as ^{85}Kr, ^{134}Cs and ^{137}Cs, which are characteristic fission products detected following cladding failures in spent fuel that has been cooled for long periods. Cladding failure~~s~~ may be more probable when the spent fuel and spent fuel cladding is subjected to high temperatures, and when chemical conditions in the medium surrounding the spent fuel promote cladding corrosion. The operating organization should ensure that adequate monitoring of environmental conditions within the facility (e.g. composition of the pool water ~~composition~~ and/or atmosphere in the storage area ~~atmosphere~~ and moisture or water on spent fuel cladding) is undertaken to prevent and provide notice of such undesirable conditions. Procedures should be provided for detecting and dealing with degraded and failed fuel.

6.96. Additionally, the operating organization should ensure that procedures exist for the receipt, handling and storage of spent fuel with failed cladding or that such fuel is not accepted at the spent fuel storage facility. In cases where ~~it~~ such fuel is accepted, in addition to containment considerations there may be implications for criticality, ~~implications~~ which should be fully assessed and, where appropriate, the receipt, handling and storage of such fuel should be made subject to specific procedures.

6.97. ~~Operational~~ Operating procedures should be developed for containment systems in the spent fuel storage facility ~~containment systems~~ (e.g. closure seals on storage casks and canisters, and ventilation and filtration systems) to provide for their monitoring ~~capability~~. ~~This~~ Such monitoring should be such that the operating organization will be able to determine when corrective actions ~~is~~ are ~~needed~~necessary to maintain safe storage conditions.

6.98. There are other safety considerations that ~~which~~ should be taken into account in the development of operating procedures and contingency and emergency arrangements. It should be noted that many ~~of these~~~~such~~ events ~~are~~ would be addressed either as anticipated operational occurrences or as design basis accidents. However, some of these events could also lead to severe accidents, which are beyond the design basis. Whilst the probability of such beyond design basis accidents occurring is extremely low, in the preparation of operating procedures and contingency plans the operating organization should consider events such as the~~se during the preparation of operating procedures and contingency plans. Some examples of these events are~~ following:

(a) Crane failure with a water filled and loaded cask, suspended outside the pool;

(b) Loss of safety related ~~plant~~facility process systems such as supplies of electricity~~al supplies~~, process water, compressed air and ventilation;

(c) Explosions due to the build-up of radiolytic gases;

(d) Fires leading to damage of items important to safety (to reduce the risk of fire~~; the accumulation~~amounts of combustible material or waste should be controlled, as should be the amount of other flammable materials (see para. 6.64));

(e) Extreme weather conditions, which could alter operating characteristics or impair pool or cask heat removal systems;

(f) Other natural events such as earthquake or tornado;

(g) External human-induced events (airplane crash, sabotage, etc.);

(h) Failure of the physical protection system.

Consideration should also be given to ~~T~~the possible misuse of chemicals (e.g. ~~accidental~~ unintended introduction into the pool water of acidic or alkaline fluids used for regeneration of ion exchange resin ~~regeneration~~) ~~should also be taken into consideration~~.

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6.99. In addition to providing ~~instructions~~ operating procedures and contingency procedures as described above, the operating organization should also ~~produce~~ develop an emergency plan in accordance with the requirements established in Ref. [20].

6.100. Operating experience and events at the facility and reported by similar facilities should be collected, screened and analysed in a systematic way. Conclusions should be drawn and implemented ~~in~~ by means of an appropriate feedback procedure. Any new standards, regulations or regulatory guidance should also be reviewed to check for their applicability for safety at the facility.

6.101. ~~During the operation of a spent fuel storage facility t~~The integrity of stored spent fuel should be monitored in the operation of a spent fuel storage facility.~~.~~ When spent fuel is stored in sealed casks, the means for ~~safeguards monitoring~~carrying out accounting and control of nuclear material or for verifying the related sealing operations will be available. Such means should not impair the integrity of the spent fuel.

6.102. Operational limits and conditions for a spent fuel storage facility should be ~~based~~ developed on the basis of the following:

(a) Design specifications and operatin~~g~~onal parameters~~,~~ and the results of commissioning tests~~ results~~;

(b) The sensitivity of ~~the~~ items important to safety and the consequences of ~~the~~ events following the failure of items, the occurrence of specific events or variations in ~~operational~~ operating parameters;

(c) The ~~A~~accuracy and calibration of instrumentation equipment ~~that~~ for measuring~~e~~ safety related operating parameters;

(d) Consideration of the technical specifications for each item important to safety and the need to ensure that ~~these~~ such items continue to function in the event of any specified fault occurring or recurring;

(e) ~~A~~ The ~~requirement that~~need for items important to safety ~~will~~ to be available to ensure safety in operational states including maintenance;

(f) ~~A definition~~Specification of the equipment ~~which~~ that should be available to enable a full and proper response to ~~foreseeable fault conditions~~postulated initiating events or design basis accidents; ~~and~~

(g) The minimum staffing levels ~~which~~ that need to~~must~~ be available to operate the spent fuel storage facility safely.

~~(g)~~

Table 1 ~~shows~~ provides examples of technical operational limits and conditions ~~which~~ that may be ~~required~~ applicable for a spent fuel storage facility.

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TABLE 1: EXAMPLES OF OPERATIONAL LIMITS AND CONDITIONS FOR SPENT FUEL STORAGE

Subjects	Operational limits and conditions
Subcriticality	Maximum allowable fresh fuel enrichment or Pu content Minimum allowable concentration of neutron poisons in fixed absorbers, if requiredapplicable Restricted movement and restrictions on storage configurations of spent fuel Restricted use of moderator Specified minimum spent fuel burnup, if applicable Spent fuel assembly characteristics
Radiation	Maximum allowable burnup of spent fuel burnup Minimum allowable water level in storage pool Specific rRequirements for radiation monitors, alarms and interlocks Minimum cooling periods after the discharge of the spent fuel from the reactor Maximum radionuclide concentrations in pool water Maximum radiation dose rates on cask surfaces and a specified distance (e.g. 1-2 meteres) from the cask Minimum tightness of spent fuel cask
Heat removal	Specified availability of cooling systems with defined specified maximum and minimum system temperatures Minimum spent fuel cooling period after discharge of the spent fuel from the reactor and maximum burnup of the spent fuel burnup Maximum temperature of concrete and of the cask surface temperature Minimum tightness of spent fuel cask
Water cComposition	Specification of water composition to that will prevent corrosion of spent fuel and storage components, to ensure adequate water clarity and to prevent microbial growth

7.98.6.103. Operational limits and conditions form an important part of the basis on which operation is authorized and as such should be incorporated into the technical and administrative arrangements which that are binding on the operating organization and operating personnel. Operational limits and conditions for spent fuel storage facilities, which result from the need to satisfy meet legal and regulatory requirements, should be set developed by the operating organization and agreed withsubject to approval by the regulatory body as part of the licence conditions. The operating organization may wish to set an administrative margin below the operational limits as an operational target level below these specified limits to assist in avoiding any breach of to remain within the approved limits and conditions.

7.99.6.104. The While all operations can be directly or indirectly related directly or indirectly to some aspect of safety, the aim of operational limits and conditions should be to manage and control the basic safety hazards associated with in the facility; operational limits and conditions and they should be directed towards:

(f)(a) Preventing situations which that might lead to the unplanned exposure of people (workers and the public) to radiation; and

(g)(b) Mitigating the consequences of any such events should they occur.

7.100.6.105. Personnel directly responsible for operation of the spent fuel storage facility operation should be thoroughly familiar with the facility''s operating procedures and the, operational limits and conditions to ensure compliance with their provisions. Systems and procedures should be developed in accordance with the approved management system so thatand the operating personnel should be able to demonstrate compliance with the operational limits and conditions.

7.101.6.106. Operational limits and conditions should be kept under review and may also have to be changed revised as necessary in accordanceing to with the national regulatory framework for the following reasons:

(a) In the light of operating experience;

(b) Following modifications made of to the spent fuel storage facility and the type of spent fuel;

(c) As part of the process of periodically reviewing the safety case (including as part of periodic safety review) for the spent fuel storage facility; and

(d) In the case thatIf there are changes in legal or regulatory conditions change.

As a result of Operationaloperating experience, technological progress or changes, may recommend correspondingent changes on to operational conditions may be necessary. Such changes must should be justified through safety assessment and should be subject to approvaled by the regulatory body.

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Maintenance, inspection and testing

~~7.102.~~6.107. A management system (see also Section 4) covering operation and maintenance, and using approved procedures, should be established for controlling ~~ensure~~:

(a) Maintenance and inspection of the lifting attachments on the casks and of the lifting apparatus (e.g. slings, beams, chains and hooks);

(b) Maintenance of ~~spent fuel storage facility~~ cranes and spent fuel grabs at the facility;

(c) Periodic load testing of cranes and other attachments;~~.~~

(d) Maintenance, inspection and testing of other safety related equipment.

~~7.103.~~6.108. ~~The o~~Operation of a spent fuel storage facility should include an appropriate programme of maintenance, inspection and testing of items important to safety, i.e. structures, systems and components. Safe access should be provided to all structures, systems, areas and components requiring periodic maintenance, inspection and testing ~~should be provided~~. Such access should be ~~sufficient~~ adequate for the safe operation of all ~~required~~ necessary tools and equipment and for the installation of spares.

~~7.104.~~6.109. Before the operation of any spent fuel storage facility is commence~~s~~d, the operating organization should prepare ~~the~~ a programme for maintenance, inspection and testing ~~programme~~. In t~~T~~he programme ~~should have specific~~ starting dates for all inspections should be specified, and ~~will need to~~ should be re-evaluated in the light of results from commissioning tests. The safety case for the spent fuel storage facility will form a basis for preparation~~ing~~ of the programme in terms of the items, i.e. structures, systems and components, ~~which~~ that should be included and the periodicity of planned activities for each ~~of these~~ item~~s~~.

~~7.105.~~6.110. Provision should be made ~~available~~ for maintenance of hot cell components, if a hot cell exists. This maintenance work can be done either in the cell or externally whatever the preferred option may be.

~~7.106.~~6.111. The programme of periodic maintenance, inspection and testing -should be subjected to periodic review, with account tak~~ing account~~en of ~~operational~~ operating experience. All ~~these~~ such activities should be covered in an integrated manner ~~consistently~~ by the management system, ~~taking into~~ with account taken of manufacturer~~s~~s' recommendations.

~~7.107.~~6.112. The standard and frequency of ~~these~~ activities for periodic maintenance, inspection and tests should ~~ensure~~ be such that the level of reliability and effectiveness is ensured and remains in

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~~7.108.~~6.113. ~~It is e~~Equally, ~~important that~~ the reliability and effectiveness of any component ~~is~~ should not be significantly affected by the frequency of testing, which may result in premature wear and failure or induced maintenance errors, or ~~can~~ which could cause ~~an excessive~~ unavailability to an unacceptable degree if the component is inoperative during maintenance and testing.

~~7.109.~~6.114. If maintenance, inspection or testing of the spent fuel storage facility can ~~only~~ be carried out only while certain equipment is in a shut-down state, the maintenance schedule should be ~~defined~~ drawn up accordingly.

~~7.110.~~6.115. The maintenance, inspection and testing programme should take into account the structures, systems and components ~~which~~ that are affected by the operational limits and conditions, as well as any regulatory requirements. Examples of structures, systems and components ~~which~~ that may be included in a maintenance, inspection and testing programme are ~~listed~~ provided in Table 2.

TABLE 2: EXAMPLES OF EQUIPMENT FOR MAINTENANCE, INSPECTION AND TESTING

Item of equipment	**Nature and subject of test**
Lifting equipment: cranes, lugs, eyebolts, chains, cables, transporters and yokes	Brake systems, interlocks, mechanical integrity, load testing, overload protection signalling
Storage structure or module	Structural integrity, accumulations of vegetation, snow~~fall~~ or other effects ~~which~~ that may impair the heat removal capability Leak detection and monitoring Detection of corrosion of storage structures and tools
Loop components for cleaning, heat removal and monitoring of cavity of transport cask ~~cavity~~	Flexible pipes for overpressure reliability Calibration, for example, of - temperature and pressure gauges - specified radiation monitoring equipment required for casks (e.g. for measurement of selected radionuclides, such as ^{85}Kr, ^{134}Cs and ^{137}Cs) - flow rate measurement
Special valve equipment to be fitted on cask	Mechanical maintenance, performance and testing of seals and valves

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Grabs to handle fuel	Mechanical verification of ability of tool to fasten onto fuel, and check for functionality of locking mechanism ~~functionality~~ Verification of mechanical integrity of tool
~~Radiological~~ Radiation monitoring equipment	Calibration and function tests of fixed or portable equipment
Storage racks	Confirmation of presence and condition of neutron absorbers (if appropriate) Inspection of mechanical wear of casks, baskets and racks, if appropriate
Video cameras	Confirmation of functionality of cameras
Security	Confirmation of functionality of perimeter fences and/or gates ~~functionality~~

~~7.111.~~6.116. Suitably qualified and experienced operating personnel should be ~~involved~~ deployed in the approval and implementation of the maintenance, inspection and testing programme and in the approval of associated working procedures and acceptance criteria ~~for these activities~~.

Operational radiation protection

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~~7.112.~~6.117. An operational radiation protection programme should be put in place that ensures that areas of the facility are classified according to the radiation levels present and that access control is in place ~~according to~~in accordance with the level of classification. It should ~~ensure~~ cover the monitoring of radiation levels ~~are monitored~~ in the facility and should include provisions to ensure that personnel working in the facility are issued with appropriate dosimetry. A programme of work planning should also be put in place to ensure that radiation ~~doses~~ exposure ~~are maintained~~is kept as low as reasonably achievable.

Characterization and acceptance of spent fuel

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Requirement 12 (GSR Part 5, Ref. [4]): Radioactive waste acceptance criteria

Waste packages and unpackaged waste that are accepted for processing, storage and/or disposal shall conform to criteria that are consistent with the safety case.

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~~7.113.~~6.118. Acceptance criteria should be developed for the spent fuel storage facility and the spent fuel, ~~taking into~~with account taken of all relevant operational limits and conditions and ~~the~~ future demands for reprocessing or disposal ~~requirements~~, including retrieval of the spent fuel. Before spent fuel is transferred to ~~the~~ a storage facility, acceptance must be given by the operating~~or~~ organization of

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the facility and the respective legal authorityregulatory body. Contingency plans should be developed and made available on to cover how to deal safely with spent fuel that does not comply with acceptance criteria.

7.114.6.119. The operating organization of a spent fuel storage facility should receive be given detailed information concerning the characteristics of the spent fuel received for storage. This information should be supplied by the nuclear facility (i.e. power plant or research reactor) that generateding the spent fuel (i.e. nuclear power plant or research reactor). The minimum information to that should be provided is the following:

(a) Fuel dDesign of the fuel, including scale drawings;

(b) Construction mMaterials of construction of fuel, the radionuclide inventory including the initial masses of the fissile content, the burnup and the cooling time of the fuel;

(c) Fuel identification numbers (e.g. serial numbers on fuel assemblies);

(d) Fuel history (e.g. burnup, reactor power rating during irradiation, decay heat and dates of loading and discharge from the reactor);

(e) Details of conditions present that wcould affect fuel handling or storage (e.g. damage to fuel cladding or structural damage);

(f) Confirmation that the fuel can be correctly handled upon receipt at the spent fuel storage facility; and

(g) Specific instructions for storage (e.g. for degraded or failed fuel).

(h) Ssurface contamination level and dose rate for the fuel assemblies.

Fuel can be considered as damaged if it displays, inter alia, one or more of the following characteristics: pinholes, cracks, mechanical deviations, missing fuel assembly components, bowing, fretting, or serious physical damage, etc. The fullFull and detailed criteria should be established to cover these issuesdetermine whether fuel is to be considered damaged.

7.115.6.120. Upon receipt, spent fuel casks should be checked for to determine gamma and neutron radiation levels, leakage, and surface contamination and to ensure that they are consistent with the accompanying documentation. Characterization of the spent fuel, for example including by means of process control and process monitoring, should be applied within as part of a formalthe management system for the facility.

7.116.6.121. In addition, information concerning the fuel transport cask must should also be transmitted by the consignor shipper originator of the spent fuel to the operating organization of the spent fuel storage facility. This information should include the following:

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(a) Type of cask and appropriate information on its design, and the arrangement of fuel and internal components inside the cask cavity;

~~(a)~~(b) Radiological survey data of the cask before shipment;

~~(b)~~(c) Cask identification (e.g. serial number) and certification of compliance with current transport regulations [15];

~~(c)~~(d) Requirements and procedures for ~~C~~cask handling and sealing ~~requirements and procedures~~; ~~and~~

~~(d)~~(e) Results of the most recent inspection of the cask.

~~7.117.~~6.122. ~~During~~ In cask handling, consideration should be given to carrying out the following operations ~~should be considered~~ in order to ensure safety:

a) Before a cask is loaded with spent fuel: decontamination, as required;

b) In loading and unloading of a cask, both under wet and dry conditions: sampling of the internal gas before the closure lid is removed and ~~examining~~ examination of the spent fuel, as appropriate; and

c) After a cask has been emptied: decontamination, as required, and routine cask maintenance and recertification operations.

~~7.118.~~6.123. For facilities receiving spent fuel from a number of sources, the operating organization of the spent fuel storage facility should ensure that each consignor ~~source~~ ~~originator~~ provides data on the characteristics of the spent fuel ~~parameters~~ in a clearly understandable form ~~which~~ that allows the operating organization to demonstrate that subcritical conditions will ~~exist~~ be maintained ~~during~~ in the handling and storage of the spent fuel. The operating organization should also ensure that the data provided ~~is~~ are supported by an approved management system and have been verified, as appropriate.

~~7.119.~~6.124. Loss of containment has the potential for both exposing workers to radiation and releasing ~~radionuclides~~ radioactive material into the environment. Mechanisms by which loss of containment might occur should be understood by the operating organization and its personnel and should be addressed, as appropriate, in operating procedures.

Fuel integrity

~~7.120.~~6.125. The integrity of spent fuel may become degraded and lead to a release ~~or~~ of radioactive material into the storage environment. There are a number of causes for the degradation of fuel, including:

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(a) Manufacturing defects, such as defects due to incomplete welds or leaking end plugs;

(b) Embrittlement of the cladding material due to interaction with hydrogen or by to exposure to high irradiation;

(c) General corrosion of the cladding as a result of an improper chemical composition of the cooling water;

(d) Mechanical damage, e.g. as a consequence of stress corrosion or handling accidents;.

(e) Unrevealed failures which that arose during reactor irradiation in the reactor.

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6.130.Loss of integrity of spent fuel cladding may lead to the release of radioactive material into the storage environment. Such fuel can be referred to as degraded or failed fuel.

6.130. Usually, spent fuel with decreased integrity should be canned to maintain the quality of the storage environment and/or to satisfy licensing requirements. Sealable casks or containers of approved design should be made readily available for canning of leaking or damaged fuel assemblies should be readily available.

6.131. Spent fuel assemblies that have become damaged as a result of mechanical events, should be kept separate from intact fuel and provided with appropriate monitoring should be provided to detect any failure of the outer containment failure. Consideration should be given to contingency arrangements on how to deal with spent fuel that is not retrievable by normal means or that cannot be transported easily.

6.132. For storage of spent fuel that has been characterizsed as defective degraded or failed, (see Section: "Characterization and Acceptance of Spent Fuel" and "Fuel Integrity") the storage approach should consideration should be given in the design to the condition of the fuel in the design. This may include additional engineered methods for the safe handling of damaged fuel during loading and unloading evolutions, e.g., instrument tube tie rods for assemblies where stress corrosion cracking of the top nozzles stress corrosion cracking is of concern, the canning of damaged fuel assemblies to maintain spent fuel configuration and ensure criticality control, and additional measures to ensure the robustness of containment since for degraded fuel the primary containment feature, i.e., the spent fuel cladding, cannot be relied upon for control of the spent fuel material. A specific task for storage facility operation in such cases is the monitoring of the Sstored degraded spent fuel should be monitored and [phrase as a recommendation?]. To manage that to carry out monitoring appropriately, it is necessarythe following should be ensured:

a) ~~to~~ Appropriate design of the storage in order to ~~make easier~~facilitate ~~the~~ monitoring ~~task~~ ;

b) ~~to~~ M~~m~~onitoring of the efficiency of the containment ~~efficiency~~ as close as possible to each containment barrier ~~-~~;

c) ~~to control p~~Periodic~~ally~~ checking of the state of the stored spent fuel (e.g. by sampling, by destructive testing, by placing corrosion test pieces ~~set up into~~in the storage location, by use of reference objects ~~use…~~).

Record of documents

6.133. Operational data of a spent fuel storage facility should be collected and maintained in accordance with the ~~requirements~~ recommendations relating to~~of~~ the management system ~~addressed~~ provided in ~~s~~Section 4.

6.134. Records ~~should be kept~~ of maintenance, inspection and testing should be retained, in order to provide a basis on which to review and justify the programme of maintenance, inspection and testing, and should be made subject to periodic examination to establish whether ~~the~~ structures, systems and components ~~give~~ have the required reliability. ~~and to provide a basis on which to review and justify the programme of maintenance, inspection and testing.~~

6.135. Since the storage time could span more than one human generation, transfer of information ~~to subsequent~~from one generation~~s~~ to the next is important. Therefore, accurate records of all relevant information should be maintained. This should include updated information on the spent fuel storage facility itself, ~~of~~ on the stored spent fuel, and also supporting data such as monitoring results and records of unplanned events.

6.136. These records should be duplicated and stored in separate locations. It should be ensured that the information is stored on media that remain accessible during and after the envisaged ~~storage lifetime~~storage period.

Retrieval of spent fuel

6.137. ~~A~~ The storage facility should be operated in such a way as to allow retrieval of spent fuel or spent fuel packages at the end of the anticipated ~~storage lifetime~~storage period and at the end of the lifetime of the storage facility.

6.138. If spent fuel or a spent fuel package cannot be retrieved from storage with normal operating procedures, special operating procedures should be developed to ensure safe retrieval of spent fuel or the spent fuel package.

6.139. A spent fuel storage facility should be considered to be an operating facility until all the spent fuel and/or spent fuel packages ~~has~~ have been removed.

Transport after storage

6.140. After storage, and before subsequent transport, the integrity of the spent fuel and the storage~~/~~ and/or transport casks and associated paperwork ~~has to~~should be examined~~ before transport~~. The following issues should be ~~checked~~addressed:

(a) Ownership and responsibility for the safe retention of records;
(b) The ~~I~~inspection and surveillance regime applied;
(c) Control of the storage environment;
(d) Conventional safety issues, such as periodic inspection of ~~the~~ handling equipments;
(e) Nuclear safety issues, such as any degradation of the spent fuel itself, of the spent fuel support structure and the neutron shielding materials.

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6.141. The safety functions of the storage and/or transport casks should be assessed periodically to demonstrate compliance with current safety standards and the approval requirements and conditions of the transport licence [15]. Possible degradation of casks should be assessed and consideration should be given to the following:

~~(h)~~(a) Spent fuel and~~,~~ fuel support structure;
~~(i)~~(b) The ~~C~~containment system: metal seals and restraining systems~~,~~ such as lid bolts;
~~(j)~~(c) Packaging components: corrosion effects, radiation effects, etc.;
~~(k)~~(d) Impact limiters: compatibility of the attachment and performance;
~~(l)~~(e) Shielding materials: changes ~~of~~ in density and composition, etc.
~~(m)~~(f) Design features incorporated to ensure sub~~-~~criticality.

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Storage beyond the original design lifetime

6.142. If storage of spent fuel is envisaged beyond the original design lifetime of the facility, the nuclear reactivity of the fuel should be re-assessed and taken into account in the decision making, as necessary. In this case an appropriately wide safety margin or additional safety provisions may be applied.

6.143. It is essential that the operating organization has developed expertise to manage difficulties that may arise from the effects of storage beyond the original design lifetime.

6.144. ~~The p~~Paragraph 3.~~36~~ 29 of Fundamental Safety Principles [9] ~~require~~ states that “Radioactive waste must be managed in such a way as to avoid imposing an undue burden on future generations”. What constitutes an ‘undue burden’ ~~to a large extent~~ will depend~~s~~ to a large extent on national circumstances. Aspects to be taken into account, ~~certainly~~ particularly if ~~long-term~~long term storage of spent fuel is anticipated to span many generations, are the following:

(a) Adequate financial resources to ensure safe management of the spent fuel over this ~~storage lifetime~~storage period;

(b) Maintaining of regulatory control;

(c) Transfer and maintenance of knowledge and technical capability; ~~and~~

(d) Continuation of ~~E~~education of specialists in spent fuel management, even ~~after~~ if electricity generation by nuclear power ~~has~~ cease~~s~~d to ~~exist~~ be part of the national energy strategy.

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6.145. Safe operation of a spent fuel storage facility should be ensured for its entire life~~-~~time. This is generally longer than the average ~~life expectation~~lifetime of a commercial company; consequently, in the event that the operating organization ceases to exist, for example after several decades, transfer of ownership of the spent fuel and the spent fuel storage facility to a government institute may be considered.

6.146. For storage of spent fuel a safety assessment should be carried out and safety case developed prior to licensing of the facility. For ~~long-term~~long term storage a re-assessment of the safety case may become necessary, for example in the event of ~~e.g. due to possible~~ degradation of the facility or any of its components or structures ~~[unclear; do you mean “to evaluate possible degradation of the containment”?]~~ important for ~~of~~ the containment of the fuel. The regulatory body should take such failure scenarios into account when determining the duration of the operating licence for the spent fuel storage facility.

6.147. A monitoring programme should be established in order to be able to detect any deficiencies at an early stage. This monitoring programme should specify the parameters to be monitored, the frequency of monitoring, reference levels for actions as well as the specific actions to be taken.

6.148. Prolonged irradiation of cladding material, gaskets~~,~~ or other materials relevant to ensuring the containment of the spent fuel~~,~~ may result in degradation of ~~the~~ safety functions. An ~~aging~~ageing management programme should be set up to deal with ageing related degradation. The programme should specify the monitoring ~~requirements aimed at~~ necessary for early detection of any deficiency.

6.149. A mechanism for incorporating changes based on new findings from research and development, especially findings relating~~with respect~~ to ageing and degradation of materials due to storage beyond the original design lifetime, should be established.

6.150. The longer the envisaged ~~storage lifetime~~storage period, the greater ~~are~~ the uncertainties in the assumptions ~~on~~ made about~~the~~ safety parameters. In order to provide the operational or regulatory decisions with a scientific basis, research and development projects should be undertaken ~~which~~ that are aimed ~~to~~ at reducing these uncertainties, if they are of specific importance.~~ or sensitivity.~~ ~~As~~ For examples~~s~~, accelerated irradiation experiments on materials used in the spent fuel storage or long-time sealing tests with intentionally aggressive media could ~~give~~ provide useful information on their sensitivity ~~for~~to ~~aging~~ageing effects.

DECOMMISSIONING OF SPENT FUEL STORAGE FACILITIES

Requirement 20 (GSR Part 5, Ref. [4]): Shutdown and decommissioning of facilities

The operator shall develop, in the design stage, an initial plan for the shutdown and decommissioning of the predisposal radioactive waste management facility~~ies~~ and shall periodically update it throughout the operational period. The decommissioning of the facility shall be carried out on the basis of the final decommissioning plan, as approved by the regulatory body. In addition, assurance shall be provided that sufficient funds will be available to carry out shutdown and decommissioning.

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6.151. Decommissioning of nuclear facilities comprises:

~~(c)~~(a) ~~p~~Preparation~~s~~ and approval of the decommissioning plan;
~~(d)~~(b) T~~t~~he actual conduct of decommissioning~~ operations~~; ~~and~~
~~(e)~~(c) T~~t~~he management of waste resulting from decommissioning activities;~~.~~
~~(f)~~(d) Release of the site for unrestricted or restricted use.

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6.152. An initial version of the decommissioning plan should be prepared during the design of the spent fuel storage facility in accordance with requirements and recommendations ~~safety standards~~ ~~in~~ on decommissioning [18, 19].

6.153. During the operation of the spent fuel storage facility, the initial decommissioning plan should be periodically reviewed and updated and should be made more comprehensive with respect to:

(a) Technological developments in decommissioning;

(b) Possible ~~man-made~~human-induced accidents and other incidents and natural events~~incidents and accidents~~;

(c) Modifications to systems and structures affecting the decommissioning plan;

(d) Amendments to regulations and changes in government policy; ~~and~~

(e) Cost estimates and financial provisions.

6.154. A comprehensive decommissioning strategy should be developed for sites having also other ~~nuclear~~ facilities ~~than a spent fuel storage~~ to ensure that interdependencies are taken into account in the planning for individual facilities [18].

6.155. A final decommissioning plan ~~should~~ is required to be submitted for approval within two years of shutdown of ~~a~~ the spent fuel storage facility, unless an alternative schedule for the submission of the final decommissioning plan has been agreed with the regulatory body [18].

6.156. Even when the bulk of the residual process material has been removed, a significant amount of contaminated ~~radioactive contamination~~ material may remain. The expeditious removal of this material should be considered as it would reduce the ~~requirements~~ need for monitoring and surveillance. Other activities associated with decommissioning may be conducted concurrently with the removal of this material, but the potential for adverse interaction~~s~~ between concurrent activities should be identified and assessed.

6.157. Dismantling and decontamination techniques ~~should~~ are required to be chosen such ~~which~~ that ~~minimize~~ generation of waste ~~arising~~ and airborne contamination~~s~~ is minimized and ~~to ensure~~ protection of both workers and members of the public ~~during decommissioning~~ is optimized [18].

6.158. Before a site is released, for example for unrestricted use, it should be monitored and, if necessary cleaned [35]. A final survey should be performed to demonstrate that the end point ~~conditions~~criteria, as established by the regulatory body, have been met.

APPENDIX I
SPECIFIC SAFETY CONSIDERATIONS FOR WET OR DRY STORAGE OF SPENT FUEL

~~I.2.~~I.1. In addition to the general safety considerations for the design and operation of spent fuel storage facilities ~~described~~ set out in Section 6, there are specific safety considerations for the design and operation of wet and dry storage facilities. These include unique characteristics, specific to wet or dry storage facilities, that maintain design parameters within acceptable limits ~~specific to wet or dry storage facilities~~ and which satisfy regulatory requirements.

~~SPECIFIC DESIGN CONSIDERATIONS FOR~~ DESIGN OF WET STORAGE FACILITIES

Subcriticality

I.2. For facilities ~~where~~ for which the safety assessment takes into consideration and makes allowance for the boiling of pool water during abnormal operating conditions, specific allowances should be provided in the design evaluations for the change in water moderator density ~~during~~ in such conditions. For water storage pools sub~~-~~criticality should be demonstrated ~~under~~ for all credible water densities, including events for which boiling of pool water cannot be excluded in the ~~from the~~ safety assessment.

I.3. ~~The c~~Criticality safety of pool storage should not rely on the use of soluble neutron poison.~~-~~ If this is not possible or if the ~~operator~~operating organization chooses to use a soluble neutron poison such as borated water for criticality control, the design of the facility should include engineering features to preclude an increase in the reactivity of stored fuel caused by ~~the~~ inadvertent dilution of the pool water by the addition of non borated water, in circumstances where soluble boron is used for criticality control.

Heat removal

I.4. Active heat removal systems for wet spent fuel storage facilities should be designed to ensure the safe operation of the facility. The primary objective of ~~the~~ heat removal systems should be to ensure that no temperature limit, as set to protect ~~the~~ structures, systems, components and the ~~inventory~~ fuel from damage, ~~should~~ will be exceeded ~~during~~ in operational states and accident conditions.

Containment of r~~R~~adioactive m~~M~~aterial~~s~~

I.5. Wet pool storage facilities should be designed to include features that prevent or limit the release of radioactive material~~s~~ to the environment. ~~These~~ Such features could include mechanisms to maintain sub-atmospheric pressures inside the storage building, to provide for filtration of potential venting pathways and~~,~~ to prevent ingress and egress of pool water, and can be used to minimize the number, size~~,~~ and location of building penetrations.

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Radiation protection

I.6. Where pool water is used to provide~~s~~ radiation shielding for the protection of ~~the~~ workers and the public, the water level should be maintained so as to provide the required degree of shielding. For that reason, the design of a wet spent fuel storage facility should include provisions for an adequate and appropriately accessible supply of water, from redundant and diverse sources and~~,~~ of a quality acceptable for use in the facility.

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I.7. Water storage pools should be not be designed with ~~to exclude~~ penetrations below the minimum water level required for adequate shielding and cooling of stored spent fuel.

I.8. The design should not allow ~~exclude~~ the permanent installation of piping or other equipment ~~which~~ that could inadvertently, e.g. by acting as a siphon, lower the pool water ~~elevation~~ level below the minimum required level.

I.9. The design of wet storage facilities should include provisions for the effective control of radioactive material~~s~~ released into the pool water and for the capability to purify the pool water. The controlled removal of dissolved and suspended radioactive material~~s~~ might be necessary to limit radiation fields at the surface of the pool. ~~The ability of p~~Permanent or temporary equipment should be provided to periodically, or as necessary, clean and remove radioactive deposits and sludges from pool liner surfaces ~~should be provided~~.

I.10. The system for providing ~~pool water~~ make-up ~~system~~ water to the pool should be designed to provide water at a rate exceeding the maximum rate of water removal possible as a consequence of losses during operation, including removal of water via the pool water removal system. Conversely, the pool water removal system~~s~~ should have a capacit~~ies~~y less than ~~those~~ that of the pool water make-up system~~s~~. Furthermore, mixing spent fuels in the same zone with different limits or control mode for criticality should be avoided.

I.11. Where water pools are to be connected by sluice ways, the design of the sluice pathways should afford containment of water and detection, collection~~,~~ and removal of leakage~~s~~. Sluice gates should be designed to withstand anticipated water pressures, ~~to~~ includ~~e~~ing those resulting from accident conditions~~,~~ and the effects of earthquakes.

I.12. Indications and alarms should be ~~designed~~ provided to alert ~~plant~~facility personal of any unintended decrease in water level and when the minimum water level is reached. [para repeated several times below]

Structure and ~~L~~layout

I.13. The storage pool and other components important to the retention of ~~the~~ cooling water should be designed to withstand conditions in operational states and accident conditions, including impacts from collisions or dropped loads, without significant leakage of water. Further, the storage pool ~~storage~~ should be designed to provide for the detectionng of leakages and the implementationing of appropriate repairs or remedial actions, as ~~required~~necessary. The ~~facility should provide the~~ means for sampling groundwater at the facility should be provided, e.g. boreholes ~~wells~~ located around the facility.

I.14. When credit ~~burnup credit~~ is given for burnup in the criticality safety analysis, the possibility of fuel assemblies being misplaced should be minimized by means of appropriate interlocks and administrative processes. For these cases the fuel handling equipment ~~must~~ should be appropriately designed.

I.15. If stacking is proposed ~~in~~ for a wet storage facility, the mechanical stability of the spent fuel and any fuel rack or basket should be designed to withstand, without unacceptable structural deformation, the mass of a full stack. Static, impact and seismic loads should also be considered in the design of spent fuel and fuel racks or baskets.

I.16. The facility should be designed in such a way as to ~~provide protection against~~prevent overfilling of the storage pool.

Materials

I.17. The materials of the following facility systems should be compatible with the pool water, and each other, or should be effectively protected against undue degradation:

(a) The spent fuel containment system, structures~~,~~ and components;

(b) ~~s~~Storage racks or casks;

(c) C~~c~~ooling water systems, structures~~,~~ and components;

(d) P~~p~~ool water make-up systems, structures~~,~~ and components; ~~and~~

(e) H~~h~~andling systems.

Due consideration should also be given to the potential for leaching of chemicals ~~leaching~~ into the pool water~~s~~ from materials present and the possible implications of the presence of such materials in the pool.

It should be ensured that ~~T~~the storage racks or casks ~~should~~ will not contaminate the pool water. The ~~E~~easey of decontamination of equipment exposed to~~,~~ or in contact with pool water is related to the surface of the materials used. The designer should provide for easy decontamination when specifying the materials for such equipment.

I.18. The chemical composition of the pool water should be consistent with the protection of the spent fuel cladding, pool structure, and handling equipment. The clarity of pool water ~~clarity required~~ necessary for pool operation should be maintained.

Handling

I.19. The design of handling systems and equipment should preclude the need for lubricants or other fluids or substances ~~which~~ that could degrade the quality or otherwise affect the purity of the pool water. ~~Should~~ If lubricants are~~be~~ necessary, design measures should be provided to prevent the leakage and escape of lubricants into the pool water. Substances ~~may~~ should be used ~~which~~ that are fully compatible with the spent fuel, the equipment and the storage structures (~~i.e.~~e.g. [?] water may be used).

I.20. Hollow handling tools intended for use under water should be designed so that they fill with water upon submergence (to maintain the water shielding effect) and drain upon removal.~~.~~

I.21. Fuel should be handled by equipment that minimizes the potential for a drop accident. Over-raising of spent fuel or other components should be prevented by design features and/or by incorporationi~~ng~~ of dedicated interlocks to inhibit hoist motion in the event that high radiation fields are detected. This should include use of single-~~-~~failure-proof cranes and positive locking mechanisms on ~~fuel assembly~~ the grapples and hooks of the fuel assembly. Operator failures should be avoided by applying the '~~"~~four eyes principle'~~"~~ or by use of check lists.

~~SPECIFIC~~ OPERATION~~AL~~ ~~CONSIDERATIONS~~ FOR WET STORAGE FACILITIES

I.22. There are several pool management features ~~which~~ that contribute to the safe operation of wet storage facilities. These include operations that maintain design parameters and minimize corrosion of pool structures, systems and components, and promote radiation protection, such as shown in Table II-1 of Annex II~~3~~. The integrity of the spent fuel, ~~and~~ the geometry ~~its required~~ necessary to maintain subcriticality and for heat removal ~~geometries~~ and its related containment barriers~~,~~ should be maintained ~~during~~ throughout the lifetime of the facility and should be verified using appropriate methods.

Subcriticality

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I.23. Where soluble boron is used for criticality control, operational controls should be implemented to maintain water conditions in accordance with specified values of temperature, ~~Ph~~pH, redox, activity, and other applicable chemical and physical characteristics so as to prevent boron dilution.

Radiation protection

I.24. Operational controls should include proper maintenance of underwater lighting and water clarity, which are important ~~from a~~for radiation protection ~~perspective to minimize~~of workers~~ dose when~~ performing duties in and around the pool. The ability to perform activities that rely upon visual examination and/or inspection ~~or sight~~ without need for repetition and ~~with~~ in minimal time will result in ~~less~~reductions in ~~worker~~ exposure of workers.

Heat removal

I.25. ~~It may be possible to d~~Damage to the pool structure may occur if ~~by cooling the~~ pool water is cooled to a very low ~~or freezing~~ temperature or freezes. Damage may also result from high rates of temperature change exceeding the design limits. Such issues relating~~ed~~ to heat removal should be considered ~~when defining~~in the specification of operational limits and in the development of administrative procedures.

I.26. ~~Operational~~ Operating procedures should be such that the pool heat removal systems are monitored to ensure that operating conditions remain within the design specifications, and to ensure maximum availability and avoid situations where the system is completely unavailable. Impairment~~s~~ or ~~degradation~~ damage to pool cooling systems ~~need a~~ should be responded~~se~~ to in a timely manner to return the system to ~~the designed~~intended operating conditions. ~~Also~~Furthermore, ~~operational~~ operating procedures should be such that ~~minimize~~ the time when the pool cooling system is unavailable due to routine maintenance and/or repair is minimized.

I.27. Heat transfer considerations may increase in importance if spent fuel is stored in high density storage.

Containment

I.28. Operational controls should be implemented to avoid a decrease in the pool water level. A decrease in the pool water level could ~~which may~~ result inter alia in~~[11]~~:

(a) Increased radiation fields and dose rates to operating personnel;

(b) Impaired fuel cooling if the reduction in water level interrupts or reduces water flow to the heat exchangers of the pool cooling system; ~~and~~

~~[11] List may not be comprehensive.~~

(c) Increased water temperature and, consequently, increased release of radioactive material~~s~~ into the water ~~because~~ owing to~~of~~ corrosion of~~ded~~ spent fuel and spent fuel cladding.

I.29. For ~~sub-underground [?]~~ wet storage facilities below ground level, operational controls should be implemented to avoid, minimize~~,~~ and manage the potential for in-leakage of water which may result in:

(a) Dilution of boron in a moderated pool environment and the potential for a criticality accident~~s~~, where soluble boron is used for criticality control;

(b) Corrosion and other degradation effects of materials important to safety.

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I.30. The operating organization should undertake suitable routine monitoring of the parameters necessary to enable remedial action to be taken on a timely basis. Alarms should be put in place to alert ~~plant~~facility personal of any unintended decrease in water level and when the minimum water level is reached. Samples of groundwater from boreholes located around the facility should be periodically collected and activity levels monitored for ~~the presence of radioactivity~~.

Shielding

I.31. Operational controls should be implemented that avoid and minimize the potential for a loss of shielding during facility activities. Loss of shielding can result in high radiation exposure.~~-~~ Operational controls should ~~consider~~ address and place limits ~~on~~to preclude:

(a) The ~~H~~hoisting of spent fuel higher than design limits during handling operations in the storage pool;

(b) Inadequate depth of pool water; ~~and~~

(c) Improper use of pool tools (e.g. ~~hollow~~ empty rather than flooded).

Drop of Loads

I.32. Operational controls ~~in areas of prime concern~~ should be implemented to ~~specifically~~ ensure that ~~abnormal conditions~~events, such as a cask drop, do not result in undue challenges to the storage facility safety systems. ~~These a~~Areas of prime concern in this regard include[3] inter alia:

(a) The zones between the ~~cask~~ entrance airlock to the cask handling area and the cask preparation area and the unloading ~~pool~~ area at the pool;~~.~~

(b) The unloading pool area;

A d~~D~~rop of a spent fuel element or assembly may result inter alia in~~[12]~~:

(a) Damage of spent fuel and ~~the~~ resulting contamination of the pool;

(b) Damage of the pool structure and ~~eventual~~ possible leakage of water;

(c) A criticality event if several spent fuel assemblies are displaced from the rack, and if there is deformation of the spent fuel array or unacceptably close proximity ~~to~~ of spent fuel assemblies or arrays in adjacent racks;

~~(a)~~(d) Release of gaseous fission products.

A further potential hazard resulting from such a drop is~~could be~~ ~~damage of the spent fuel in the cask,~~ loss of water from the pool either by direct expulsion or by gross leakage arising from structural damage.

I.33. Operational controls and engineered safety features should be implemented to preclude the drop of a spent fuel element or an assembly of fuel elements onto a pool storage rack during transfer.

~~SPECIFIC~~ DESIGN ~~CONSIDERATIONS FOR~~ OF DRY STORAGE FACILITIES

Subcriticality

I.34. Fuel baskets and containers for spent fuel storage should be designed in such a way as to ensure that the spent fuel will remain in a configuration which has been determined to be subcritical during loading, transfer, storage, and retrieval.

I.35. Dry spent fuel storage facilities should be designed either to exclude the introduction of a moderator or in such a way that consequences likely to result from the redistribution or the introduction of a moderator as a consequence of an internal or external event can be accommodated

Heat removal

I.36. The storage facility should be constructed in a location, with due consideration of climate changes and associated potential increase in ambient temperatures and/or the level of naturally occurring bodies of water adjacent to the facility, and maintained in a manner which permits adequate heat dissipation. Design features should include provisions to maintain cooling during adverse weather conditions including high winds that might affect the performance of natural circulation design elements of a dry storage cask and the forced circulation and ventilation systems of a storage facility.

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~~I.38.~~I.36. To the maximum extent practicable~~-extent~~, cooling systems for dry spent fuel storage should be passive and should require minimal maintenance. Maximizationing of the passive design features for heat removal will minimize the need for monitoring and operational considerations. Passive systems rely on natural convection, conduction and radiant heat transfer. ~~Should~~ If forced circulation of coolants ~~be~~ is used, it should be demonstrated to be sufficiently reliable during normal operation and ~~off-normal~~accident conditions with no adverse effects on systems, structures and components that are important to safety.

~~I.39.~~I.37. Where the integrity of spent fuel relies on a cask's internal gas medium, the design of the associated spent fuel storage cask should ensure the medium is maintained for the ~~design life~~design lifetime or ~~provide~~ should make provisions for monitoring and maintaining of both the presence and quality of the ~~cooling~~ medium for a time period as long as demonstrated to be necessary by the safety case.

Containment of Radioactive Materials

~~I.40.~~I.38. The storage facility and dry storage casks should be designed to facilitate monitoring of the spent fuel containment and detection of containment failures. If continuous monitoring is not provided, periodic verification by observation or measurement should be carried out to ensure that the containment systems are performing satisfactorily. For dry storage casks this should include monitoring of seal integrity for bolted closure designs.

~~I.41.~~I.39. The storage facility should be designed in such a way as to incorporate containment barriers to prevent the release of radionuclides. This ~~might~~ could include liners or canisters as an integral part of the dry storage system.

Radiation protection

~~I.42.~~I.40. Spent fuel loading and unloading operations should be carried out ~~by~~ using equipment and methods that limit sky shine and reflections of radiation to workers and the public.~~.~~

~~I.43.~~I.41. The dry storage facility should be monitored in order to detect increases in gamma and neutron fields that may indicate a degradation of containment or shielding.

~~I.44.~~I.42. Dry storage areas with a significant potential for generating or accumulating unacceptable concentrations of airborne radionuclides should be either ~~be~~ maintained ~~under~~ at below sub-atmospheric pressures to prevent the spread of airborne radionuclides to other areas of the spent fuel storage facility, or ventilated and filtered in order to maintain concentrations of airborne radionuclides at acceptable levels. For ~~O~~open dry storage facilities that do not use an overstructure or

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building ~~should,~~ at a minimum, ~~provide for~~ radiation monitoring should be provided at the site boundary to ~~indicate~~ detect any abnormal levels of airborne radionuclides.

Structure and l~~L~~ayout

~~I.45.~~I.43. Storage casks equipped with liners should be designed to prevent the accumulation of water between the liner and the body of the cask. Storage vaults and silos should be provided with features to facilitate drainage or ~~a~~ it should be demonstrat~~ion~~ed that the potential for water accumulation is not of concern, i.e.~~,~~ decay heat generated by the stored fuel is sufficient to evaporate and drive off any accumulated water.

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~~1.~~I.46. If stacking is proposed for a dry fuel storage facility, the mechanical stability of the spent fuel and any cask or basket should be designed to withstand, without unacceptable structural deformation, the mass of a full stack. Static, impact and seismic loads should be considered in the design of spent fuel and casks or baskets.

~~1.~~I.47. Ease of access should be considered in the design to facilitate the transfer of spent fuel to or from storage positions ~~during~~ in normal operation~~s~~ or during recovery operations after anticipated operational occurrences or accident conditions. Sufficient clearances should be provided from all directions and on all sides to provide the ~~required~~ necessary access.

~~2.~~I.48. Casks should be designed in such a way as to provide stability and prevent them from tipping over.

~~3.~~I.49. The dry storage system area should be planned and the storage system itself effectively sealed~~,~~ such that unacceptable leakage of radionuclides and ~~/~~ or inert gases is prevented and ingress of water (moderator) and ~~/~~ or air is prevented.

~~4.~~I.50. The foundation~~s~~ of the dry storage area should be capable of withstanding the ~~load~~ weight of the loaded spent fuel casks and the handling equipment without excessive settling and degr~~ae~~adation.

~~5.~~I.51. The design of an open dry spent fuel storage facility should be ~~carried out in~~ such ~~a way~~ as to provide for appropriate collection, monitoring and processing of surface runoff water.

~~6.~~I.52. Inclusion of a hot ~~-~~cell in the design of a dry spent fuel storage facility should be considered to allow for unloading the cask and subsequent re-packaging of the fuel or repairs.

7.I.53. If a hot cell or other capabilities for unloading or repairs are not available, the casks should be designed for maintenance or repair. Alternatively, they may be designed and maintained in order to enable for transport to a location where such facilities are available.

Materials

8.I.54. The storage system, particularly the storage cask, should be constructed of suitable materials, using appropriate design codes and standards and construction methods, to maintain shielding and containment functions under the storage and loading and/ unloading conditions expected during throughout its design lifetime, unless adequate maintenance and/or replacement methods during operation can be demonstrated. These loading and unloading conditions include exposure to the atmosphere, internal and external humidity, fission products, temperature variations, the internal build-up of gas, and high radiation fields.

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9.I.55. Industry codes and standards used should be acceptable to the regulatory body. If codes and standards are not yet accepted by the regulatory body, sufficient justification for their use should be provided.

10.I.56. The dry storage system, including any closures, especially cask closures, should be constructed of materials which that provide chemical and radiological stability, and appropriate resistance to mechanical and thermal impacts.

11.I.57. The fuel storage container atmosphere should be adequately dried in order to attain and maintain the gaseous environment required to protect the integrity of the spent fuel. Drying of the fuel storage container atmosphere also ensures that any water entrained inside damaged fuel rods is adequately evacuated. This reduces the potential for additional fuel damage or /degradation during the drying activity, where higher fuel temperatures may be experienced, and in the subsequent storage term. Maintaining of the required internal environment in the storage container is also key to ensuring continued functionality of the containment, particularly the seal(s). For this reasons, and to ensure retrieve ability of the fuel, it is critical that the condition of the spent fuel should– be correctly characterisszed and analysed and/or inspected if necessary prior to its loading into a storage container.

Handling

12.I.58. The design of casks intended to be portable should include provisions for lifting and handling which that minimizes the potential for a drop accident. This should include the use of single-failure-proof cranes and positive locking mechanisms on lifting yokes.. Lifting and handling

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13.I.59. For those dry spent fuel storage facilities incorporating canisters that requirefor which shielding is necessary, consideration should be given to the need for on-site handling and for off-site transportation.

14.I.60. For multipurpose (storage, transport and maybe disposal) casks intended for storage, transport and potential disposal after storage, the means for appropriate handling at the end of the storage lifetimestorage period should be considered in the design.

SPECIFIC OPERATIONAL CONSIDERATIONS FOR OF DRY STORAGE FACILITIES

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15.I.61. To limit corrosion, radiolysis phenomena and criticality issues, spent fuel should be dried to the greatest extent possible prior to being put in a dry storage.

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16.I.62. There are several elements in the management of a dry spent fuel storage facility which that contribute to the its safe operation. Some of the key elements are listed in Table II-24 of Annex II. Since dry storage facilities are by design principally passive, there are fewer specific operational considerations than for wet storage facilities.

Subcriticality

17.I.63. In most cases, it can be shown by deterministic arguments that dry storage facilities remain subcritical. The effect of possible water ingress to areas where fuel may be present, possibly for example as a result of climate change and an associated potential increase in the levels of naturally occurring bodies of water adjacent to the facility, should be analysed. This can be done either deterministically or using a probabilistic analysis based upon considerationationing of external environmental events or human-induced accidents combined with an induced breach in the containment barriers. Additionally, if spent fuel is either loaded or unloaded from a dry storage cask in a pool environment, then subcriticality should be evaluated with assuming credible optimum moderation.

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Heat removal

18.I.64. Heat is removedal from the spent fuel casks and/or the spent fuel storage facility is affected by conduction, radiation, and natural or, in some cases, forced convection. Operational controls should consist of verificationying that there are no impairments to the flow of the cooling medium. The cask internal cooling medium for casks is typically is an inert gas, whereas the external cooling medium for dry storage is typically air. If heat removal requires forced circulation is necessary for heat removal, additional operational controls and maintenance will be required on air moving systems.

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Maximiz~~ing~~ation of the passive design features for heat removal will minimize the need for operational considerations.

~~19.~~I.65. Operating temperatures should be monitored to ensure the dissipation of spent fuel decay heat to the environment to maintain the integrity of materials important to safety.

~~20.~~I.66. For casks relying upon a gas medium for internal convective cooling~~,~~ the quality and/or density of the gas should be monitored and maintained if maintenance of the gas medium is not ensured by the design.

Containment

~~21.~~I.67. For ~~dry storage cask~~ double seal systems for dry storage casks, monitoring should be implemented ~~and should~~to detect ~~the~~ any loss of effectiveness of any of the seals ~~in order~~and thereby ~~to~~ prevent ~~potential~~ releases of radioactive material~~s~~ to the environment. For single seal systems and ventilation systems, releases of radioactive material~~s~~ (e.g. ^{85}Kr, ^{134}Cs and ^{137}Cs) should be monitored.

~~22.~~I.68. For dry cask storage systems with welded closure lids monitoring may not be necessary.

Shielding

~~23.~~I.69. Operational controls should be implemented to avoid ~~the~~ a loss of shielding ~~during~~ in spent fuel storage. ~~The~~ A loss of shielding can lead to high radiation exposure. Specifically, operational controls should address the potential for, inter alia, the following~~[13]~~:

(a) Handling errors when closing or sealing dry storage casks or~~/~~ containers;

(b) Improper operation or failure of protective interlocks on shielding cells; ~~and~~

(c) Melting of neutron shielding material due to high temperatures.

Drop of Loads

~~24.~~I.70. Operational controls should be implemented ~~to~~ that avoid a drop of spent fuel during transfer from the cask to the storage rack (or vice versa in the case of cask loading for dry storage). A drop of spent fuel ~~can~~ could result inter alia in[5]:

(a) Partial defects in the spent fuel cladding, leading to leaks, and, in case of cask loading in a storage pool, result~~-~~ing ~~fission product~~ contamination of the storage pool water by fission products;

(b) ~~Spent fuel D~~deformation (e.g. bending) or damage of the spent fuel, which ~~may~~ could lead to difficulties in its subsequent ~~spent fuel~~ handling;

~~[13] List may not be comprehensive~~

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(c) An increased probability or potential for the occurrence of a criticality accident if new spent fuel or low burnup spent fuel with low burn up were to beis inadvertently dropped in the vicinity of other spent fuel in the pool storage racks; and

(d) Personnel rRadiation exposure of workers due to the release of volatile radionuclides.

I.71 Processes should be established to evaluate the effect of any dropped fuel on the integrity of the cladding of the dropped fuel and on any other structure or component impacted by the drop. The results of the evaluation should be used to inform the future management of the dropped fuel.

APPENDIX II
CONDITIONS FOR SPECIFIC TYPES OF FUEL AND ADDITIONAL CONSIDERATIONS

GENERAL

II.1. There are numerous types of ~~F~~fuel element ~~types~~ that have to be considered for storage ~~are numerous~~. The~~yse~~ differ by the type of fuel, the enrichment in ^{235}U for fresh uranium fuel, the cladding material and geometry. After irradiation in a reactor, there will be large ~~variations~~differences ~~occur~~ in heat generation, gamma and neutron dose rates and in criticality safety requirements. In selecting a storage mode, due consideration should be given to the specific properties of the respective fuel.

MOX FUEL

II.2. Fuel made from a mixture of uranium and recycled plutonium oxide (MOX fuel) is increasingly being utilized in light water reactors. Although the fuel rods and fuel assemblies are essentially identical in structure and in form to analogous uranium oxide fuels, they differ from the latter in the radionuclide inventory and by substantially higher decay heat generation and higher neutron radiation rates. These properties can significantly reduce the number of spent MOX fuel assemblies that can be loaded into a dry storage cask, when cooling times are short. To facilitate the most efficient storage of MOX fuel and reduce the number of dry storage casks necessary, the operating organization of a spent fuel storage facility should optimize the cooling time, to allow sufficient reduction in decay heat generation rate, before the spent MOX fuel is loaded into a dry storage system.

II.3. ~~Safety~~ Protection against criticality constitutes an important design requirement. ~~For~~ In the analysis of nuclear reactivity, ~~analysis~~ special consideration has to be given ~~-~~to the nuclide vector of plutonium as well as in the ~~definition~~ specification of an enveloping plutonium and uranium ratio.

II.4. Spent MOX fuel may be loaded amongst uranium fuel assemblies. In ~~that~~ such cases, the MOX assemblies should be ~~positioned~~ placed only at specific positions to allow for the effective dissipation of heat and to provide for adequate radiation shielding.

II.5. Compared to uranium fuel, the increased heat generation, the high alpha activity and the higher build up of gaseous fission products of spent MOX fuel will impose additional stress on the cladding material. Therefore, for each type of cladding, the cladding integrity should be demonstrated before storage takes place, ~~regardless~~ irrespective of whether the ~~storage approach;~~ wet or dry storage is used.

FUEL WITH HIGH BURNUP

II.6. Most safety measures necessary for the storage of MOX fuel are also applicable to the storage of high burnup fuel (a high ~~typical~~ burnup ~~above~~ may be defined as a level higher than 55 GWd/t uranium for light water reactors (LWRs)).

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BURNUP CREDIT

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II.7. The use of bBurnup credit is a methodology that takesin the safety assessment means that credit is given for the reduction in spent fuel nuclear reactivity as a result of fission. It is a move away fromdiffers from the more conservative ‘fresh fuel’ assumption and, consequently, is may be considered a choice to adopt a more realistic approach. ThisA choice decision to take credit for burnup requires should be fully justifiedeation with accurate experimental data, approved calculation methods and validated and verified benchmarked computer codes in accordanceing to with international standards. This applies to both inventory determination calculations and criticality calculations. A licence application for the storage of spent fuel with the inclusion of burnup credit should be supported by an adequate safety assessment that demonstrates achieving that the required safety level will be achieved.

II.8. Approval to consider burnup credit in the safety assessment should only be granted only if based on design engineered safety features and operational controls. Operational controls provide defence in depth and increase confidence incontribute to maintaining subcritical conditions. The minimum required burnup value should be verified by independent measurements. .

II.9. Approval to consider burnup credit in the safety assessment should be granted in an incremental manner. Priority should be given to consideration of Ssimple cases should be prioritized before considering more complex cases, such as spent fuel with mixed enrichments. This would allow for the accumulation of the necessary experience with fuel that can easily be characterized, such as standard pressurized water reactor (PWR) fuel.

FUEL FROM RESEARCH REACTORS

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II.10. The basic safety aspects for storage of spent fuel from power reactors are applicable for storage of spent fuel from research reactors. A proper gradeding approach, which takesing the differences between the fuel types into account, has to should be applied. Issues relatinged specifically to the storage of research reactor fuel, e.g. lower heat generation, higher enrichment and the use of [?] cladding materials that are less corrosion -resistant cladding materials, need should be given particular attentionconsideration.

II.11. Fuel composition, cladding material and, shapes and sizes of fuel assemblies vary differ significantly in research reactors. In a research reactor, different fuel elements can be loaded to the research reactor and thus a variety of spent fuel is generated. This may comprise, for example, fuel assemblies with different cladding material (e.g. Al, stainless steel, Zr) or with different fuel composition. In certain research reactors, reconstitution of an irradiated fuel assembly (for example, by replacement of pins) is carried out.

II.12. In addition to the ~~guidance~~ recommendations provided in this ~~document~~Safety Guide, it is essential that all aspects relating~~ed~~ to the specific fuel assemblies used in the research reactor are taken into consideration.

II.13. A~~D~~ detailed assessment of all fuel assemblies, including reconstituted assemblies, should be carried out for storage. Proper ~~design~~ provision~~s~~ in the design should be made for storage of research reactor fuel assemblies commensurate with their shape, size, clad ~~-~~type~~,~~ and fuel composition~~ should be made~~. ~~Design P~~provision~~s~~ for safe storage of any separated pins resulting from reconstitution of fuel should also be made in the design.

II.14. ~~Due~~ Owing to the higher enrichment of fuel used in research reactors, the potential for inadvertent criticality may be higher. Therefore the design of a spent fuel storage facility should incorporate features that will add additional subcriticality margins ~~during~~ in storage, as noted in ~~earlier sections~~paras 6.33 and 6.34 of this Safety Guide.

II.15. The compatibility of the cladding of the research reactor fuel ~~cladding~~ with wet storage conditions ~~needs to~~should be assessed in order to ~~as~~ensure integrity.

II.16. Since aluminium and its alloys, which are widely used as cladding materials for research reactor fuel, have relatively less corrosion resistance, meticulous control of pool water composition is ~~required~~ necessary to ensure the integrity of the fuel cladding. In view of this, it ~~should be~~ may be considered preferable in the longer term to store spent research reactor fuel in a dry storage environment.

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II.17. Spent research reactor fuel should be dried to the greatest extent possible prior to transferring it to dry storage. This may require placement in a suitably designed canister and specific treatment ~~prior~~before it is ~~to~~ transferred~~ing to the dry storage facility~~. The dry storage facility should be designed to ensure that the environment surrounding the fuel will inhibit corrosion and thus eliminate the possible release of airborne or water-borne radionuclides.

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ANNEX I~~1~~
SHORT TERM AND LONG TERM STORAGE

Short term storage

Short term storage (conventional storage) is defined in this ~~report~~ Safety Guide as storage that could last up to approximately fifty years, since this period is representative for:

- The typical ~~design life~~design lifetime for conventional storage structures and facilities;
- A~~a~~ period over which one may be reasonably confident that the ~~operator~~operating organization will have sufficient funds to continue operating;
- W~~w~~ithin the realm of conventional regulatory experience;
- T~~t~~he time to produce an adequate quantity of material to make it economical to process (for interim or buffer storage);
- A~~a~~ period over which wastes are held to allow treatment and conditioning plants to be developed (e.g.~~,~~ a fuel encapsulation plant)(for interim storage); ~~and~~
- T~~t~~he time to decide whether the material is a resource or a waste and to allow the development of the ~~required~~ necessary processing techniques (for strategic or interim storage). [explain interim, buffer, strategic storage as footnotes?]

To satisfy safety considerations, a short term storage concept ~~must~~ needs to include an end point that will be reached within ~~the~~ a time period of approximately fifty years ~~time period~~. ~~Where~~ If this is not possible, ~~then~~ the safety considerations ~~concept~~ should be compared against the safety ~~requirements~~ considerations for~~of~~ a long term waste storage facility.[?unclear, comparing a concept with safety requirements?]

Long term storage

Long term storage is considered in this ~~report~~ Safety Guide ~~as~~ to be storage beyond approximately fifty years, and with a defined end point. The storage end point is important since it becomes the basis for the ~~design life~~design lifetime of the facility, packaging requirements and~~,~~ financial guarantees and the planning basis for subsequent disposal facilities. Long term storage ~~should not~~is not ~~be~~ expected to last more than approximately one hundred years. This timeframe is based on technical experience with civil construction. However, it is a fact that many existing industrial and civil analogues [example?] exist that have lifetimes of 100-150 years and more. Archeological analogues [example?] can be found with lifetimes of 1000-2000 years. Societal acceptance of longer ~~design life~~design lifetimes, which is based

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ANNEX II~~2~~
OPERATIONAL AND SAFETY CONSIDERATIONS FOR WET AND DRY SPENT FUEL STORAGE FACILITIES

TABLE II-1. OPERATIONAL AND SAFETY CONSIDERATIONS FOR A WET SPENT FUEL STORAGE FACILITY

Formatiert: Links

Element	Applicable safety ~~considerations~~functions
1. Control of the amount of spent fuel loaded in the pool, with account tak~~en~~ing account of decay heat, nuclear reactivity and floor static loadings	Subcriticality, heat removal
2. Protection of pool floors and walls from impact loads	Containment, radiation protection, structural integrity of spent fuel assemblies~~y~~ ~~structural integrity~~
3. Control of pool water (specific activity, temperature, chemical composition)	Containment, radiation protection, structural integrity of spent fuel assemblies~~y~~ ~~structural integrity~~
4. Control of pool water level	Radiation protection, heat protection
5. Maintenance of ventilation systems	Containment
6. Maintenance of pool heat removal systems	Containment, heat removal
7. Maintenance of handling equipment	Radiation protection, containment, structural integrity of spent fuel assemblies~~y~~ ~~structural integrity~~
8. Maintenance of underwater lighting	Radiation protection
9. Administrative controls to prevent misplacement of~~ing~~ spent fuel	Subcriticality
10. Spent f~~F~~uel integrity	Radiation p~~P~~rotection

TABLE II-2. OPERATIONAL AND SAFETY CONSIDERATIONS FOR A DRY SPENT FUEL STORAGE FACILITY

Formatiert: Links

Element	Applicable safety ~~considerations~~functions

1. Control~~ling~~ of the type and amount of spent fuel in the storage compartments	Subcriticality, heat removal
2. Monitoring of gamma and neutron radiation fields near the location of spent fuel in the storage area	Radiation protection
3. Monitoring of heat removal and heat dissipation from spent fuel to the environment	Heat removal, radiation protection, containment, structural integrity of spent fuel assemblies~~y~~ ~~structural integrity~~
4. Direct monitoring of spent fuel containment integrity (if permitted by ~~the~~ design)	Radiation protection, containment
5. Indirect monitoring of atmosphere in volumes and/or spaces inside the facility containing sealed spent fuel casks (if present~~ in the design~~)	Radiation protection, containment, structural integrity of spent fuel assemblies~~y~~ ~~structural integrity~~
6. Maintenance and monitoring of the inert gas in sealed casks (if present and ~~possible~~ permitted by ~~the~~ design)	Heat removal, spent fuel integrity

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ANNEX III
EXAMPLES OF SECTIONS IN OPERATING PROCEDURES FOR A SPENT FUEL STORAGE FACILITY

[make this a separate annex?]

An example of the sections ~~defining~~ that may be included in the operating procedures for a spent fuel storage facility is as follows:

~~(e)~~(a) Title description with revision number, date and approval status;

~~(f)~~(b) Purpose of the procedure;

~~(g)~~(c) Initial conditions required before the procedure can be used;

~~(h)~~(d) Precautions and limitations that must be observed;

~~(i)~~(e) Limitations and action levels on parameters being controlled (e.g. pool water composition) and corrective measures to return parameters to within normal range;

~~(j)~~(f) Procedures providing completely detailed, step by step operating instructions;

~~(k)~~(g) Acceptance criteria, where applicable, for judging the success or failure of activities;

~~(l)~~(h) Checklists for complex procedures, either included or referenced;

~~(m)~~(i) References used in ~~producing~~ developing the procedure; ~~and~~

~~(n)~~(j) Testing to verify radiation dose levels and heat removal performance after spent fuel loading;~~.~~

~~(o)~~(k) Monitoring of ~~boreholes~~ bore wells [see para. I.13] around the facility;~~.~~

~~(p)~~(l) Monitoring of stack discharge.

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ANNEX IV

RELATED PUBLICATIONS IN THE IAEA SAFETY STANDARDS SERIES

[make this a separate annex?]

Safety Fundamentals

- Fundamental Safety Principles, IAEA Safety Standards Series No. SF-1

Safety Requirements

- Predisposal Management of Radioactive Waste, IAEA Safety Standards Series No. GSR Part 5
- Safety of Nuclear Power Plants: Design, IAEA Safety Standards Series No. NS-R-1
- Safety of Nuclear Fuel Cycle Facilities, IAEA Safety Standards Series No. NS-R-5
- The Management System for Facilities and Activities, IAEA Safety Standards Series No. GS-R-3
- Safety Assessment for Facilities and Activities, IAEA Safety Standards Series No. GSR Part 4

Safety Guides

- Storage of Radioactive Waste, IAEA Safety Standards Series No. WS-G-6.1
- The Management System for the Processing, Handling and Storage of Radioactive Waste, IAEA Safety Standards Series No. GS-G-3.3
- Safety Case and Safety Assessment for Predisposal Management of Radioactive Waste (in preparation, DS284)

~~Safety Assessment for Facilities and Activities~~

~~Hierarchical linkage of the Safety Guide on Storage of Spent Fuel with related publications in the Safety Standards Series Standard documents~~

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Formatiert: Nummerierung und Aufzählungszeichen

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ANNEX V~~3~~

SITE CONDITIONS, PROCESSES AND EVENTS FOR CONSIDERATION IN A SAFETY ASSESSMENT (EXTERNAL NATURAL PHENOMENA)

In making use of this list it ~~should~~ is to be recognized that the initiating events ~~given~~ included would not necessarily be applicable to all facilities and all sites. The list is provided for use as an aid to memory.

(1) The meteorology and climatology of the site and region:

(i) Precipitation (averages and extremes, including frequency, duration and intensity):

— R~~r~~ain, hail, snow and ice;

— S~~s~~now cover and ice cover (including the potential for blocking inlets or outlets);

— D~~d~~rought.

(ii) Wind (averages and extremes, including frequency, duration and intensity):

— T~~t~~ornadoes, hurricanes and cyclones.

(iii) Rate and duration of the input of direct solar radiation (insolation, averages and extremes).

(iv) Temperature (averages and extremes, including frequency and duration):

— ~~p~~Permafrost and the cyclic freezing and thawing of soil.

(v) Barometric pressure (averages and extremes, including frequency and duration).

(vi) Humidity (averages and extremes, including frequency and duration):

— F~~f~~og and frost.

(vii) Lightning (frequency and intensity).

(2) The hydrology and hydrogeology of the site and region:

(i) Surface runoff (averages and extremes, including frequency, duration and intensity):

— F~~f~~looding (frequency, duration and intensity);

— E~~e~~rosion (rate).

(ii) Groundwater conditions (averages and extremes, including frequency and duration).

(iii) Wave action (averages and extremes, including frequency, duration and intensity):

— H~~h~~igh tides, storm surges and tsunami;

— F~~f~~looding (frequency, duration and intensity);

— S~~s~~hore erosion (rate).

(3) The geology of the site and region:

(i) Lithology and stratigraphy:

— T~~t~~he geotechnical characteristics of site materials.

(ii) Seismicity:

— F~~f~~aults and zones of weakness;

— E~~e~~arthquakes (frequency and intensity).

(iii) Vulcanology:

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— V~~v~~olcanic debris and ash.

(iv) Historical mining and quarrying:

— G~~g~~round subsidence.

(4) The geomorphology and topography of the site:

(i) Stability of natural material:

— S~~s~~lope failures, landslides and subsidence;

— A~~a~~valanches.

(ii) Surface erosion.

(iii) The effects of the terrain (topography) on weather conditions or on the consequences of extreme weather.

(5) The terrestrial and aquatic flora and fauna of the site (in terms of their effects on the facility):

(i) Vegetation (terrestrial and aquatic):

— T~~t~~he blocking of inlets and outlets;

— D~~d~~amage to structures.

(ii) Rodents, birds and other wildlife:

— D~~d~~irect damage due to burrowing, chewing, etc.

— A~~a~~ccumulation of nesting debris, guano, etc.

(6) The potential for:

(i) Naturally occurring fires and explosions at the site;~~.~~

(ii) Methane gas or natural toxic gas (from marshland or landfill sites);~~.~~

(iii) Dust storms or sand storms (including the possible blocking of inlets and outlets).

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ANNEX VI4

SITE CONDITIONS, PROCESSES AND EVENTS FOR CONSIDERATION IN A SAFETY ASSESSMENT (EXTERNAL HUMAN INDUCED PHENOMENA)

In making use of this list it ~~should~~ is to be recognized that the initiating events ~~given~~ included would not necessarily be applicable to all facilities and all sites. The list is provided for use as an aid to memory.

(1) Explosion:

(i) Solid substance;

(ii) Gas, dust or aerosol cloud.

(2) Fire:

(i) Solid substance;

(ii) Liquid substance;

(iii) Gas, dust or aerosol cloud.

(3) Aircraft crash.

(4) Missiles ~~due~~ generated as a result of~~to~~ structural or mechanical failure in nearby installations.

(5) Flooding:

(i) The structural failure of a dam;

(ii) The blockage of a river.

(6) Ground subsidence or collapse due to tunnelling or mining.

(7) Ground vibration.

(8) The release of any corrosive, toxic and/or radioactive substance:

(i) Liquid;

(ii) Gas, dust or aerosol cloud.

(9) Geographic and demographic data:

(i) Population density and expected changes over the lifetime of the facility;

(ii) Industrial and military installations and related activities and the effects on the facility of accidents at such installations;

(iii) Traffic;

(iv) Transport infrastructure (highways, airports and/or flight paths, railway lines, rivers and canals, pipelines and the potential for impacts or accidents involving hazardous material).

(10) Power supply and the potential loss of power.

(11) Civil strife:

(i) Terrorism, sabotage and perimeter incursions;

(ii) The failure of infrastructure;

(iii) Civil disorder;

(iv) Strikes and blockades;

(v) Health issues (e.g. endemic diseases or epidemics).

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ANNEX VII~~5~~

POSTULATED INITIATING EVENTS FOR CONSIDERATION IN A SAFETY ASSESSMENT (INTERNAL PHENOMENA)

In making use of this list it ~~should~~ is to be recognized that the initiating events ~~given~~ included would not necessarily be applicable to all facilities and all sites. The list is provided for use as an aid to memory.

(1) The acceptance (inadvertent or otherwise) of incoming ~~waste~~spent fuel, spent fuel ~~waste~~ containers, process chemicals, conditioning agents, etc., that do not meet the specifications (acceptance criteria) included in the design basis.

(2) The processing of spent fuel ~~waste~~ that meets acceptance criteria but ~~that~~ which is subsequently processed in an inappropriate way for the particular type of spent fuel ~~waste~~ (either inadvertently or otherwise).

(3) A criticality event due to the inappropriate accumulation of fissile material, change of geometrical configuration, introduction of moderating material, removal of neutron absorbing material or various combinations of these.

(4) Explosion due to the evolution of explosive gas mixtures as a result of:

(i) Radiolysis.

(ii) Off-gassing or volatilization.

(iii) Chemical reactions from inappropriate mixing or contact with:

— D~~d~~ifferent spent fuel ~~waste~~ streams;

— Spent fuel~~waste~~ and conditioning agents;

— Spent fuel ~~waste container~~ cask [?] material and conditioning agents;

— P~~p~~rocess chemicals;

— Spent fuel~~waste~~, spent fuel ~~waste containers~~casks, conditioning agents, process chemicals and the prevailing conditions of the working environment or storage environment.

(iv) The inclusion of items such as bottles of compressed gas in the input to incinerators or compactors.

(5) Fire due to:

(i) Spontaneous combustion;

(ii) Local hot spots generated by malfunctions of structures, systems or components.

(iii) Sparks from machinery, equipment or electrical circuits.

(iv) Sparks from human activities such as welding or smoking.

(v) Explosions.

(6) Gross incompatibilities between the components of a process system and the materials introduced into the system.

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(7) The degradation of process materials (chemicals, additives or binders) due to improper handling or storage.

(8) The failure to take account of the non-radiological hazards presented by the spent fuel ~~waste~~ (physical, chemical or pathogenic).

(9) The generation of a toxic atmosphere by chemical reactions due to ~~the~~ inappropriate mixing or contact of various reagents and materials.

(10) Dropping of spent fuel ~~waste packages~~ elements [?] or other loads due to mishandling or equipment failure, with consequences to the dropped spent fuel ~~waste package~~ elements and possibly to other spent fuel ~~waste packages~~ elements or to the structures, systems and components of the facility.

(11) Collisions of vehicles or suspended loads with structures, systems and components of the facility or with spent fuel ~~waste~~ ~~packages~~elements, spent fuel ~~waste containment vessels~~casks [?] and pipes.

(12) Failures of structures, systems and components due to:

- (i) ~~The~~ A loss of structural ~~competence~~ integrity [used in main text] or mechanical integrity.
- (ii) Vibrations originating within the facility.
- (iii) Pressure imbalances (pressure surges or pressure collapses).
- (iv) Internal corrosion or erosion or the chemical effects of the working or storage environment.

(13) The generation of missiles and flying debris due to ~~the~~ explosion of pressurized components or ~~the~~ gross failure of rotating equipment.

(14) The malfunctioning of heating or cooling equipment, leading to unintended temperature excursions in process systems or storage systems.

(15) The malfunctioning of process control equipment.

(16) The malfunctioning of equipment that maintains the ambient conditions in the facility, such as the ventilation system or dewatering system.

(17) The malfunctioning of monitoring or alarm systems so that an adverse condition goes unnoticed.

(18) Incorrect settings (errors or unauthorized changes) on monitors, alarms or control equipment.

(19) The failure ~~to function when called upon~~ of emergency equipment, such as the fire suppression system, pressure relief valves and ducts, to function when called upon.

(20) The failure of the power supply, either the main system or various subsystems.

(21) The malfunctioning of key equipment for handling spent fuel~~waste~~, such as transfer cranes or conveyors.

(22) The malfunctioning of structures, systems and components that control releases to the environment, such as filters or valves.

(23) The failure properly to inspect, test and maintain structures, systems and components.

(24) Incorrect operator action due to inaccurate or incomplete information.

(25) Incorrect operator action in spite of having accurate and complete information.

(26) Sabotage by employees.

(27) The failure of systems and components such as incinerator linings, compactor hydraulics or cutting machinery that poses the risk of significant additional radiation exposure of personnel called on to assist in effecting repairs or replacements.

(28) Encountering of an unanticipated radiation source in decommissioning (e.g. different in nature or amount) and not recognizingwith immediately recognition of the changed circumstances.

(29) Removaling or weakening of a structure or component in decommissioning without realizing realization of the possible effects on the structural competence integrity of other structures and components.

CONTRIBUTORS TO DRAFTING AND REVIEW

[please supply]

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BODIES FOR THE ENDORSEMENT OF SAFETY STANDARDS
(To be inserted later)