



GOVERNMENT OF INDIA

AERB SAFETY GUIDE

DESIGN OF FUEL HANDLING AND STORAGE SYSTEMS FOR NUCLEAR POWER PLANTS



ATOMIC ENERGY REGULATORY BOARD

GUIDE NO. AERB/NPP/SG/D-24, Rev.1



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FOR NUCLEAR POWER PLANTS**

**Atomic Energy Regulatory Board
Mumbai-400094
India
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Orders for this Guide should be addressed to:

Chief Administrative Officer
Atomic Energy Regulatory Board
Niyamak Bhavan
Anushaktinagar
Mumbai-400094
India

FOREWORD

The Atomic Energy Regulatory Board (AERB) was constituted in 1983, to carry out certain regulatory and safety functions envisaged under Section 16, 17 and 23 of the Atomic Energy Act, 1962. AERB has powers to lay down safety standards and frame rules and regulations with regard to the regulatory and safety requirements envisaged under the Act. The Atomic Energy (Radiation Protection) Rules, 2004, provide for issue of requirements by the Competent Authority for radiation installations, sealed sources, radiation generating equipment and equipment containing radioactive sources, and transport of radioactive materials.

With a view to ensure the protection of occupational workers, members of the public and the environment from harmful effects of ionizing radiations, AERB regulatory safety documents establish the requirements and guidance for all stages during the lifetime of nuclear and radiation facilities and transport of radioactive materials. These requirements and guidance are developed such that the radiation exposure of the public and the release of radioactive materials to the environment are controlled; the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation is limited, and the consequences of such events if they were to occur are mitigated.

The regulatory documents apply to nuclear and radiation facilities and activities giving rise to radiation risks, the use of radiation and radioactive sources, the transport of radioactive materials and the management of radioactive waste.

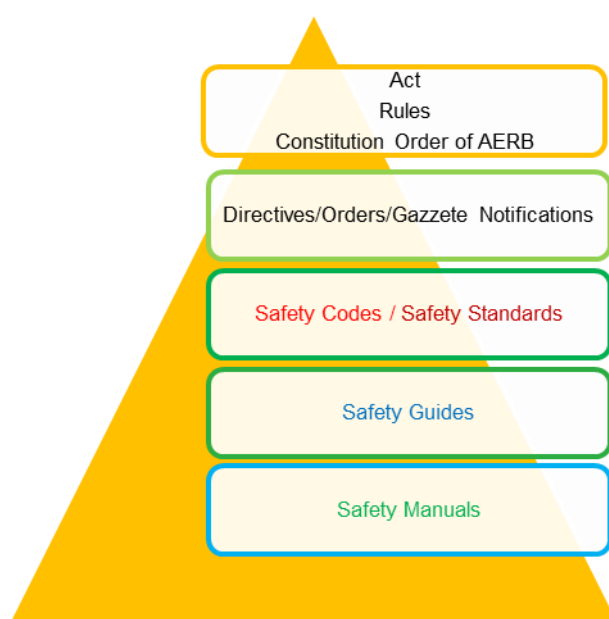


Fig. 1 Hierarchy of Regulatory Documents

Safety codes establish the objectives and set requirements that shall be fulfilled to provide adequate assurance for safety. Safety Standards provide models and methods, approaches to achieve those requirements specified in the safety codes. Safety guides elaborate various requirements specified in the safety codes and furnish approaches for their implementation. Safety manuals detail instructions/safety aspects relating to a particular application. The hierarchy of Regulatory Documents is depicted in Figure.1.

The safety guide on the 'Design of Fuel Handling and Storage Systems for Pressurized Heavy Water Reactors' (AERB/SG/D-24), was issued in October, 2002. Considering the vast experience gained in

the design, construction, safe operation and regulation of different types of Nuclear Power Plants (NPPs) such as Pressurised Heavy Water Reactors (PHWRs) of different capacities, Light Water Reactors (LWRs) and experimental Sodium cooled Fast Reactors (SFRs), it was decided to review and revise the existing version of the Safety Guide. This revised Safety Guide supersedes earlier published Safety Guide on 'Design of Fuel Handling and Storage Systems for Pressurized Heavy Water Reactors' (AERB/SG/D-24, October 2002). The contents of this Safety Guide are made to the extent possible in a reactor technology neutral manner and in general are applicable to PHWR, LWR and SFR based NPPs. The reactor specific guidance are mentioned explicitly, wherever applicable.

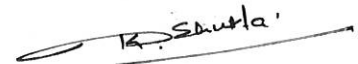
The recommendations of international expert bodies, notably the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) are taken into account while developing the AERB Regulatory safety documents.

The principal users of AERB regulatory safety documents are the applicants, licensees, and other associated persons in nuclear and radiation facilities including members of the public. The AERB regulatory safety documents are applicable, as relevant, throughout the entire lifetime of the nuclear and radiation facilities and associated activities. The AERB regulatory safety documents also form the basis for AERB's core activities of regulation such as safety review and assessment, regulatory inspections and enforcement.

Safety related terms used in this safety guide are to be understood as defined in the AERB Safety Glossary (AERB/GLO, Rev.1). The special terms which are specific to this safety guide are included under section on 'Special Terms and Interpretation'. In addition, the terms already defined in AERB Safety Glossary AERB/GLO, Rev.1, and being used in this safety guide with a specific context and requires interpretation or explanation are also included in this section.

Appendix is an integral part of the safety guide, whereas references and bibliography provide information that might be helpful to the user. For aspects not covered in this safety guide, applicable and acceptable National and International codes and standards shall be followed. Industrial safety shall be assured through good engineering practices and by complying with the Factories Act, 1948 as amended in 1987, and the Atomic Energy (Factories) Rules, 1996.

This safety guide has been drafted by an in-house working group. The draft was further reviewed by a Task Group with specialists drawn from technical support organisations and institutions, and other consultants. The comments obtained from all the major stake holders have been suitably incorporated. The safety guide has been vetted by the AERB Advisory Committee on Nuclear and Radiation Safety (ACNRS). AERB wishes to thank all individuals and organizations who have contributed to the preparation, review and finalization of the safety guide.



Dinesh Kumar Shukla

Chairman, AERB

SPECIAL TERMS AND INTERPRETATION

Away From Reactor (AFR) Spent Fuel Storage Facility

The AFR spent fuel storage facilities are, by definition, those facilities that are not built and operated as integral part of the nuclear power plants, such as at-reactor cooling pools, that exist at most nuclear power plants to provide for initial storage of spent fuel.

Fuel

The term "fuel" is a generic term that covers the nuclear fuel used in different types of Nuclear Power Plants, while "Fuel Bundle" "Fuel Assembly" and "Fuel Sub Assembly" are specific terms used to describe the nuclear fuel assembly for PHWRs, LWRs, and SFRs respectively.

New Fuel

New fuel means fuel before use in the reactor that contains a negligible fission product inventory; new fuel includes fuel manufactured from unirradiated material or fuel manufactured using a mixture of unirradiated and reprocessed material.

Cask

Container for transport of new fuel or spent fuel.

Shipping Container (Radioactive Components)

Container for the transfer or transport of irradiated core components, except irradiated fuel.

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1. INTRODUCTION

1.1. General

Fuel handling and storage system involves activities related to the receipt of new fuel in the Nuclear Power Plant (NPP), the storage and inspection before use, transfer of new fuel into the reactor, removal of spent fuel from the reactor and its reinsertion if required, transfer and storage of the spent fuel, inspection of spent fuel, loading into a spent fuel cask and handling of the spent fuel cask for dispatch to Away From Reactor (AFR) Spent Fuel Storage Facility or Reprocessing Facility or Disposal Facility etc.

This Safety Guide describes the safety aspects in the Design of Fuel Handling and Storage Systems for Pressurized Heavy Water Reactor (PHWR), Light Water Reactors (LWR) and Sodium Cooled Fast Reactor (SFR) based NPPs. This Safety Guide can be used as a reference for other reactor types (e.g., advanced heavy water reactors, gas-cooled reactors, small and modular reactors, innovative reactors) based on engineering judgement.

1.2. Objective

The objective of this Safety Guide is to provide guidance to meet the requirements related to Fuel Handling and Storage Systems contained in AERB Safety Codes on 'Design of Pressurized Heavy Water Reactor based Nuclear Power Plants' (AERB/NPP-PHWR/SC/D, Rev.2), 'Design of Light Water Reactor based Nuclear Power Plants' (AERB/NPP-LWR/SC/D) and 'Design of Sodium Cooled Fast Reactor based Nuclear Power Plants' (AERB/NPP-SFR/SC/D).

1.3. Scope

1.3.1. This Safety Guide is for application to fuel handling and storage systems for Nuclear Power Plants and Away From Reactor (AFR) spent fuel storage facility.

1.3.2. The scope of this Guide includes the design of fuel handling and storage systems covering the following stages:

- (a) receipt of new fuel;
- (b) storage and inspection of new fuel in new fuel storage facility;
- (c) transfer and loading of new fuel into the reactor;
- (d) removal of spent fuel from the reactor and its transfer to spent fuel storage facility;
- (e) reloading/shuffling of fuel in the reactor including that from the at-reactor spent fuel pool;
- (f) inspection and storage of spent fuel in the spent fuel storage facility;
- (g) removal of spent fuel from the spent fuel storage facility and facilitate its transfer to Reprocessing / AFR facility;
- (h) handling of casks in the new / spent fuel storage facility; and
- (i) storage of spent fuel in AFR facility received from the spent fuel storage facility.

1.3.3. The scope of this Guide includes safety in design of equipment used for handling and storage of new fuel, spent fuel, failed or damaged fuel and other irradiated core components. This guide also addresses the safety aspects in design related to control &

instrumentation, auxiliary systems, Quality Assurance (QA) and In-Service Inspection (ISI) aspects.

1.3.4. The following are not included in the scope of this Guide:

- (a) Design of support systems such as ventilation, compressed air, electrical power supply, fire-fighting and communication for the fuel handling and storage.
- (b) Storage and handling of spent fuel beyond AFR facility.
- (c) Design of new/ spent fuel cask used for transportation.
- (d) Design of special handling cask used for handling of irradiated components
- (e) Transportation of new/ spent fuel using a cask.

2. SAFETY AND DESIGN CONSIDERATIONS

2.1. General

2.1.1. The safety and design considerations provided in this chapter are based on the requirements specified in AERB Safety Codes on ‘Design of Pressurized Heavy Water Reactor based Nuclear Power Plants’ (AERB/NPP-PHWR/SC/D, Rev.2), ‘Design of Light Water Reactor based Nuclear Power Plants’ (AERB/NPP-LWR/SC/D) and ‘Design of Sodium Cooled Fast Reactor based Nuclear Power Plants’ (AERB/NPP-SFR/SC/D).

2.1.2. In addition to the safety and design considerations mentioned in this Safety Guide, other associated ‘D’ series guides applicable to fuel handling and storage systems should also be taken into account.

2.2. Safety Considerations

2.2.1. The structures, systems and components (SSCs) of fuel handling and storage systems should be designed such that following fundamental safety functions are met during all operational states and accident conditions:

- (a) Maintaining the subcriticality of the new fuel and spent fuel
- (b) Removal of the decay heat from spent fuel
- (c) Shielding against radiation
- (d) Confinement of radioactive material and limiting the accidental radioactivity releases.

2.2.2. The fuel handling and storage systems of spent fuel should be designed in conjunction with other appropriate systems to prevent the following occurrences during all operational and accident conditions:

- (a) Undue radiation exposure to operating personnel
- (b) Radiation damage to items important to safety
- (c) Damage to spent fuel
- (d) Release of radioactivity beyond prescribed limits.

2.3. Design Considerations

In order to fulfil the above, the following design considerations should be met:

- (a) The fuel handling and storage system should be classified and designed as per the AERB Guide on ‘Safety Classification and Seismic Categorisation for Nuclear power Plants’ (AERB/NPP/SG/D-1).
- (b) The design should ensure adequate capability to withstand all static and dynamic loading that may be imposed on SSCs.
- (c) Handling equipment should be designed to prevent dropping of fuel and imposition of unacceptable loads on the fuel.
- (d) The dropping of any object (which has the potential to cause damage) onto the fuel stored or other items important for fuel handling and storage should be prevented.

- (e) The design should ensure that the fuel is placed in the reactor in the intended orientation and manner, as applicable.
- (f) The design should be such that procedures can be instituted for proper accounting of fuel.
- (g) The fuel handling and storage system should be designed to prevent criticality by maintaining specified subcriticality margins as mentioned in AERB Safety Guide on 'Criticality Safety of Fissile Material handling Facilities' (AERB/FCF/SG-3) under all operational states and accident conditions. The design should include provision for functional checking and/or hydro testing of fuel handling equipment /machine.
- (h) Structures, systems and components (SSCs) whose failure can result in loss of shielding or cooling to the fuel during storage should meet the single-failure criteria.
- (i) The design of storage and handling facilities/equipment should provide for adequate accessibility in order to facilitate inspection, testing and maintenance of the equipment. It should also allow for radiation monitoring and contamination checks.
- (j) The design should facilitate decommissioning of the fuel storage and handling facilities.
- (k) Adequate means should be provided for inspecting new fuel and spent fuel.
- (l) The design should include provisions for detection of failed fuel and storage of failed / damaged fuel.
- (m) The design should facilitate for decontamination of fuel handling and storage areas/equipment, where necessary.
- (n) Adequate shielding should be provided for the protection of operating personnel under all design basis events.
- (o) The design should include heat removal under all conditions as per the AERB Guides on 'Design basis events for water cooled Nuclear Power Plants' (AERB/NPP-WCR/SG/D-5, Rev.1) and 'Deterministic Safety Analysis for Sodium Cooled Fast Reactors based Nuclear Power Plants' (AERB/NPP-SFR/SG/D-19) respectively.
- (p) Appropriate combinations of physical barriers, interlocks and administrative controls should be in place to prevent transfer of spent fuel/ irradiated components to unshielded positions.
- (q) Ventilation and off-gas systems should be provided to protect safety-related components from the effects of high temperatures and moisture. Additionally, where necessary, these systems should ensure the collection of airborne radioactive particulate material during both operational states and accident conditions, to limit airborne radioactivity to acceptable levels.
- (r) The design should include systems to detect and keep within acceptable limits the release of radioactivity to the public and the exposure to operators, occurring

as a result of accident conditions involving fuel damage during handling or storage.

- (s) For underwater storage systems, provisions for monitoring and controlling the level, temperature, chemistry, clarity and radioactivity of water in which the fuel is handled or stored, should be provided.
- (t) Adequate illumination should be provided to ensure safe handling of fuel in the fuel storage facilities.
- (u) In the spent fuel storage facility, adequate water shielding over the top of the stored fuel should be maintained all the time.
- (v) Remote viewing system should be provided as required in all fuel handling and storage areas.

3. DESIGN APPROACH

3.1. **General**

- 3.1.1. The fuel handling and storage system should be designed to ensure the integrity of the fuel during handling and storage.
- 3.1.2. The design should ensure prevention of criticality, adequate shielding and cooling during handling, storage, transfer and transport of fuel.

3.2. **Maintaining Subcriticality**

- 3.2.1. The design of storage systems for new or spent fuel should be such as to prevent criticality, preferably by control of geometry.
- 3.2.2. The design of fuel storage systems should also consider use of physical means or physical processes to increase subcriticality margins in normal operation in order to prevent from reaching the criticality during postulated initiating events taking into account the effect of associated hazards.
- 3.2.3. The design of fuel handling and storage systems should be such as to prevent criticality by maintaining specified subcriticality margins as mentioned in AERB Safety Guide on 'Criticality Safety in Fissile Material handling Facilities' (AERB/FCF/SG-3) under all operational states and accident conditions.

3.3. **Removal of Decay Heat from Spent Fuel**

The design of fuel handling and storage system should be such as to maintain adequate fuel cooling capabilities¹ for spent fuel and not to exceed fuel cladding or coolant temperature limits defined for operational and accident conditions.

3.4. **Confinement of Radioactive Materials and Limiting Radioactive Releases**

- 3.4.1. The design of handling and storage systems for new or spent fuel should be provided with appropriate and adequate measures for containing radioactive material so as to prevent an uncontrolled release of radionuclides to the environment.
- 3.4.2. Design should prevent damage to fuel during handling and to collect and filter radioactive releases from the fuel storage facilities in order to keep radioactive releases as low as reasonably achievable during all operational states.
- 3.4.3. In order to reduce the concentrations of air borne radioactive materials and thus to prevent or reduce direct exposure and contamination in areas with radiation hazards; ventilation systems should be provided as necessary.
- 3.4.4. Design provisions should be made to collect and filter radioactive materials released in case of fuel handling accidents and also in case of uncovering of spent fuel in the spent fuel storage facilities during accident conditions.

3.5. **Shielding Against Radiation**

- 3.5.1. Shielding should be provided in fuel handling and fuel storage to keep occupational doses as low as reasonably achievable in all operational states without exceeding the dose limits specified by AERB.

¹ Refer AERB safety guide on 'Fuel Design for Water Cooled based Reactors', AERB/NPP-WCR/SG/D-6, under preparation.

- 3.5.2. Design provisions should be made to prevent loss of shielding for spent fuel resulting in unacceptable radiation doses to radiation workers during operational states and accident conditions.
- 3.6. **Operating Experience Feedback**
- The design should take into consideration the operating experience feedback of similar systems for learning from the events that have occurred and measures evolved to prevent the recurrence.
- 3.7. **Interfaces of Safety with Security**
- 3.7.1. All the SSCs important to safety of fuel handling and storage should be designed in an integrated manner taking into account design recommendations for safety and security such that safety and security measures do not compromise each other.
- 3.7.2. The design of fuel handling and storage systems should facilitate the application of safeguards, wherever applicable.
- 3.8. **Proven Engineering Practices**
- The design of SSCs important to safety of fuel handling and storage should be proven either by equivalent applications based on operational experience, or on the results of relevant research programme, or according to the design and design verification/validation processes stated in applicable codes and standards.
- 3.9. **Safety Assessment in Design Process**
- The safety assessment of fuel handling and storage systems should be performed as part of the design process to ensure that all safety requirements for the design of the system are met during operational states and accident conditions.
- 3.10. **Other Considerations**
- 3.10.1. Where the same fuel handling equipment is used for more than one reactor, it should be demonstrated that the capability to meet individual requirements of any of the units, including that of containment isolation, is not impaired and that the faults arising at one unit does not affect the safety of any other unit.
- 3.10.2. Identification features (fuel, its location and movement) should be made indelible such that they will remain effective during the handling and storage.
- 3.10.3. The choice of materials and the chemistry of the cooling medium, corrosion of fuel, storage racks / trays and storage pool liners should be compatible and consistent with intended design life.
- 3.10.4. Design provisions should be introduced to minimize the potential for generating radioactive effluents and wastes during normal operation.
- 3.10.5. The effects of irradiation should be considered in the design of SSCs.

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

4.1. General

- 4.1.1. Items important to safety are required to be designed considering the following:
- (a) protection of radiation workers, the public and the environment against the effects of ionizing radiation in operational and accident conditions; and
 - (b) adequate reliability of the various systems.
- 4.1.2. The design basis of items important to safety should be established as per requirements specified in AERB Safety Codes on Design of ‘Pressurized Heavy Water Reactor based Nuclear Power Plants’ (AERB/NPP-PHWR/SC/D, Rev.2), ‘Design of Light Water Reactor based Nuclear Power Plants’ (AERB/NPP-LWR/SC/D) and ‘Design of Sodium Cooled Fast Reactor based Nuclear Power Plants’ (AERB/NPP-SFR/SC/D), as applicable, and taking into account following aspects:
- (a) The safety function(s) to which they contribute
 - (b) The postulated initiating events they have to cope with
 - (c) The protection against the effect of internal hazards and external hazards
 - (d) The safety classification
 - (e) Design limits or acceptance criteria
 - (f) The engineering design rules applicable to the system
 - (g) Maintainability of systems and components
 - (h) Instrumentation & control and monitoring
 - (i) Provisions against common cause failures
 - (j) Environmental conditions for qualification
 - (k) Selection of materials.
- 4.1.3. The design should have provisions and include devices necessary to facilitate the use of non-permanent equipment for the re-establishment of safe conditions in the fuel storage facility in case of multiple failures, which are not accounted for in the design basis. This may include the provision of flanges and sockets for the use of mobile equipment.
- 4.1.4. To prevent the loss of water, the spent fuel storage pool should be designed such that:
- (a) a substantial loss of coolant inventory from spent fuel storage systems resulting from pipe break should be avoided by ensuring that all penetrations in the fuel storage pool are above the elevation necessary for adequate shielding in the spent fuel storage pool;
 - (b) piping break should not lower the water level to a point that would compromise cooling or the radiation shielding of the spent fuel;
 - (c) the gates of the pool should be so designed that they retain their leak-tightness if subjected to hydrostatic pressure from one side in case other side is emptied out;
 - (d) any loss of coolant water in a storage pool due to an operational occurrence should be compensated for by a make-up water system;

- (e) measurement and data logging of water level and temperature of the storage pool should be available during operational states and accident conditions;
- (f) it should be equipped with monitoring, collection and leak detection system including leak through liner welds; and
- (g) leak monitoring between gates should be available.

4.2. **Defence in Depth (DID)**

- 4.2.1. The design of spent fuel storage systems should include multiple means to remove decay heat from spent fuel and maintain subcriticality margins in all plant conditions considered in the design.
- 4.2.2. The need for redundancy, diversity and independence should be defined taking into account para. 4.2.3. Implemented combination of redundancy, diversity and independence among the various cooling means in spent fuel storage systems should be adequate to demonstrate that the uncovering of the spent fuel is prevented with a high level of confidence.
- 4.2.3. The risk for common cause failures in the decay heat removal means should be identified and the consequences should be assessed. In cases that may result in uncovering of spent fuel, the identified vulnerabilities of the decay heat removal means should be removed to the extent possible by the implementation of diverse and redundant provisions.
- 4.2.4. The design of new fuel storage systems should include various means to maintain subcriticality margins during all plant states (considered in design).

4.3. **Safety Functions**

- 4.3.1. The following safety functions should be considered in the design of new fuel storage systems:-
 - (a) To ensure subcriticality at all times.
 - (b) To prevent physical damage to the new fuel when they are being stored or handled.
 - (c) To ensure heat removal in case of reprocessed fuel.
 - (d) To ensure that radiation exposure and the release of radioactive substances during the handling of new fuel are kept as low as reasonably achievable.
- 4.3.2. The following safety functions should be considered in the design of spent fuel storage systems:-
 - (a) To ensure subcriticality at all times.
 - (b) To prevent physical damage to spent fuel when they are being stored or handled.
 - (c) To ensure an adequate rate of removal of heat.
 - (d) To ensure that radiation exposure and the release of radioactive substances during the handling and storage of spent fuel are kept as low as reasonably achievable.

4.4. **Layout**

Design aspects associated with the layout of a fuel storage facility, which are to be considered are detailed below:

- (a) The pool and its supporting systems should be so located within structures that protect against internal and external hazards.
- (b) Handling and storage areas for fuel should be protected against unauthorized access and unauthorized removal of fuel.
- (c) The area used for storage should not be part of an access route to other operating areas.
- (d) Space required to receive and store any other radioactive components may also be considered.
- (e) Sufficient space should be provided to allow for free movement of the fuel and casks.
- (f) Sufficient space should be provided for the storage and use of the tools and equipment which are used during storage and handling of fuel.
- (g) Sufficient space should be provided for support systems associated with fuel storage and handling systems (e.g. ventilation system, Spent Fuel Storage Pool purification system, cask decontamination system etc.).
- (h) Sufficient space should be provided to permit inspection of fuel and inspection and maintenance of components, including fuel handling equipment. Also, layout should facilitate ease of in-service inspection.
- (i) Sufficient space should be provided for the safe handling of casks. This may be achieved by using a separate cask loading / unloading area or by including a dedicated space within the fuel storage facility.
- (j) Transport routes for handling fuel within the site should be arranged to be as direct and as short as practicable, so as to avoid the need for complex or unnecessary moving and handling operations.
- (k) The need to move heavy objects over stored fuel and items important to safety should be minimized by the layout.
- (l) The layout should be such that all fuel handling operations and the storage of fuel are optimized.
- (m) The layout should facilitate access to any stored fuel without the need to move or handle other stored fuel to the extent possible.
- (n) Retrieval of fuel as well as the possible need for fuel inspection, failed fuel detection, repair and reconstitution and encapsulation should be addressed in the layout of the facility.
- (o) Facility for decontamination of fuel handling equipment and casks should be provided.
- (p) Arrangement for inspection of new fuel / spent fuel / failed fuel / damaged fuel and their storage in safe manner should be made.
- (q) Storage positions should be earmarked for fuel, reactivity control devices, dummy fuel, components of fuel handling equipment etc., as applicable.
- (r) Appropriate arrangements for containment and safe storage of damaged or failed fuel should be provided.

- (s) The floor area on which any transport vehicle with cask may move or be parked should be designed with adequate floor loading margins. Such areas should be clearly marked to avoid overloading the designed floor area.
- (t) Layout should consider the fuel storage capacity requirements of the spent fuel storage pool as specified in 4.9.4.
- (u) Design should be such that it effectively prevents entry of animals/birds inside the pool area.
- (v) The design should prevent ingress of water or inadvertent addition of any material to the spent fuel storage facility, which could impair heat transfer or increase corrosion and degradation of the storage facilities.
- (w) Penetrations should be designed in such a way as to prevent the ingress of foreign material (e.g. rain, inorganic solutions, and organic materials) that could reduce subcriticality margins, impair heat transfer or increase corrosion and degradation of the storage facility in ways that might reduce the effectiveness of the main safety functions or prevent inspection or repair. Wherever necessary, appropriate siphon breaker should be provided.
- (x) When the spent fuel storage pool is outside the containment, design provisions should be implemented to meet the containment isolation requirements.
- (y) The layout should provide for an easy exit by personnel in case of an emergency.
- (z) Layout should have suitable provisions for maintenance in case of liner leakage, such as separate compartments in spent fuel storage pool to facilitate the repair of liner by shifting the fuel to other compartment.

4.5. **Design Basis Events**

4.5.1. Initiating events relevant to the design of fuel storage systems should be those events that potentially lead to a reduction in subcriticality margin, reduction in decay heat removal capability, a significant release of radioactive materials or a significant direct radiation exposure of operating personnel. Such postulated initiating events (PIEs) may be caused by equipment failures, operating errors, external hazards, or internal hazards. The guidance for identifying events relevant to design of fuel storage systems is given in AERB Safety Guides on ‘Design Basis Events for Water Cooled Nuclear Power Plants’ (AERB/NPP-WCR/SG/D-5, Rev.1) and ‘Deterministic Safety Analysis for Sodium Cooled Fast Breeder Reactors based Nuclear Power Plants’ (AERB/NPP-SFR/SG/D-19) respectively.

4.5.2. Bounding conditions for the events should be determined to define necessary performance capabilities of the equipment designed to mitigate their consequences.

4.6. **Internal Hazards**

4.6.1. All safety related SSCs should be designed to withstand loads resulting from or be protected against the effects of internal hazards. That protection should also consider the consequences of the failure of unprotected equipment.

4.6.2. The redundant systems / equipment should be segregated to the extent possible or adequately separated to prevent common cause failures which may result in loss of safety functions performed by the system.

- 4.6.3. The effect of a single hazard should not result in failure of all cooling capability of fuel storage system.
- 4.6.4. The storage building should be designed to withstand the hazard loads occurring within the plant site.
- 4.6.5. Design methods and construction codes used should provide adequate margins to prevent cliff edge effects in the event of a minor increase in the severity of an internal hazard above the design basis.
- 4.6.6. Typical examples of internal hazards which influence the design of fuel handling and storage systems are:
- 4.6.6.1. **Heavy load drop**
- (a) The potential of heavy loads falling on stored fuel which can lead to damage or otherwise impact the continued implementation of safety functions should be considered in the design. Falling objects are primarily the result of component failures and operator errors during fuel handling.
 - (b) Due to frequency of fuel handling, the drop of a fuel in any area traversed during the handling should be considered. Other potential load drops in the fuel storage area may include the movement of water-tight gates, the transfer of handling tools, installation or removal of fuel storage racks/trays/core components, components of fuel handling equipment etc., as applicable.
 - (c) Very heavy objects associated with refuelling operations (e.g., reactor vessel head and activated reactor internal structures in case of Light Water Reactors) and fuel transfer or storage cask loading operations should be excluded from consideration as hazards in the fuel storage area through prevention by careful design of the handling equipment and layout of the facility viz., refuelling, fuel storage and cask loading areas.
 - (d) The design and layout of fuel handling and storage system should prevent the movement of heavy objects over the fuel storage areas through spatial separation and prevent indirect effect through structural independence of the fuel storage area and the construction of weirs or other structures to prevent a substantial loss of coolant inventory in the event of heavy load drops that damage structures in nearby areas.
- 4.6.6.2. **Internal flooding**
- The design and layout of fuel storage facility (dry storage type) should provide protection against internal flooding, for example, by means of flood barriers, routing of water piping through areas isolated from the fuel storage or adequate drains in order to keep the minimum subcriticality margins.
- 4.6.6.3. **Pipe breaks**
- (a) Equipment performing the safety functions should be protected against the effect of high-energy pipe breaks.
 - (b) A substantial loss of coolant inventory from spent fuel storage systems resulting from pipe break should be avoided by ensuring that all liner penetrations in the fuel

storage area are above the elevation necessary for adequate shielding in the spent fuel storage pool area.

4.6.6.4. **Fire**

All relevant guidelines provided in AERB Safety Standard on 'Fire Protection systems for Nuclear Facilities' (AERB/NF/SS/FPS, Rev.1) to reduce the probability for a fire to start, to limit its propagation, to protect items important to safety and to prevent the loss of safety functions should be implemented. The following aspects specific to fuel storage should be implemented as applicable:

- (a) New fuel storage facility (dry storage type) should be implemented inside a fire compartment.
- (b) The effects of fire and firefighting agents on the subcriticality of fuel should be accounted for.
- (c) For spent fuel storage facility, the different cooling capabilities and each redundant division of a cooling system should be implemented in its own fire compartment or at least in its own fire cell, where implementing a fire compartment is not achievable.
- (d) Fire risks should be minimized by preventing the accumulation of combustible material in the storage area.
- (e) The piping system carrying combustible materials and electrical cables which are not directly necessary for supplying power to the equipment for handling and storing fuel should not be routed through the storage areas.

4.6.6.5. **Explosion**

If hydrogen generation or storage of hazardous / flammable chemicals is considered as a hazard, specific design provisions should be implemented to prevent or to limit concentration of these materials (e.g., ensure material compatibility with spent fuel storage pool coolant chemistry or provide ventilation) so that the concentration is kept at a safe level below the lower flammability limits taking into account locations where higher concentration may exist.

4.7. **External Hazards**

- 4.7.1. All the relevant AERB publications on external events should be considered to understand the general concept for identification of the relevant hazards and for an adequate protection of the SSCs against the effects of the external hazards.
- 4.7.2. All safety related SSCs should be protected against, or designed to withstand the effects of the external hazards.
- 4.7.3. The protection should primarily rely on an adequate layout and design of the buildings at the site.
- 4.7.4. For hazards or likely combinations of hazards, SSCs whose operability or/and integrity is required to be maintained during or after the hazard should be identified and specified. Where protection of the building is not effective, SSCs should be designed to withstand the hazard loads and loads from likely combinations of hazards.

- 4.7.5. The seismic design specifications for items important to safety should be established on the basis of the consequences of potential damage to stored fuel, the release of radioactive material in the building and the need to operate the storage systems during and after an earthquake. The design of the spent fuel storage for seismic qualification should take into account the potential for a decrease of the coolant inventory due to sloshing and for a reduction of subcriticality margins due to the potential displacement of solid neutron absorbers.
- 4.7.6. In the event of external hazards, decay heat removal from spent fuel storage pool, and maintaining sufficient inventory in the pool should be ensured for at least seven days and should not rely on off-site services. Capability should also exist for continued decay heat removal beyond seven days, with reliance on external services, if necessary.
- 4.7.7. Methods of design and construction codes and standards used should provide adequate margins to prevent cliff edge effects in the event of an increase of the severity of the external hazards.
- 4.7.8. Margins provided by the design of the SSCs ultimately necessary to avoid unacceptable radiation doses and a large radioactive release should be such that it can be demonstrated that the integrity of the structures, and the operability of those systems and components would be reasonably preserved in case of natural hazards causing loads exceeding those resulting from the hazard evaluation at the site. In this regard, criticality and unacceptable radiation doses should be prevented, and spent fuel cooling capability should be preserved.
- 4.8. **Plant Conditions to be Taken into Account in Design**
- 4.8.1. **Normal operation**
- 4.8.1.1. During normal operation, the safety functions should be accomplished without exceeding the limits and boundary conditions established for normal operation with regard to subcriticality margin, coolant temperature and occupational doses (radiation level and airborne activity).
- 4.8.1.2. Decay heat should be removed by a dedicated cooling system designed to maintain the coolant temperature below the maximum temperature specified for normal operation.
- 4.8.1.3. In the design of spent fuel (wet) storage system, adequate means should be implemented for:
- (a) Maintaining coolant activity within the specifications established for normal operation.
 - (b) Maintaining coolant chemistry within the specifications established for normal operation.
 - (c) Compensating for water losses by evaporation.
 - (d) Collecting radioactive gas potentially leaking from defective fuel.
 - (e) Maintaining appropriate clarity of the coolant for fuel handling operation.
 - (f) Monitoring and controlling coolant temperature.
 - (g) Monitoring and controlling coolant level.
 - (h) Protection against over-filling of water in the storage pool.

- (i) Monitoring of radiation levels.
 - (j) Monitoring and controlling of airborne activity.
 - (k) Monitoring and controlling the activity in sodium and in cover gas during operational states and accident conditions (specific for sodium tank system for fuel storage).
 - (l) Preventing sodium freezing to avoid blockage of coolant circulation (specific for sodium tank system for Fuel storage).
- 4.8.1.4. In general, the design should be such as to prevent damages to the equipment by operator error.
- 4.8.1.5. Provision should be made through equipment and procedures for retrieving spent fuel from storage or from wrong locations arising from malfunctioning of the equipment or operator error.
- 4.8.1.6. The design should ensure that the system can be maintained or repaired by use of suitably designed tools, so that the radiation exposure to the maintenance personnel is minimal.
- 4.8.1.7. The design should provide for measures to check proper functioning of the equipment after maintenance.
- 4.8.2. **Anticipated Operational Occurrences (AOOs)**
- 4.8.2.1. Anticipated operational occurrences should be identified and postulated to define design provisions necessary to maintain subcriticality margin, cooling conditions, the coolant inventory and radiation consequences within the limits established for anticipated operational occurrences.
- 4.8.2.2. Typical examples of postulated initiating events that can result in anticipated operational occurrences include the following
- (a) Loss of off-site power;
 - (b) Loss of cooling water flow, or dilution of soluble neutron absorbers (only relevant to pressurized water reactors);
 - (c) Loss of coolant (small leaks) in the cooling and filtration/purification system or through the seals of gates;
 - (d) Malfunctioning of a normal operation fuel cooling system; and
 - (e) Abnormal fuel configurations with single misplaced fuel or dropped fuel (without cladding damage) in the fuel storage.
- 4.8.3. **Accident conditions**
- 4.8.3.1. Credible equipment failures causing conditions more severe than anticipated operational occurrences with regard to the accomplishment of the fundamental safety functions should be postulated.
- 4.8.3.2. Single equipment failures and multiple equipment failures should be considered to define design basis accident conditions and design extension conditions (DEC) respectively. Typical examples of such failures to be considered include the following:
- (a) Design Basis Accidents (DBA)

- (i) Significant loss of coolant (e.g., breaks of piping connected to the spent fuel pool);
- (ii) Failure of the normal operation cooling system;
- (iii) Abnormal fuel configurations (e.g. fuel positioning errors and dropped spent fuel with cladding damage); and
- (iv) Significant change of moderation conditions in fuel storage (e.g., large dilution of soluble neutron absorber (pressurized water reactor only) in wet storage area, or flooding of dry storage area).

(b) Design Extension Conditions (DEC)

- (i) Multiple failures leading to the sustained loss of the forced cooling system;
- (ii) Partial or complete exposure of spent fuel due to loss of coolant inventory; and
- (iii) Combinations of failures selected on the basis of PSAs (e.g., Combination of anticipated operational occurrences or postulated accidents with a common cause failure affecting the system designed for mitigating the event of concern).

4.8.3.3. If manual interventions are to be depended upon for ensuring safety after a failure, the time available for operator actions should be considered.

4.9. **Design Considerations**

4.9.1. The performance of SSCs for fuel storage should meet the acceptance criteria established for the different operational states and accident conditions.

4.9.2. Stresses caused by load combinations should not exceed the stress limits defined by the codes used for the design of the SSCs.

4.9.3. Criticality should be prevented in all operational states and accident conditions with specified margins.

4.9.4. **Fuel storage capacity**

4.9.4.1. The fuel storage capacity should be designed in accordance with the fuel management policy with specific design capacity and positions for the storage of fuel. Fuel management policy should address the onsite storage of new fuel and spent fuel considering the fuel cycle being followed and lead times involved.

4.9.4.2. In the design of spent fuel storage facility, adequate capacity for spent fuel storage should be provided to allow sufficient radioactive decay time and removal of residual heat before removal from the spent fuel storage pool.

4.9.4.3. The storage capacity should allow for storage of all expected discharged fuel (according to the fuel management policy) and additional storage locations for unloading one full reactor core. In case of common spent fuel storage facility for a twin unit, there should be enough unused capacity to permit full discharge of at least one reactor core.

4.9.5. **Wet storage of spent fuel**

4.9.5.1. For wet storage of spent fuel, adequate coolant inventory should be maintained over the top of the spent fuel for shielding in all operational states and accident conditions:

- (a) The water level in the pools should be appropriate for radiological shielding of the operating personnel during normal operation and under anticipated operational occurrences.
 - (b) Substantial coolant inventory in the pools should be maintained for radiological shielding during design basis accidents.
 - (c) Ensure availability of continuous monitoring of water level under Station Black Out (SBO) of extended duration, extreme external events and accident conditions.
- 4.9.5.2. For wet storage of spent fuel, decay heat removal should be adequate to maintain spent fuel storage pool temperature at acceptable levels for operating personnel and for normal operation of purification system under all normal operating conditions, including high decay heat loads associated with refuelling. For anticipated operational occurrences, decay heat removal capability should be promptly restored for attaining pool temperature to normal operating conditions without reaching steaming conditions. In accident conditions, adequate removal of decay heat should be maintained.
- 4.9.6. For a wet storage of new fuel, the water conditions and rack layout should ensure the specified limits of subcriticality margins. Moreover, strict observance of the requirements for water chemistry should minimize the corrosion of the fuel cladding and the storage components.
- 4.9.7. For wet and dry storage systems that use fixed solid neutron absorbers, a lifetime surveillance programme should be put in place to ensure that the absorbers are installed and that they have not lost their effectiveness or been displaced.
- 4.9.8. When new fuel are stored outside their sealed transport containers, the ventilation system should be used to prevent dust and other airborne particles from entering the new fuel storage area.
- 4.10. **Reliability**
- 4.10.1. The design of SSCs important to safety of fuel storage should be consistent with their design bases with sufficient reliability and effectiveness.
- 4.10.2. The reliability of the design for fuel storage systems should be such that the possibility of conditions arising that could lead to a large radioactive release is practically eliminated so as to avoid high radiation fields on the site.
- 4.10.3. The reliability of the different means designed to operate in different operational and accident conditions should be commensurate with the safety significance of the function to be accomplished.
- 4.10.4. Different factors influencing the reliability should be considered to achieve the adequate reliability of different systems necessary to remove decay heat from spent fuel storage and to maintain an adequate coolant inventory in the pool such as:
 - (a) Safety classification and the associated engineering rules for design and manufacturing of individual SSCs.
 - (b) Design criteria relevant for the systems (number of redundant trains, seismic qualification, qualification to environmental conditions, power supplies).
 - (c) Consideration of vulnerabilities for common cause failures and related design provisions (by means of, for example, diversity, separation, independence).

- (d) Layout provisions to protect the system against the effects of internal and external hazards.
 - (e) Design provisions for monitoring, inspection, testing and maintenance.
- 4.10.5. For normal operation, anticipated operational occurrences and accident conditions, the heat removal capacity should be designed taking into account maximum heat loads and maximum heat sink temperature.
- 4.10.6. For all safety classes identified for SSCs, corresponding engineering design rules should be specified and applied. These include:
 - (a) Use of appropriate codes and standards
 - (b) Proven engineering practices
 - (c) Conservative safety margins
 - (d) Qualification of the components and equipment for design loads and conditions.
- 4.10.7. **Reliability for operational states**
 - (a) Gates separating the fuel pools from other pools or compartments should be water-tight under normal operating conditions and during anticipated operational occurrences (i.e., gates with pneumatic seals should be provided with reliable back-up air supplies to maintain pressure following a loss of offsite power).
 - (b) Provisions should be implemented to detect, locate, collect and isolate (or) repair any leakage through the pool metallic liners.
 - (c) The cooling system operated in normal operation should be designed to maintain the coolant temperature below the maximum temperature specified for normal operation despite the unavailability of components of the system for maintenance purposes.
 - (d) The cooling system should be designed to maintain the coolant temperature below the maximum temperature specified for anticipated operational occurrences.
- 4.10.8. **Reliability for accident conditions**
 - (a) The system(s) required to remove decay heat in design basis accidents should be designed to meet the single failure criterion.
 - (b) The forced cooling system required to remove decay heat in design basis accidents should be supplied with emergency power.
 - (c) A single equipment failure or piping break in the forced cooling system should not lead to the total loss of cooling.
 - (d) Means (e.g. isolation valves, anti-siphoning devices) should be implemented to minimize the loss of coolant in the event of a pipe break.
 - (e) The system required to remove decay heat in accident conditions should be designed so that it can be restarted even in conditions in which the pool water sub-cooling is lost.
 - (f) Water storage pools should not be designed with penetrations below the minimum water level required for shielding and cooling of stored spent fuel in accident conditions.

- (g) The volume of the spent fuel storage pool should be adequate to ensure that in the event of loss of forced cooling, a sufficient period of time is available to allow for implementation of corrective measures before the water reaches the boiling point.
- (h) Design layout provisions should be implemented to prevent from uncovering the top of the spent fuel and to maintain a sufficient radiological shielding in the case of inadvertent or accidental leakage through a gate between the spent fuel storage pool and a drained fuel handling compartment(s).
- (i) The spent fuel storage racks / trays should be designed to maintain adequate heat transfer from each spent fuel through natural convective flow to prevent nucleate boiling within the fuel.
- (j) Design provisions should be implemented to compensate for the loss of coolant by evaporation and potential leakage associated with postulated accidents. Such provision includes a permanently installed system that provides makeup to deal with coolant losses.
- (k) Additional provisions should be implemented to facilitate use of non-permanently or other permanently installed equipment to recover the coolant inventory and decay heat removal capability. Such provisions should be in an area where access can be ensured. Connecting devices should be provided outside of the spent fuel storage area. Typical provisions can include:
 - (i) Connection to other permanently installed systems, for example, service water system and the fire water system.
 - (ii) Installation of piping and fittings to allow connection of cooling system or delivery of makeup water using portable equipment in areas away from the spent fuel storage pool.
 - (iii) Provisions for ventilation of the spent fuel storage pool area to remove decay heat and steam.
 - (iv) Adequate provisions to recover forced cooling of the spent fuel storage pool in the event of extended loss of AC power (i.e., station blackout).

4.11. **Structural Integrity**

- 4.11.1. Structural integrity of structures and operability of components designed to accomplish the fundamental safety functions should be maintained throughout their lifetime in all operational states and accident conditions during which they are designed to operate. The design should take into account the relevant loading conditions (e.g., seismic, stress, temperature, corrosive environment, radiation levels), and should consider creep, fatigue, thermal stresses, corrosion, changes in material properties with time (e.g. concrete shrinkage) and potential for degradation of reinforcement considered.
- 4.11.2. Loads and load combinations considered in the design should be identified, justified and documented. Typical examples of design loads, load combinations for strength analyses and evaluation of stress analysis results are given in the subsequent paras.
- 4.11.3. Design loads that should be considered in the design of the new fuel storage racks include:
 - (a) Static loads

- (b) Fuel handling machine/equipment uplift forces on the racks (with an assumption that the forces are applied to a postulated stuck fuel)
 - (c) Seismic loads of the safe shutdown earthquake.
- 4.11.4. Design loads that should be considered in the design of the spent fuel storage racks include:
 - (a) Items (a), (b) and (c) in the above para
 - (b) Dynamic loads resulting from the fuel drop accident
 - (c) Thermal loads.
- 4.11.5. Design loads that should be considered in the design of the fuel storage structure include:
 - (a) Seismic loads (SSE & OBE) and in case of wet storage, associated hydro-dynamic loads due to water movement (sloshing) in the storage area
 - (b) Loads from thermal effects of extended loss of cooling event
 - (c) Static loads.
- 4.11.6. Methods for combining the individual loads should be established according to applicable codes and standards.
- 4.11.7. The allowable stresses for given loading conditions should comply with the applicable limits of proven codes and standards. If no such standards apply, justification should be provided for the allowable stress levels selected.
- 4.12. **Safety Classification**
- 4.12.1. Any SSCs with a major bearing on the prevention of a criticality accident, cooling of fuel, confinement of radioactive substances, radiation shielding, preventing mechanical damage to or corrosion of fuel, or fire safety should be classified in terms of the safety of the fuel storage facility.
- 4.12.2. SSCs important to safety of fuel storage should be classified and assigned to the appropriate seismic categories in accordance with the recommendations and guidance given in AERB Safety Guide on 'Safety Classification and Seismic Categorisation for Structures, Systems and Components of Nuclear Power Plants' (AERB/NPP/SG/D-1).
- 4.13. **Environmental Qualification**
- 4.13.1. SSCs should be qualified to perform their intended functions in the entire range of environmental conditions that might prevail prior to or during their operation or else should be adequately protected from those environmental conditions.
- 4.13.2. The relevant environmental and seismic conditions that may prevail prior to, during and following an accident; the ageing of SSCs throughout the lifetime of the plant; synergistic effects and margins should all be taken into consideration in the environmental qualification.
- 4.13.3. Environmental qualification should include the consideration of such factors as temperature, pressure, humidity, radiation levels, radioactive aerosols, vibration, water spray, steam, contact with chemical agents and their combination.
- 4.13.4. Environmental qualification should be carried out by means of testing or analysis or by a combination of these.

- 4.13.5. For components subject to the effects of ageing by various mechanisms; a design life, inspection program and replacement frequency (if appropriate) should be established. In the qualification of such components, samples should be subjected to artificial ageing experiments to simulate end of their design life before being tested under design basis accident conditions.
- 4.13.6. Qualification data and results should be documented and kept available as part of the design documentation.
- 4.13.7. SSCs important to safety of fuel storage and handling should be qualified in accordance with the recommendations and guidance given in AERB Safety Guide on 'Equipment Qualification for Nuclear Power Plants' (AERB/NPP/SG/D-27).
- 4.14. **Prevention of Criticality**
- 4.14.1. When subcritical margin cannot be maintained by control of geometry, then additional means such as fixed neutron absorbers should be applied. If fixed neutron absorbers are used, it should be ensured by proper design and fabrication that the absorbers will not separate or displace during operational states and accident conditions and during or after an earthquake.
- 4.14.2. When soluble absorbers are used to meet the design limit for accident conditions, it should be demonstrated that criticality is not reached without taking credit of soluble absorber in normal operation.
- 4.14.3. Any geometric deformation of the fuel and storage equipment that could be caused by any postulated initiating event should be taken into account. Consideration should also be given to routine fuel movement, which could bring the fuel being moved into close proximity with stored fuel or in which fuel could be dropped and fall onto or next to stored fuel.
- 4.14.4. The lattice of the spent fuel storage racks should be designed to prevent any reduction of subcriticality margins viz., entrapment of air or steam during fuel handling or storage.
- 4.14.5. Provisions should be made in the design of fuel storage racks to prevent placement of fuel into positions not justified for their storage.
- 4.14.6. In determining the subcriticality, a conservatively calculated value of the effective multiplication factor or the infinite multiplication factor alternatively should be used. General guidance for criticality safety in the handling of fission material is described in AERB Safety Guide on 'Criticality Safety in Fissile Material handling Facilities' (AERB/FCF/SG-3). The following typical design aspects should also be taken into consideration:
- (a) An adequate subcriticality margin under all credible conditions should be demonstrated, with account taken of all the uncertainties in the calculation codes and experimental data.
 - (b) If the enrichment is variable within a fuel, exact modelling should be used or a conservative uniform enrichment of the fuel should be assumed.
 - (c) If the enrichments for the fuel differ, the design of the new fuel storage racks should generally be based on the enrichment value corresponding to that of the fuel with highest enrichment or the most reactive fuel.

- (d) All spent fuel should be assumed to have a burnup and enrichment that result in maximum reactivity, unless credit for burnup is assumed on the basis of a justification that includes appropriate measurements confirming the calculated values for fissile content or depletion level prior to storage of the fuel.
- (e) Where the fuel design is variable and/or there are uncertainties in any data relating to the fuel (in terms of design, geometrical and material specifications, manufacturing tolerances and nuclear data), conservative values should be used in all subcriticality calculations. If necessary, a sensitivity analysis should be performed.
- (f) The inventory of the fuel in the storage racks should be assumed to be at the maximum capacity of the design.
- (g) Credit should not be claimed for neutron absorbing parts or components of fuel storage racks unless they are permanently installed.
- (h) The fuel storage racks should be designed so that lateral, axial and bending loads leading to unacceptable dimensional change of the fuel is prevented;
- (i) Appropriate conservative assumptions for moderation should be made.
- (j) Consideration should be given to the effects of neutron reflection, by taking into account precisely the design of the fuel storage racks including materials, dimensions and spacing between the fuel storage racks and the structures near the racks (e.g., floors and walls).
- (k) Assumptions of neutronic decoupling for different storage zones, if applicable, should be substantiated by appropriate calculations.

4.15. **Radiation Protection**

- 4.15.1. The design of a fuel storage facility should be such as to provide adequate radiation protection of radiation workers, the public and the environment in accordance with the requirements established in AERB Safety Code on 'Radiation Protection in Nuclear Fuel Cycle Facilities' (AERB/NF/SC/RP) and AERB Safety Guide on 'Radiation Protection Aspects in Design for Nuclear Power Plants' (AERB/NPP/SG/RP-1).
- 4.15.2. Suitable ventilation system(s) and shielding should be implemented to maintain the concentrations of airborne radioactive material and the exposure of radiation workers to radiation as low as reasonably achievable in operational states without exceeding limits specified by AERB.
- 4.15.3. Suitable confinement and filtration systems should be implemented to minimize radiological consequences to the public and the environment and to keep them below the limits specified for operational states and accident conditions by AERB.
- 4.15.4. For the design of shielding, bounding conditions such as initial fuel composition, burnup and cooling times for gamma and neutron radiation, the inventory at the maximum design capacity of the spent fuel storage facility, the effects of axial burnup on gamma and neutron sources, the mobility of activated crud and the activation of non-fuel hardware should be considered. Also, the following aspects should be considered to meet shielding requirements:

- (a) For analysis, it should be assumed that all the positions, which may contain fuel, are occupied with fuel that has reached the maximum design burn up and the decay time is the minimum that could occur as a result of the unloading procedures and schedule.
 - (b) Handling equipment should be designed to prevent inadvertent placing or lifting of spent fuel into unintended positions.
 - (c) Entire movement of spent fuel should be adequately monitored. Provision should exist to barricade/shield any location, in case the fuel gets stuck during its movement.
- 4.15.5. 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.
- 4.15.6. In dry storage, new fuel containing fissionable material recovered through reprocessing emits significant radiation. In such cases, handling and storage should include additional shielding to limit the exposure to operating personnel within acceptable levels.
- 4.16. **Heat Removal**
- 4.16.1. Spent fuel storage facilities should be designed with heat removal systems that are capable of reliably cooling the stored spent fuel when the fuel is initially 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 other safety related components in the facility should not exceed their maximum allowable temperatures. Active heat removal systems performing a safety function should be designed to withstand conditions in all operational states and accident conditions and should satisfy the single failure criterion.
- 4.16.2. In the design of heat removal systems for a spent fuel storage facility, appropriate provision should be made for maintaining fuel temperature within acceptable limits during handling and transfer of spent fuel.
- 4.16.3. 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 of the facility, the post-irradiation minimum cooling interval and the maximum 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 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 facility. The cooling medium should be compatible with the cladding and fuel.
- 4.16.4. The decay heat removal system should be designed as follows:
 - (a) To provide diversity to the extent practicable and redundancy for reducing common cause failures, including external events.
 - (b) To provide detection and mitigation measures against postulated leak in decay heat removal system.

- 4.16.5. 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, natural cooling may be adequate later in a facility's lifetime, even if forced cooling was initially necessary. An analysis should be performed to determine how long forced cooling will be required, with due consideration given to maintaining operability of the forced cooling system and the potential effects of its failure.
- 4.16.6. The use of redundant and/or diverse heat removal systems may be appropriate, depending on the type of storage system used and the potential for fuel overheating over an extended period of time.
- 4.16.7. In Sodium Cooled Fast Reactors, the spent fuel are stored in the in-vessel storage locations in the reactor / ex-vessel sodium tank system for a specified time based on their burn-up before they are transferred to the spent fuel storage area to reduce the decay heat. The heat removal system should be designed to prevent freezing of the sodium coolant to avoid blockage of coolant circulation. In case of ex-vessel sodium tank system, there should be diverse means for monitoring the level of sodium in the storage tank and for detecting leak.
- 4.16.8. The spent fuel storage pool cooling system should keep fuel temperatures low enough that, even if cooling is lost, operators should have substantial time to restore cooling before boiling could occur in the spent fuel storage pool. Design should also have backup arrangements to cool the spent fuel storage pool, using temporary equipment that would be available even after fire, explosion, or other unlikely event that could damage large portions of the facility and prevent operation of normal cooling systems.
- 4.17. **Containment of Radioactive Material**
- 4.17.1. In the design of fuel storage and handling systems, appropriate and adequate measures should be provided for containing radioactive material so as to prevent an uncontrolled release of radionuclides to the environment. The fuel cladding should be protected during storage against degradation in operational states and accident conditions and also during retrieval of the fuel. As necessary, and as far as possible, the effectiveness of the fuel storage containment system should be monitored to determine whether corrective action is necessary to maintain safe storage conditions.
- 4.17.2. Ventilation and off-gas systems should be provided where necessary to ensure collection of airborne radioactive particulate material 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 in the external environment, which could be detrimental to the integrity of the fuel cladding or other safety related component.
- 4.17.3. Appropriate and adequate measures should be provided for storage, management and disposal of radioactive waste.
- 4.18. **Materials**
- 4.18.1. Structural materials should be selected on the basis of accepted codes and standards. Consideration should be given to potential cumulative effects of radiation on materials likely to be subjected to significant radiation fields. In addition, potential thermal effects on material degradation should also be considered.

- 4.18.2. The material used for the pool liner and other structure materials in contact with coolant (e.g. racks/trays) should have low sensitivity to corrosion phenomena taking into account coolant chemistry.
- 4.18.3. Materials in direct contact with fuel should be compatible with, 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 that might significantly degrade the integrity of the spent fuel during their storage.
- 4.18.4. Compatibility of decontamination materials with the operating environment should be considered.
- 4.18.5. Materials used in the construction of fuel storage systems should comply with the recommendations with regard to fire hazard and allow easy decontamination of surfaces.
- 4.18.6. For storage racks that use fixed solid neutron absorbers, it should be possible throughout the operating lifetime of the storage racks to demonstrate that:
 - (a) Fixed solid neutron absorbers have not lost their effectiveness.
 - (b) Fixed solid neutron absorbers are chemically compatible with the other rack components and are chemically stable when immersed in water.
- 4.19. **Monitoring**
- 4.19.1. Adequate and qualified instrumentation should be implemented for monitoring air activity in fuel storage and fuel handling areas in operational states, during and after accident conditions.
- 4.19.2. Areas in which fuel is handled and stored should be provided with suitable radiation monitoring equipment i.e. low or high and/or wide range with alarms for the protection of operating personnel. This should include an adequate number of radiation monitors. Provisions should be made for continuous air monitoring in any area in which airborne radioactive material may be released during the handling of fuel.
- 4.19.3. Instrumentation required for monitoring of key parameters that will be used in accident management should have redundancy as well as functionality in Design Extension Conditions, as required.
- 4.19.4. The following details should be considered for wet storage of spent fuel:-
 - (a) Adequate and qualified instrumentation should be implemented for continuous monitoring of water level in the spent fuel storage in operational and accident conditions. Reliable wide-range level instrumentation should be implemented for monitoring under accident conditions.
 - (b) Adequate and qualified instrumentation should be implemented for monitoring water temperature in the fuel storage in operational and accident conditions.
 - (c) Adequate and qualified instrumentation should be implemented for monitoring water activity in the spent fuel storage for operational states and relevant accident conditions.
 - (d) Adequate means should be implemented for monitoring chemical parameters in the spent fuel storage pool in operational states, including monitoring concentration of soluble absorbers, as appropriate.

4.20. **Design Considerations For Spent Fuel Storage Pool Water Purification Systems**

- 4.20.1. Systems for spent fuel storage pool water purification should be designed to ensure:
- (a) Radioactive, ionic and solid impurities arising from activation products, damaged fuel and other materials can be removed from the water so as to ensure that the activity level in the pool water are maintained within the specified limits.
 - (b) The limits relating to the chemistry of the pool water (for instance, boron concentration, content of chloride, sulphate and fluoride as appropriate, pH value and conductivity) which are defined for operation in relation to maintaining subcriticality and minimizing corrosion are complied with.
 - (c) The clarity of water can be maintained at an acceptable level so that fuel handling operations underwater can be performed and monitored.
 - (d) Capacity of purification system is able to purify the water volume in the spent fuel storage pool within a given period of time.
 - (e) Control of microbial growth, as appropriate.
- 4.20.2. Systems for spent fuel storage pool water purification should be designed to be able to remove impurities and suspended particles from the surface of the pool water.
- 4.20.3. The design for the spent fuel storage pool water purification systems should provide measures for preventing the unacceptable buildup of contamination in all storage areas and permitting contamination to be reduced to acceptable levels if buildup does occur. Piping should be designed with a minimum number of flanges and other features (such as traps or loops) as practicable in which radioactive material may accumulate.
- 4.20.4. The maximum coolant temperature in normal operation should not exceed the maximum permissible temperature of the purification equipment (e.g., ion exchange).
- 4.21. **Illumination Equipment**
- 4.21.1. All the fuel handling areas including storage areas should be provided with normal and emergency illuminating equipment. For storage pool, consideration should be given for providing under-water lighting near the work areas and means for replacement of underwater lamps.
- 4.21.2. Materials used in underwater lighting should be compatible with the environment and, in particular, should not undergo degradation due to radiation, unacceptable corrosion or water contamination.

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

5.1. General

- 5.1.1. Fuel handling systems are mainly used to load, unload and reload the reactor core and also to transfer spent fuel to spent fuel pool. The term "fuel" is a generic term that covers the nuclear fuel used in different types of Nuclear Power Plants, while "Fuel Bundle", "Fuel Assembly" and "Fuel Sub Assembly" are specific terms used to describe the nuclear fuel for PHWRs, LWRs and SFRs respectively. The specific terminology used depends on the type of reactor being discussed. The brief description of fuel handling systems used in various types of NPPs is given below:-

Pressurized Heavy Water Reactors

Pressurised Heavy Water Reactors (PHWRs) are generally fuelled by natural uranium and hence have low excess reactivity. Due to this, on-power refuelling on regular basis is necessary for their sustained operation. Fuel handling system mainly performs the functions to load, unload and reshuffle the fuel bundles in the reactor core and to transfer the spent fuel bundles to the spent fuel storage pool.

Refuelling in PHWR is normally carried out on-power by employing two fuelling machines, located one each on either side of the reactor, which work in unison. During refuelling, both fuelling machines are clamped on the reactor channel to be refuelled and establish hydraulic communication with the channel by removing the sealing plugs. Normally eight fuel bundles are loaded by upstream fuelling machine in the coolant channel and equal number of spent fuel bundles are received in the downstream fuelling machine and transferred to the Fuel Transfer System. The spent fuel bundles are further transferred to the spent fuel storage pool remotely for storage till their shifting to AFR / reprocessing facility or disposal.

Fuel handling system used in Pressurized Heavy Water based NPPs (PHWRs) includes:

- System to transport new fuel bundles to a fuelling machine (i.e., fuel transfer equipment)
- System to load new fuel bundles into the core and discharge spent fuel from the core with reactor on-power (i.e., fuelling machines)
- System to transfer the spent fuel bundles discharged from the fuelling machine to the spent fuel storage pool (fuel transfer system)
- Auxiliary equipment such as shielding cum sealing doors, roll-on-shield, radiation shielding windows etc.
- Material handling equipment (pool gantry, cask handling crane, Auxiliary crane or hoist etc.).
- Fuel handling tools (e.g., fuel bundle lifting tools, tray handling tool, cage handling tool etc.) and storage trays
- Process and control systems
- Spent fuel inspection, sniffing and canning facility

Typical scheme for the handling and storage of fuel bundles in PHWRs is shown in Figure-1.

Light Water Reactors

Refuelling in Light Water Reactors (LWRs) is carried out during refuelling shutdown. In general, new fuel assemblies are first received and stored in a designated dry storage area where they are inspected. The new fuel assemblies will then be transferred to wet storage (located inside Reactor Building) before being loaded into the core. Refuelling machine is used for loading and unloading the fuel assemblies in reactor core and spent fuel storage pool. Spent fuel assemblies are stored and cooled in the wet storage facility. After the required period, cooled spent fuel assemblies are transported to AFR / Reprocessing Facility.

Fuel handling system used in Light Water based NPPs includes:

- Refuelling machine to handle the new or spent fuel assemblies for loading into and unloading from the core and move the fuel assemblies between the core and spent fuel storage pool
- System to transfer fuel assemblies between the reactor pool and the spent fuel storage pool through the fuel transfer tube (for pressurized water reactors, as applicable)
- Fuel handling tools (e.g., control rod drive shaft unlatching tool, new fuel assembly handling tool, spent fuel assembly handling tool)
- System/equipment for the handling of fuel transport casks

Typical scheme for the handling and storage of fuel assemblies in LWRs is shown in Figure-2.

Sodium Cooled Fast Reactors

Fuel handling in Sodium cooled Fast Reactors (SFRs) is carried out under reactor shut down condition after sodium temperature is lowered and maintained at a specified value above its melting point. The types of sub assemblies handled during normal fuel handling are fuel sub assemblies, blanket sub assemblies and absorber sub assemblies. However, irradiated core components like reflector sub assemblies and shielding sub assemblies are also handled by the fuel handling system whenever required. The handling operation of new fuel sub assembly involves receipt, inspection, storage and loading of the sub assemblies into the reactor. Whereas handling operation of spent fuel sub assembly involves in-vessel transfer, storage within the reactor main vessel at designated storage locations, discharge outside from the reactor main vessel, washing and transferring to spent fuel storage pool for storage.

Typically, new fuel sub assemblies are received at fuel building in fresh fuel transport cask. These assemblies are unloaded from the cask using fresh sub assembly transfer gripper. The new fuel sub assemblies are further stored in the fresh fuel storage bay after inspection. At the time of fuel handling, these assemblies are transferred to fresh sub assembly transfer chamber where air medium is changed to inert atmosphere. New fuel sub assemblies are further transferred to ex-vessel transfer position (EVTP) through an inert cell called fuel transfer cell. Machines are provided inside the fuel transfer cell (Fresh sub assembly cell transfer machine and spent sub assembly cell transfer machine) for handling new and spent fuel sub assemblies respectively. New fuel sub assemblies

are preheated to avoid thermal shock before loading into the sodium filled pot. They are transferred to the in-vessel transfer position (IVTP) within the reactor main vessel by ex-vessel transfer machine (EVTM).

The fuel sub assemblies are further handled from IVTP by the in-vessel transfer machine (IVTM) to load them within the reactor core by the combined rotation of rotatable plugs and IVTM. Using IVTM and rotatable plugs, the spent fuel sub assemblies are transferred from the core to in-vessel storage location within the reactor main vessel for cooling. After sufficient cooling, spent fuel sub assemblies are transferred one by one to sodium filled pot of EVTMM positioned at IVTP using IVTM and rotatable plugs.

The spent sub assemblies are further transferred to EVTP by EVTMM. Using spent sub assembly cell transfer machine, the spent sub assemblies are transferred to spent fuel washing facility for sodium removal. After sodium removal, the spent fuel sub assemblies are stored in the water filled spent fuel storage bay for further cooling. Failed fuel sub assemblies are canned after washing and stored in the spent fuel storage bay at earmarked locations. Transfer of spent fuel sub assemblies from the fuel transfer cell to spent fuel storage bay is carried out by an underwater trolley and spent sub assembly transfer machine operating over the bay. Spent fuel sub assemblies are inspected for dimensional change within the storage bay by spent fuel inspection facility mounted over the storage bay. After the required period, cooled spent fuel sub assemblies are transported to AFR / Reprocessing Facility.

Fuel handling system used in Sodium Cooled Fast Reactor based Nuclear Power Plants (SFRs) includes:

- System/equipment to receive, inspect, store, condition, and transfer the new fuel sub assemblies to the reactor vessel (e.g., fresh sub assembly receiving facility, fresh sub assembly inspection facility, fresh sub assembly transfer chamber, fresh sub assembly preheating facility, cell transfer machine, ex-vessel transfer machine etc.)
- System/equipment to handle the new or spent fuel sub assemblies for loading and unloading the core within the reactor vessel (e.g., rotatable plugs and in-vessel transfer machine)
- System/equipment to transfer spent fuel sub assemblies between the reactor vessel and the spent fuel storage pool (e.g., Ex-vessel transfer machine, sodium cleaning facility, inert transfer cell, cell transfer machine etc.)
- System/equipment to move and locate fuel sub assemblies at fuel storages (e.g., spent sub assembly transfer machine, fresh sub assembly transfer gripper etc.)
- System/equipment for the handling of fuel transport casks

Typical scheme for the handling and storage of fuel sub assemblies in SFRs is shown in Figure-3.

- 5.1.2. The design basis of items important to safety are to be established as per requirements specified in AERB Safety Code on ‘Design of Pressurized Heavy Water Reactor based Nuclear Power Plants’ (AERB/NPP-PHWR/SC/D, Rev.2), ‘Design of Light Water based Nuclear Power Plants’ (AERB/NPP-LWR/SC/D) and ‘Design of Sodium Cooled Fast Reactor based Nuclear Power Plants’ (AERB/NPP-SFR/SC/D) taking into account the following:

- (a) The safety function(s) to which they contribute
- (b) The postulated initiating events they have to cope with
- (c) The protection against the effect of internal hazards
- (d) The protection against the effect of external hazards
- (e) The safety classification
- (f) Design limits or acceptance criteria
- (g) The engineering design rules applicable to the system
- (h) Instrumentation and control and monitoring
- (i) Provisions against common cause failures
- (j) Environmental conditions for qualification
- (k) Selection of materials.

5.2. **Defence in Depth**

The probable common cause failures of the decay heat removal means should be identified and the consequences should be assessed during fuel handling operation. In the cases that may result in overheating of spent fuel bundles, the identified vulnerabilities of the decay heat removal means should be removed by the implementation of diverse and / or redundant provisions.

5.3. **Safety Functions**

5.3.1. The safety functions during fuel handling operations are:

- (a) Ensuring subcriticality at all times.
- (b) Prevention of physical damage to the fuel and maintaining the integrity of fuel when they are being handled.
- (c) Ensuring adequate heat removal rate.
- (d) Radiation exposure and the release of radioactive substances during the handling of spent fuel are kept as low as reasonably achievable.

5.3.2. The specific safety functions associated with on-power refuelling of PHWRs are:

- (a) Maintaining integrity of pressure boundary of the reactor coolant system.
- (b) Ensuring cooling of spent fuel bundles in the fuelling machine under all design basis events.
- (c) Consistent with (a) and (b) above, maintaining the loads on fuel bundles within specified acceptable limits.

5.4. **Layout**

Design of equipment and components for fuel handling system should consider the relevant requirements related to the layout as indicated in section 4.4. The additional design requirements associated with the layout of fuel handling system and associated process system in PHWRs are as follows:

- (a) the layout should provide for bringing the fuelling machine to an accessible service area for maintenance even when reactor is in operation;
- (b) the layout should facilitate access to fuel transfer equipment for maintenance even when reactor is in operation;
- (c) the layout should facilitate access to process system components to the extent necessary to carry out trouble shooting and resolving problems; and
- (d) passage of fuelling machine and fuel transfer tubes through the containment should meet the requirements of containment isolation.

5.5. **Design Basis Events**

- 5.5.1. Initiating events relevant for the design of fuel handling systems should include equipment failures, operational errors potentially leading to a significant release of radioactive materials, or to a significant direct radiation exposure of operating personnel. Such postulated initiating events should be identified to design the preventive measures. The methodology for identifying events relevant to design of fuel handling systems is given in AERB Safety Guide on 'Design Basis Events for Water Cooled Nuclear Power Plants' (AERB/NPP-WCR/SG/D-5, Rev.1) and Safety Guide on 'Deterministic Safety Analysis for Sodium Cooled Fast Breeder Reactors based Nuclear Power Plants' (AERB/NPP-SFR/SG/D-19) respectively.
- 5.5.2. Boundary conditions for the events should be determined to define necessary performance capabilities of the equipment designed to mitigate their consequences.
- 5.5.3. Potential dropping of fuel being handled should be considered as a postulated initiating event. Potential release of radioactive material should be considered regarding the protection of radiation workers and the environment.
- 5.5.4. Mechanical damage caused by excess handling force beyond specified limits or drop should be considered among internal events unless precluded by suitable interlocks.
- 5.5.5. The operational errors such as wrong placement of fuel and uncontrolled drop of fuel should be considered as postulated initiating events in cases where fuel handling constraints are essential for maintaining an adequate margin of sub criticality. [*specific to LWRs/SFRs*]

5.6. **Internal Hazards**

- 5.6.1. In general, the protection of fuel handling systems against internal hazards should be primarily assured by the layout of the building in which they are installed.
- 5.6.2. All safety related SSCs should be designed to withstand loads resulting from or be protected against the effects of internal hazards. Protection should also consider the consequences of the failure of unprotected equipment.
- 5.6.3. The redundant systems / equipment should be segregated to the extent possible or adequately separated to prevent common cause failures which may result in loss of safety functions performed by the system.
- 5.6.4. The effect of a single hazard should not result in failure of all cooling capability of fuel handling system.

- 5.6.5. Design methods and construction codes used should provide adequate margins to prevent the cliff edge effects in the event of a minor increase in the severity of an internal hazard above the design basis.
- 5.6.6. Typical examples of internal hazards which influence the design of fuel handling system are:-
- 5.6.6.1. Internal flooding
The design and layout should provide protection against internal flooding.
- 5.6.6.2. Pipe breaks
Equipment performing the safety functions should be protected against the effect of high-energy pipe break.
- 5.6.6.3. Fire
All relevant guidelines provided in AERB Safety Standard on 'Fire Protection systems for Nuclear Facilities' (AERB/NF/SS/FPS, Rev.1) and other applicable AERB Safety Guides to reduce the probability of a fire (including sodium fire in case of SFRs) to start, to limit its propagation, to protect items important to safety and to prevent the loss of fundamental safety functions should be implemented.
- 5.7. **External Hazards**
- 5.7.1. Equipment and components of fuel handling systems should be designed or protected against the effects of external hazards and their combination.
- 5.7.2. Seismic design specifications for fuel handling systems should be established on the basis of consequences with regard to potential damage to fuel (stored or in handling), release of radioactive materials in the building and necessity to operate the equipment during and after an earthquake.
- 5.7.3. The handling equipment should be designed to keep integrity of the fuel and not to drop the loads in the event of an earthquake.
- 5.7.4. The fuelling machines should be designed to ensure integrity of the reactor coolant pressure boundary during refuelling operation in case of an earthquake. [*specific to PHWRs*]
- 5.7.5. The protection should primarily rely on an adequate layout and design of the buildings at the site.
- 5.7.6. In the event of external hazards, decay heat removal from spent fuel being handled should be ensured.
- 5.7.7. Methods of design, and construction codes & standards used should provide adequate margins to prevent cliff edge effects in the event of an increase of the severity of the external hazards.
- 5.7.8. Margins provided in the design of the SSCs ultimately necessary to avoid unacceptable radiation doses and a large radioactive release should be such that it can be demonstrated that the integrity of the structures, and the operability of those systems and components would be preserved in case of natural hazards causing loads exceeding those resulting from the hazard evaluation at the site. In this regard, criticality and unacceptable

radiation doses (also sodium fires in case of SFRs) should be prevented, and spent fuel cooling capability should be preserved.

5.8. **Design Limits**

5.8.1. Stresses caused by design load combinations should remain below allowable limits established for fuel, individual components and equipment of fuel handling systems.

5.8.2. Limits and conditions for the operation of handling equipment (e.g., speed for lifting, lowering, rotating and traversing movement, restricted movement of handling equipment, limitation on lifting travel to restrict the reduction in shielding, etc.) should be defined and not be exceeded by provision of interlocks or by other suitable provisions.

5.9. **Reliability**

5.9.1. The fuel handling system should be reliable. The reliability should take into account consequences of the failure of the equipment. The following factors contribute for achieving the reliability:

(a) Safety classification and the associated engineering rules for design and manufacturing of individual SSCs.

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

5.9.2. Fuel handling systems should be designed by means of conservative methods for load bearing parts.

5.9.3. Reliability assessment should be conducted to verify whether reliability target has been achieved, wherever required.

5.10. **Structural Design**

5.10.1. By analyses, it should be demonstrated that stresses caused by load combinations meet the design limits established for individual structures and equipment of fuel handling systems.

Typical examples of loads considered in the analyses include:

(a) Static loads

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

(c) Dynamic loads derived from abnormal operation of equipment and non-symmetrical loads

(d) Seismic loads defined according to the seismic categorization

(e) Thermal loads

(f) Load imposed in-core due to dimensional changes (swelling, bowing etc.) of fuel due to irradiation effects.

5.10.2. Methods for combining the individual loads should be established according to applicable codes and standards.

5.10.3. The analysis should take credit of equipment provided to limit loads (through devices such as dampers or shock absorbers), and failure modes for this equipment should also be considered.

5.11. **Design Considerations**

5.11.1. **General**

- 5.11.1.1. Core loading errors during handling should be prevented by design and administrative procedures. There should be a provision to assess the subcriticality of the core and any unacceptable reduction in subcritical margin due to core loading errors should give alarms and should automatically stop the operation.
- 5.11.1.2. The fuel handling system should be designed to prevent criticality with a specified margin by physical means or by physical processes.
- 5.11.1.3. The systems used for handling fuel should be designed so that abnormal handling operation cannot result in unacceptable loads for the fuel, by means of physical limitations or automatic protection actions (passive or actuated by I&C system). Methods, as applicable, may be used including:
 - (a) Restriction of the force applied by the actuator.
 - (b) A specified speed limitation.
 - (c) Provision of slipping clutches within the drive mechanisms.
 - (d) Automatic and continuous load sensing and registering devices linked to the hoist motor or cable.
- 5.11.1.4. Provisions should be made in the design for the use of manual operating mode that is capable of ensuring fuel into a safe state in the event of the failure of the auto mode of operation of fuel handling system.
- 5.11.1.5. Handling equipment should be designed to prevent leakage and escape of lubricants or substances which could degrade the chemistry of the coolant / pool water. Such substances either should be prevented from entering wet storage systems or, preferably, should be fully compatible with fuel, equipment and storage structures.
- 5.11.1.6. Handling equipment should have provision to prevent the inadvertent placement of fuel and core components into a position that is already occupied or into an inappropriate position.
- 5.11.1.7. The design of fuel handling system can include computerized operation management systems to manage and monitor fuel handling operations conducted in the reactor building. The computerized operation management systems can be used to prevent an inadvertent emplacement of a fuel into an inappropriate position and incorrect movements of the fuel. The reliability of this system should be appropriate to conduct fuel loading and unloading operation. The consequences of malfunctioning of this computerized operational management system should be considered.
- 5.11.1.8. Measures should be provided in the design of fuel handling systems to avoid incorrect positioning of fuelling machine / fuel transfer equipment during fuel handling operations.
- 5.11.1.9. Adequate cooling with backup arrangements should be provided for the spent fuel during movement / transit storage in the fuel handling equipment, ensuring cooling of fuel under normal and design basis events so that the clad temperature does not exceed design limits.

- 5.11.1.10. Fuel handling equipment which may be in contact with fuel should be compatible with respect to material, geometry, dimensions, continuation of flow, etc.
- 5.11.1.11. During handling of spent fuel, decay heat should be removed to keep temperatures below permissible limits with sufficient safety margin. Decay heat should be conservatively estimated taking into account all uncertainties. Possibility of fuel getting stuck for indefinite period during transit should be considered for estimating maximum temperatures. Radiological consequences of failure of all elements of a fuel should be analysed in case high temperatures are reached by cladding.
- 5.11.1.12. Provisions should be made in the design for handling and storage of failed fuel considering release of radioactivity, fuel-coolant compatibility, decay heat removal, contamination of operation area etc.
- 5.11.1.13. Design should ensure the smooth passage of fuel across all the junctions likely to be crossed in fuel handling equipment during fuel transfer operations.
- 5.11.1.14. All the containment penetrations related to fuel handling system should meet the containment isolation philosophy.
- 5.11.1.15. Interlocks should be provided in the fuel handling system to prevent erroneous operations.
- 5.11.1.16. In normal operation and in accident conditions, loads should be appropriately limited to ensure that fuel damage is not caused and that no damage is caused to the handling equipment or the structure of the spent fuel storage pool.
- 5.11.1.17. Provision should be made in the design of fuel handling system to avoid fuel dropping or getting stuck during handling and transfer operations.
- 5.11.1.18. Provision should be made in the design of fuel handling systems to avoid dropping of fuel handling tools during handling operation.
- 5.11.1.19. Design should ensure loading of fuel into its intended position and proper seating. [*Specific to LWRs/SFRs*]
- 5.11.1.20. Provision should be made in the design of fuel handling systems to facilitate the safe retrieval of fuel, if dropped accidentally during handling operations.
- 5.11.1.21. The design of all fuel handling equipment should include wherever possible, standby / emergency drives to handle contingencies involving single failure of mechanism / devices resulting in incapacitation of fuel handling equipment.
- 5.11.1.22. The design should ensure that adequate operating procedures and a system of accounting for, and control of, nuclear material can be implemented to prevent any loss of, or loss of control over, nuclear material.
- 5.11.1.23. Design should minimise the handling time for the fuel.
- 5.11.1.24. Proper material selection should be made to minimise activation and radiation damage to the handling equipment.
- 5.11.1.25. The handling crane should be designed with single failure proof features such that dropping of cask during handling is highly unlikely.
- 5.11.1.26. Instrumentation should be provided to monitor parameters of the fuel handling system that are important to safety and to alarm or initiate protective action, if required.

- 5.11.1.27. Provision should be made for checking the reactor worthiness of the fuel handling machine after each major maintenance before starting the refuelling.
- 5.11.1.28. Provision should be made for avoiding the loosening of assembly components of equipment/tools.
- 5.11.1.29. The specific safety considerations associated to SFRs are detailed below:-
 - (a) Provision should be made for controlled preheating of fuel sub assemblies prior to introducing them to hot sodium environment.
 - (b) Provision should be there in the design to inspect the space above core before fuel handling.
 - (c) Design should provide suitable means to prevent removal of insufficiently cooled fuel sub assembly located in the storage space of the core.
 - (d) Design should provide suitable means to minimise residual sodium deposits in the handling equipment.
 - (e) The design should provide means for removal of sodium adhered to the spent fuel sub assemblies during the transport from a sodium environment to a water pool, in order to prevent fuel damage and for keeping quality of the water in the pool.
 - (f) Ingress of air and moisture into cover gas and leakage of cover gas should be minimised.
 - (g) Maintain inert atmosphere till sub-assembly is washed completely.

5.11.2. **Specific design aspects for the fuelling/refuelling machine**

Pressurized Heavy Water Reactors

- (a) Protection devices (electrical and/or mechanical interlocks) should be provided to ensure that fuelling machine cannot move when clamped to a channel.
- (b) Protection devices (electrical and/or mechanical interlocks) supplemented by administrative measures should be provided to prevent fuel damage.
- (c) Design provisions should be implemented to provide continuous cooling in order to prevent damage of the spent fuel bundles.
- (d) The fuelling machine should maintain the integrity and function of the reactor coolant circuit.
- (e) Conditions or failures that could result in a fuelling machine becoming stuck (on channel or otherwise) during the refuelling cycle should be anticipated and provisions put in place to prevent or mitigate consequences.
- (f) The fuelling machine design should prevent mechanical loads on fuel bundles and interfacing equipment from exceeding design limits.
- (g) The fuelling machine should be designed to withstand loads caused by interfacing systems in operational states.
- (h) The fuelling machine should be designed such that contamination of the fuelling machine while transporting defective fuel is minimized, and should be designed so as to facilitate decontamination afterwards.

- (i) During normal operation, fuel bundles should be moved in and out of the coolant channel or fuel handling equipment by push force only and no torsion / transverse shear force should be experienced by fuel bundle.
- (j) During normal operation, direction of new fuel bundle loading should be only in the direction of coolant flow. Whenever refuelling against the flow direction is considered, the addition of positive reactivity should be analysed. It should be ensured that such reactivity excursion is within the capability of the reactor regulating system.
- (k) The movement of fuel string including ram extensions should take place at a controlled speed in either direction so that reactivity excursion is within the capability of the reactor regulating system at all times.
- (l) The system design should ensure that hot water from the reactor channel does not enter the fuelling Machine.
- (m) Operating pressures of oil and water hydraulic and pneumatic systems are to be limited to specified values to ensure equipment safety.
- (n) Back-up power supply for actuators important to safety should be provided.
- (o) Rams of fuelling machine should be compatible with coolant channel components and fuel bundles w.r.t. material, geometry, dimensions, flow path, etc.
- (p) Design of each fuelling machine should consider all loads likely to be seen during its operation including seismic loading.
- (q) Apart from the normal refuelling operations, the fuelling machine should be capable for the following additional functions based on requirement:-
 - (i) Removal of all the fuel bundles from a channel.
 - (ii) Grappling and retrieval of the fuel bundles from the channel by the healthy fuelling machine in case of other machine gets stuck / develops a snag.
 - (iii) Retrieval of damaged / disintegrated fuel bundle (fuel elements, fuel pellets or debris) from the channel by using a special tool like scoop.
 - (iv) For facilitating in-service inspection, repair and maintenance of the coolant channels so as to reduce man-rem expenditure (e.g. measurement of axial creep, delivery of channel inspection system, scraping of pressure tubes, delivery of channel service tools like Channel Isolation Plug, Flow Restricting Plug, Flow Blocking Plug to facilitate maintenance of channel in water flooded condition etc.).

Light Water Reactors & Sodium Cooled Fast Reactors

- (a) The hoist gripper of the refuelling machine should be designed to grasp securely and to transport fuel assemblies or other assemblies safely. Consequently, the following safety features and safety systems should be provided:
 - (i) A positive indication that the hoist gripper is correctly located and locked on the fuel assembly before lifting is commenced should be obtained.
 - (ii) The gripper should remain latched upon loss of power.

- (iii) The gripper should not decouple from the fuel while the refuelling machine is exerting a force on the fuel assembly.
- (iv) The gripper should only decouple from a fuel assembly at specified elevations.
- (v) The gripper should have an inherent safety device that prevents the fuel assembly from getting unlocked inadvertently.
- (b) Protection devices / interlocks should be provided to ensure that refuelling machine cannot perform horizontal movements during the lifting or lowering of fuel /core components.
- (c) Protection devices/interlocks supplemented by administrative measures should be provided to limit the movement of refuelling machine in order to prevent fuel damage (for instance, a safe load path that is clearly prescribed for each lift).
- (d) Provision should exist to ensure that the handling machine distinguishes between control rod assembly and fuel assembly at the time of latching.
- (e) The refuelling machine design should prevent mechanical loads on fuel and core components from exceeding design limits.
- (f) The refuelling machine should be designed such that contamination of the fuelling machine during transportation of defective fuel is minimized, and should be designed so as to facilitate decontamination afterwards.
- (g) The movement of fuel assembly should take place at a controlled speed in either direction so that reactivity changes in the reactor remain within permissible limits at all times.
- (h) Design provision should be made for functional checking of the refuelling machine after reach maintenance before starting the refuelling.
- (i) Design provision should be made in the refuelling machine (or) by other means for identifying the suspected failed fuel.
- (j) Design of refuelling machine should ensure that:-
 - (i) During the handling of a fuel assembly the rest of the core is not disturbed.
 - (ii) Design of refuelling machine should consider all loads likely to be seen during its operation including seismic loading.
 - (iii) Design of refuelling machine is done with sufficient factors of safety for mechanical loads. Suitable provisions should be made to limit the force/torque during fuel handling.
 - (iv) Design provision is made on machines to prevent accidental dropping of the fuel assembly during handling.
 - (v) Interlocks are provided on the refuelling machine to prevent wrong operation.
 - (vi) Design provision for identification of fuel assembly (applicable to LWR) or the type of fuel assembly (applicable to SFR) being handled should be available, preferably in refuelling machine.

In addition, the specific design considerations related to In-vessel Transfer Machine (IVTM) for SFRs are:

- (a) In-vessel transfer machine should have provision for clear identification of the type of fuel sub assembly being handled.
- (b) Provisions should be in place to ensure that the handling machine distinguishes between control sub assembly and fuel sub assembly at the time of latching to prevent inadvertent substitution of one for the other.
- (c) In-vessel transfer machine should have provision to detect wrong loading of a fuel sub assembly on grid plate.
- (d) Provisions should be made in the design to check operational errors (like wrong positioning of rotatable plugs, incorrect operation of machine etc.) by diverse means. Interlocks should be provided on the handling machine to prevent wrong operation leading to damaging of reactor core, fuel sub assemblies, reactivity control sub assemblies or other safety related equipment within the reactor vessel during fuel handling operations.

5.11.3. **Specific design aspects for the Fuel Transfer System**

Pressurized Heavy Water Reactors

- (a) Spent fuel bundles from the reactor are received in the fuelling machine in heavy water medium and further transferred to spent fuel storage pool through various fuel transfer equipment. During fuel transfer operation, it is necessary to minimise contamination of light water with heavy water and vice-versa.
- (b) To facilitate transfer from heavy water to light water media without mixing them up, it would be necessary to transfer the fuel bundles in air. This operation is called “dry transfer”. Maximum time allowed during the dry transfer should be derived based on allowed temperature rise of fuel. Dry transfer should be carried out within a stipulated time. Design provision should be made by providing suitable timers to monitor the time elapsed during dry transfer operation. Provision for auto-initiated cooling should be made in case dry transfer operation is not completed within the stipulated time.
- (c) Provision with adequate redundancy, should be made for cooling of spent fuel bundles during transfer between the core and storage pool to remove residual heat, even during off-normal conditions.
- (d) The design of the fuel transfer system should facilitate retrieval of stuck fuel.
- (e) The design of fuel transfer system should include provision to handle contingencies involving single failure of mechanism / devices resulting in incapacitation of the mechanisms.
- (f) The fuel transfer system should prevent excessive loads on fuel and interfacing equipment from exceeding design limits.
- (g) All the rams used for pushing the fuel bundles should have compatibility with regard to material, geometry and dimensions etc. and should preferably make full face contact with the fuel bundle.

Light Water Reactors & Sodium Cooled Fast Reactors

- (a) The gripper should be designed to avoid inadvertent disengagement of fuel assembly.

- (b) The nominal and approaching speeds of cranes used for lifting and transferring fuel assemblies should be limited to prevent damage of fuel assemblies, equipment and other safety related systems.
- (c) Tilting mechanism angular speed should be limited to prevent damage of fuel assemblies.

5.11.4. **Specific design aspects for the Handling Tools used in Spent Fuel Pool**

- (a) Handling tools refer to portable, manual or power-operated devices designed for handling and performing operations on spent fuel or irradiated components. These devices include tools for handling fuel elements and other components of a fuel as well as other irradiated components. The following aspects should be considered in the design of the handling tools:
 - (i) Handling tools should be designed to perform their intended function without compromising personnel safety. The tools should provide positive means of latching so as to preclude dropping of fuel or components. Means should be provided to indicate visually whether the tool is in the latched or unlatched condition. The tools should remain in the latched condition upon loss of power (e.g. electrical power or compressed air).
 - (ii) Handling tools should not contain sharp corners and edges that could damage the surfaces of fuel and other irradiated parts.
 - (iii) Hollow handling tools used under water should be so designed as to get filled with water on submergence (to maintain water shielding) and be drained on removal.
- (b) All the tools used in the spent fuel storage pool should be designed considering its interface with handling mechanism (such as crane), engagement and disengagement.
- (c) Lengths of the tool handles should be such that in the accidental lifting condition also, adequate water shielding is available over the spent fuel being handled.

5.11.5. **Inspection, Maintenance and Test Facilities**

Various inspection, maintenance and test facilities generally required for Fuel Handling System are as follows:

(a) New Fuel Inspection

Design of new fuel inspection system should provide adequate means to check the new fuel before loading into the reactor core. Design should provide means for the following inspections on each fuel, as applicable:-

- Visual examination
- Foot profile checking
- Helium Leak Test
- Identification of the fuel
- Straightness of the fuel
- Gross blockage of flow passages of the fuel
- Enrichment level of the fuel etc.

Also, design should avoid any physical damage to the fuel during inspection.

(b) Maintenance facility

Separate provision should be made to carry out periodic maintenance, calibration and functional testing of fuel handling equipment, their subassemblies and other critical components including associated process and control equipment.

(c) Wash Down Area

Various fuel handling equipment and tools get contaminated during operation under pool water. To facilitate maintenance and testing of these equipment and tools, a wash down area should be provided in close proximity with the fuel pool. It should have suitable provisions for washing / cleaning and also facilitate minor maintenance of the tools.

(d) Rehearsal Test Facility [*Specific to PHWRs*]

Considering the complexity of the fuelling machines and their controls, it is necessary to test each fuelling machine head in conditions closely simulated to actual operation. It is also desirable to perform certain tests after a major overhaul or maintenance before going to a channel for refuelling. For this purpose, a rehearsal test facility should be provided.

The rehearsal test facility should be preferably located close to the reactor. This facility should have provisions to perform rehearsal of refuelling operation sequences (in auto, semi-auto and manual modes), both at high pressure and low pressure, to observe and record important parameters and to ensure proper functioning. The fuelling machine should be accessible when it is on the rehearsal test facility, so that any fault can be rectified without undue exposure.

This facility should be designed to withstand the loads subjected to it by fuelling machine and the components should be compatible with the fuelling machine.

5.11.6. **Integrity of Reactor Pressure Boundary during refuelling in PHWRs**

During refuelling, the fuelling machine is considered to be a part of the reactor coolant system pressure boundary, starting from coupling of fuelling machine on to the coolant channel till its decoupling from the coolant channel. Hence, the fuelling machine integrity should be consistent with the integrity of the reactor coolant pressure boundary. To achieve this, the following design provisions should be made:

- (a) Clamping mechanism of the fuelling machine should make leak-tight connection with coolant channel before opening of the reactor pressure boundary. Reliable and redundant safety provisions should be made to prevent accidental unclamping.
- (b) Since sealing plugs form a part of the primary pressure boundary, means should be provided for proper installation of sealing plugs and checking for its leak tightness.
- (c) Means should be provided to verify the leak tightness of the system before removal and after installation of the sealing plugs.
- (d) The movement of fuelling machine, while connected to a coolant channel, may lead to breaching of reactor coolant pressure boundary. Protection to prevent this from occurring should be implemented.

- (e) Postulated off-normal situations arising out of failure of certain mechanisms and common cause failures should be analysed and mitigating provisions made in the design.

5.11.7. **Specific design considerations for process systems for fuel handling systems of PHWRs**

Various fuel handling operations are performed using heavy water, light water, Oil hydraulic and / or pneumatic power actuators such as oil hydraulic motors, fuelling machine rams, hydraulic cylinders, actuators for valves etc. Heavy water, light water and air are also used for cooling of spent fuel bundles, seals supply, air curtains etc. Some of the design considerations of these systems are indicated below:-

5.11.7.1. **Design considerations for heavy water system and light water System**

Heavy water process system is used for various fuel handling equipment such as fuelling machines, Rehearsal Test Facility etc. It is designed to maintain the fuelling machine at the required pressure during channel and rehearsal operations. It provides adequate cooling flow for the spent fuel bundles in the magazine in all modes of operations and for the various seals. It controls speed, direction and force for various actuators.

Light water process system is required for cooling of spent fuel bundles in equipment operating in light water medium. It is used to control pressure, speed, and direction for various actuators.

Following are the design considerations:

- (a) Heavy water /light water process system should ensure adequate cooling flow to spent fuel bundles received in various fuel handling equipment in all states of operations and accident conditions including those which are not related to fuel handling system.
- (b) Heavy water /light water process system should be designed such that forces applied on fuel bundle are within the design limits.
- (c) Heavy water process system should be designed such that hot water from the reactor channel does not enter the fuelling machine in the event of the failure of fuelling machine supply pump/Class IV and Class III power supply/air supply.
- (d) During refuelling, system should ensure that speed of movement of fuel string including ram extensions is controlled in either direction so that reactivity changes in the reactor remain within permissible limits at all times.
- (e) Major equipment, control devices and valves should be located in accessible areas for ease of operation and maintenance.
- (f) Monitoring of necessary process parameters should be provided to detect the possibility of the failure in the system, especially various drives, well in advance so that catastrophic failure requiring emergency actions are avoided.
- (g) Provisions should be made to prevent mixing of heavy water and light water.
- (h) Monitoring, with adequate backup, should be provided to ensure cooling of fuel bundles in equipment.

- (i) Design should ensure that failure in heavy water /light water hydraulic system should not lead fuel handling equipment to unsafe state.

5.11.7.2. **Design considerations for oil hydraulic system**

Oil hydraulic system is used to power various linear and rotary actuators of fuelling machine and fuel transfer equipment. It is also used for counterbalancing and also locking the motion of devices. Design considerations of the system are indicated below:-

- (a) Adequate redundancy and design margins should be provided over the normal requirements for off-normal conditions.
- (b) Back-up power supply for actuators important to safety should be provided. System pressure should be limited to specified values to ensure equipment safety.
- (c) Provision should be made to limit maximum torque generated by a motor or force generated by a cylinder to preclude excessive loads on the fuel bundles, drives, equipment and exceedance of limiting speeds beyond permissible limits.
- (d) Major equipment, control devices and valves should be located in accessible areas for ease of operation and maintenance.
- (e) Fire hazards should be analysed to ensure that safety is not hampered.
- (f) Design should ensure that failure in oil hydraulic system should not lead fuel handling equipment to unsafe state.
- (g) During refuelling, system should ensure that speed of movement of fuel string including ram extensions is controlled in either direction so that reactivity changes in the reactor remain within permissible limits at all times

5.11.7.3. **Design considerations for pneumatic system**

Pneumatic system provides air to seals of fuel handling access door, air curtain to separate light water and heavy water environments, valve actuators etc. Pneumatic system for door seals should be designed to provide controlled pressure to seals to achieve/maintain leak tight sealing between accessible and inaccessible areas and to detect seal failure.

5.12. **Safety Classification**

5.12.1. The equipment and components of fuel handling systems need to be classified taking into account their function and safety significance. SSCs important to safety of fuel handling system should be classified and assigned to the appropriate seismic categories in accordance with the recommendations and guidance given in AERB Safety Guide on 'Safety Classification and Seismic Categorisation for Structures, Systems and Components of Nuclear Power Plants' (AERB/NPP/SG/D-1).

5.12.2. Safety classified equipment should be designed according to requirements established by national or international codes and proven engineering practices as appropriate to their safety classification and the applicability of the selected design standard justified.

5.13. **Environmental Qualification**

Any operating conditions such as radiation, temperature, humidity, Electro Magnetic Interference (EMI) / Electro Magnetic Compatibility (EMC) requirement etc. for which the system provides safety functions should be considered in the qualification of fuel

handling system. SSCs important to safety of fuel storage and handling should be qualified in accordance with the recommendations and guidance given in AERB Safety Guide on 'Equipment Qualification for Nuclear Power Plants' (AERB/NPP/SG/D-27).

5.14. **Prevention of Criticality**

5.14.1. When subcriticality margin cannot be maintained by control of geometry in the design of fuel handling machine/equipment, then additional means such as fixed neutron absorbers should be provided. 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 and during or after an earthquake.

5.14.2. Any geometric deformation of the fuel handling equipment that could be caused by any postulated initiating event should be taken into account.

5.14.3. In determining the subcriticality, a conservatively calculated value of the effective multiplication factor or the infinite multiplication factor alternatively should be used. General guidance for criticality safety in the handling of fission material is described in AERB Safety Guide on 'Criticality Safety in Fissile Material handling Facilities' (AERB/FCF/SG-3).

5.15. **Radiation Protection**

5.15.1. Lifting equipment for spent fuel under water should be designed so that the lift is controlled within limits so as to maintain the minimum required water shielding.

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

5.15.3. During the handling new fuel containing fissionable material recovered through reprocessing, which may emit significant radiation, adequate shielding should be provided to limit the exposure to operating personnel within acceptable levels.

5.16. **Heat Removal**

Fuel handling systems should be designed with heat removal systems that are capable of cooling the spent fuel being handled or during transit storage. The heat removal capability should be such that the temperature of spent fuel, including that of the spent fuel cladding, does not exceed the maximum allowable temperature.

5.17. **Containment of Radioactive Material**

In the design of equipment & components of fuel handling systems, appropriate and adequate measures should be provided for containing radioactive material so as to prevent an uncontrolled release of radionuclides to the environment. The fuel cladding should be protected during handling in operational states and accident conditions and also during retrieval of the fuel.

5.18. **Materials**

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

5.18.2. Materials in direct contact with fuel (and sodium in case of SFRs) should be compatible with, and should be such as to minimize chemical and galvanic reactions, which might

degrade the integrity of the spent fuel during its handling. Materials of handling systems should also be compatible with fluids in contact.

- 5.18.3. Materials used in the construction of fuel handling systems should allow easy decontamination of surfaces.

6. DESIGN BASIS FOR EQUIPMENT USED FOR SPENT FUEL INSPECTION, REPAIR AND HANDLING OF DAMAGED FUEL

6.1. General

Considerations for handling equipment used for inspection, repair (dismantling and reconstitution), and damaged fuel should be established considering those provided in Section 5 applying a graded approach taking into account the consequences of equipment failure.

6.2. Inspection Equipment

6.2.1. Equipment should be provided for the inspection of spent fuel and other core components by visual (e.g. underwater camera, periscope etc.) and/or other means.

6.2.2. Inspection equipment should be designed to withstand the effect of irradiation and decay heat of the fuel.

6.2.3. The equipment used for handling fuel for inspection should not cause damage to the fuel and overheating of the fuel.

6.2.4. During fuel inspection, reliable means for removing residual heat from spent fuel should be provided.

6.3. Failed Fuel Detection Equipment

6.3.1. Failed Fuel Detection Equipment (e.g. sniffing) should be provided to detect failed fuel for the purpose of segregated storage.

6.3.2. Equipment should be designed to withstand the effects of irradiation and decay heat of the fuel.

6.3.3. The equipment used for detecting failed fuel should not cause damage to the fuel.

6.3.4. During detection, reliable means for removing residual heat from spent fuel should be provided.

6.4. Repair and Reconstitution Equipment

6.4.1. Repair and reconstitution equipment should be designed to minimize the effect of irradiation and to prevent overheating of the fuel.

6.4.2. The repair and reconstitution equipment should be designed to preserve the integrity of the fuel. The design should prevent possible fuel damage during the lifting of dismantled fuel or fuel element.

6.4.3. In the design of repair and reconstitution equipment, reliable means should be provided for removing residual heat from the spent fuel.

6.4.4. Repair and reconstitution equipment should enable retention of reusable parts such as fuel channels, if the dismantling of the fuel is necessary before storage.

6.5. Equipment for Handling of Damaged fuel

6.5.1. Given a potential source of contamination, provisions should be available to place leaking / damaged fuel at designated locations and/or in appropriate special containers.

6.5.2. Handling equipment for damaged fuel should not further impair the structural integrity of the fuel.

- 6.5.3. The container should be designed to withstand the temperature and pressure resulting from the residual heat of the spent fuel and from chemical reactions between the fuel or its cladding and the surrounding water.
- 6.5.4. In the design, consideration should be given to the procedures to be adopted for the removal of damaged fuel or other irradiated core components. The design of special tools for the manipulation of damaged fuel should ensure adequate margin of subcriticality, adequate decay heat removal and required shielding.
- 6.5.5. Design of container ('sealed bottle' in case of PWR, 'failed fuel storage container' in case of SFRs, 'can' in case of PHWRs) encapsulating damaged fuel should be compatible with interim storage, long-term storage, or be capable of being safely unloaded and transferred after the interim storage period.

7. DESIGN BASIS FOR HANDLING AND STORAGE SYSTEMS OF IRRADIATED CORE COMPONENTS

7.1. General

- 7.1.1. A number of miscellaneous irradiated core components that do not contain fuel may be stored in the spent fuel storage facility and handled with use of the same handling systems designed for spent fuel. Irradiated core components include components such as reactivity control devices or shutdown devices, in-core instrumentation, neutron sources, flow restrictors, fuel channels, channel components, burnable absorbers and samples of reactor vessel material etc.
- 7.1.2. In general, recommendations on fuel storage and handling systems provided in Sections 4 and 5 should be followed.
- 7.1.3. Specific considerations for irradiated core components are described in subsequent paragraphs.

7.2. Irradiated Core Components

- 7.2.1. For irradiated core components, particular attention should be paid to the following:
 - (a) Adequate shielding of irradiated core components should be ensured.
 - (b) Where inspection of irradiated core components is necessary, measures should be provided, as appropriate, to ensure protection of the operator from exposure.
 - (c) Means of transferring irradiated core components into a suitable shipping container should be provided where necessary.
 - (d) Specified storage and disposal systems should be provided, together with inspection systems where necessary.
 - (e) Appropriate care should be taken in handling to protect stored fuel and to limit possible spread of contamination.
 - (f) Irradiated core components should not be stored in the storage area for new fuel.

7.3. Neutron Sources

- 7.3.1. Sufficient shielding and monitoring equipment should be provided to protect operating personnel against ionizing radiation from neutron sources.
- 7.3.2. Neutron sources should be separated from the area for fuel handling and storage with a distance enough to ensure neutronic decoupling unless a suitable safety case is demonstrated to ensure adequate shielding or decoupling between source and fuel.
- 7.3.3. Arrangements should be made for the clear identification of all sources and administrative controls should be in place for controlling them.

7.4. Reusable Reactor Items

- 7.4.1. In most reactor types there are some core components and fuel items that can be reused (such as fuel channels in boiling water reactors or flow restrictor assemblies in pressurized water reactors). These items may be highly activated. If such items are being handled, the spread of contamination and the radiation exposure of operating personnel should be minimized.

- 7.4.2. Inspection facility for reusable components should be available to check their dimensional stability and the absence of any possible damage resulting from operation or handling. Where reusable components contain replaceable items (such as seals) it should be possible to inspect the replaceable component.
- 7.4.3. The design of the area for reusable reactor items storage should be such as to prevent reusable components from being contaminated with materials that may affect the integrity of reactor components after the reusable components are reinserted.

8. HANDLING OF CASKS FOR NEW AND SPENT FUEL

8.1. General

Casks are used for transportation of new fuel and spent fuel between different facilities. A cask is designed and qualified to meet the guidelines specified in AERB Safety Code on 'Safe Transport of Radioactive Materials' (AERB/NRF-TS/SC-1, Rev.1). Generally, for fuel of LWR and SFR, cylindrical cask having internal geometrical fixtures is used. For fuel of PHWRs, typically a cuboidal shape cask having provision to store spent fuel in a cage loaded with trays is used. Normally, tilting mechanism is provided to facilitate orientation of the cylindrical cask in required position. The specific trailer with tie down arrangement is used for transportation. The plant specific SOP is followed for handling as well as transportation of the cask. The cranes used at either end are generally fail-safe otherwise damping provisions are provided. To facilitate handling of cask, yoke assembly is used in conjunction with crane. A suitable attachment of the yoke assembly is used to remove and place the lid on the cask under water. After loading cask with spent fuel, sealed cask is lifted, drained and decontaminated before loading on the transport trailer. Radiological survey and temperature measurements are carried out before dispatch. Normally, cask transport in the public domain is carried out with required security measures.

The design of equipment used for handling the cask should be compatible with the design of the cask. These should fulfil the requirements specified in AERB Safety Codes on 'Design of Pressurized Heavy Water Reactor based Nuclear Power Plants' (AERB/NPP-PHWR/SC/D, Rev.2), 'Design of Light Water Reactor based Nuclear Power Plants' (AERB/NPP-LWR/SC/D) and 'Design of Sodium Cooled Fast Reactor based Nuclear Power Plants' (AERB/NPP-SFR/SC/D).

8.2. Design for Facilitating Handling of Casks for New Fuel and Spent Fuel

- 8.2.1. General considerations in Section 5 regarding safety classification, environmental qualification, radiation protection and material should be applied as appropriate to the design of handling equipment of cask.
- 8.2.2. The fuel storage area should be designed to facilitate the handling of cask that are to be transported off the site. The design of cask is outside the scope of this Safety Guide and is specified in AERB Safety Code on 'Safe Transport of Radioactive Materials' (AERB/NRF-TS/SC-1, Rev.1).
- 8.2.3. The design should include systems for decontaminating the casks prior to transport or transfer to storage and to perform leakage tests, surface contamination tests and other necessary tests on the cask. Provision should be made for draining fluids used in decontamination or flushing the cask coolant system (if relevant) to the radioactive waste management system.
- 8.2.4. The transport route inside the plant should be as short as possible, consistent with safety. The movement of cask over stored fuel should be prevented. Stored fuel, the spent fuel pool liner, cooling systems and systems essential to reactor safety should be adequately protected from the dropping or tilting of a fuel cask.
- 8.2.5. The probability of a cask drop accident should be reduced by means of an appropriate crane design and procedures for the inspection, testing and maintenance of the crane and the associated lifting gear, and also by means of adequate operator training. If the cask

lifting system is such that failure of a single component could result in an unacceptable drop of load, damping devices should be used together with restrictions on the lifting height in order to be able to mitigate the potential consequences.

- 8.2.6. Cask handling systems should be designed such as to prevent dropping of heavy loads while transfer / loading operations and during a design basis earthquake.
- 8.2.7. Layout of the area for cask handling should be designed so as to provide adequate space around the cask for inspection, radiation monitoring and decontamination tests. The necessary storage area for casks and associated equipment (such as shock absorbers) should be provided.
- 8.2.8. Administrative means should be developed to ensure that there is no loading of spent fuel that has not been cooled for a sufficient period of time or of a combination of spent fuel assemblies that is not permitted in the cask.

8.3. **External Hazards**

- 8.3.1. Protection of handling equipment of cask against external hazards should be primarily assured by the appropriate design of the building in which they are installed. Seismic design specifications for handling equipment of cask should be established on the basis of consequences with regard to potential damage to fuel inside the cask and necessity to operate the handling equipment during and after an earthquake.
- 8.3.2. The protection should primarily rely on an adequate layout and design of the buildings at the site.

8.4. **Vehicles and Cranes Used for Transfer of New Fuel and Spent Fuel Casks**

- 8.4.1. The cranes used for transfer of casks should meet the requirements of AERB Safety Code on 'Safe Transport of Radioactive Materials' (AERB/NRF-TS/SC-1, Rev.1). The cask handling crane should meet the requirements of single failure-proof criteria.
- 8.4.2. The vehicles or cranes used in the transfer of casks should be designed to limit the possibility of dropping or inadvertent tilting of the casks. Vehicles and cranes should be provided with a reliable braking system to ensure that they are not moved unintentionally. Consideration should be given to increasing the reliability of the lifting and transport equipment such that dropping of the load can be treated as a low-frequency event, for example, by the use of single failure proof cranes. Suitably diverse speed limitations on the horizontal and vertical movements of the cranes should be provided so as to ensure the safe handling of the cask.
- 8.4.3. Safety related cranes and trolleys used for transport of fresh and spent fuel casks to/from of Reactor Building should be provided with locking arrangement such that during seismic event the cranes remain parked safely. Preferably, parking for overhead crane should be provided in such a way that any safety related item is not coming under it.

9. FUEL HANDLING AUXILIARY EQUIPMENT

9.1. General

The fuel handling system handles both new fuel and spent fuel. In some reactor designs, the fuel handling equipment are located in inaccessible areas during reactor operation. It is necessary to gain access to this equipment for periodic maintenance, calibration and testing during reactor operation. In view of this, auxiliary equipment such as shielding doors, roll-on-shields along with sealing arrangements are provided suitably to / for facilitate access to these equipment.

9.2. Design Considerations

- (a) Adequate shielding from gamma and neutron radiations should be provided so that the radiation field in the accessible areas are within permissible limits.
- (b) Adequate sealing should be provided to achieve leak-tight isolation at various sealing doors in order to limit the air-borne activity to permissible values.
- (c) The equipment should have interlocks to prevent unsafe operation.
- (d) All loads derived from the operational states and accidental conditions, including the seismic loads, should be considered. The stresses resulting from these loads should be within permissible limits of appropriate design codes. Loading imposed on it by other systems if any, should also be considered.
- (e) The equipment should be provided with mechanical stop and lock arrangements.
- (f) The equipment should have provision for checking the adequacy of sealing.
- (g) Position feedback should be directly from the moving component.
- (h) Provision should be made for avoiding the loosening of assembly components of equipment.

10. INSTRUMENTATION AND CONTROL

10.1. General

The design of Instrumentation and Control for fuel handling and storage systems should be in accordance with AERB Safety Guide on ‘Design of Instrumentation and Control systems for Nuclear Power Plants’ (AERB/NPP/SG/D-25).

10.2. Design Considerations

- (a) Operation of the fuel handling and storage systems involves a large number of sequential steps, whose initiation should be in accordance with specified logic. Hence, automatic sequential logic system should be provided to reduce the possibility of operator errors. It should be possible to put a hold on automatic sequential operations at any stage. The design should also provide for manual mode to facilitate operations under off-normal conditions.
- (b) Adequate safety interlocks should be provided to prevent unsafe situations resulting from wrong commands. The commands issued by the operator in the manual mode and the sequential logic in the auto mode should be routed through the interlock logic.
- (c) A control console in the control room should be provided to carry out most of the operations and use of local panels should be restricted to either maintenance activities or specific operations not involving high man-rem. Status of the system should be displayed on the respective local consoles.
- (d) Auto-initiated mitigating actions should be provided if the system is likely to become unsafe in less than 15 minutes after a DBE. If the system remains safe for more than 15 minutes after a DBE and the operator actions are depended upon for ensuring further safety, it should be ensured that sufficient redundant indications/alarms are provided to draw the attention of the operator in case of any abnormal situation or condition. Since the control console of fuel handling system is manned throughout the refuelling operation, a minimum duration of 20 minutes is considered adequate for operator intervention.
- (e) For critical safety functions two out of two logic should be provided.
- (f) The design should ensure that the system remains safe even when the power supply unit fails.
- (g) Back-up field devices should be provided, wherever required, for ensuring safety or ease of retrieval in the event of failure of a primary device.
- (h) Diverse cabling routes should be employed for the field devices related to safety functions.
- (i) A simulator panel should be provided to test the functioning of the control system.
- (j) The computer system, if used, should include on-line and off-line diagnostics. Design, testing and review of the control system architecture, hardware and software should be in accordance with the AERB Safety Guide on ‘Design of Instrumentation and Control systems for Nuclear Power Plants’ (AERB/NPP/SG/D-25). In addition, the following design considerations should be met:

- (i) The control system design should facilitate checking of logic interlocks by simulating the required field devices.
- (ii) Operator interface of the control system should display status of various electrical, hydraulic and mechanical devices.
- (iii) The control system should provide features to carry out recalibration of the fuel handling system components at any time.
- (iv) A real-time clock should be provided with computer based system. Time of the day should be synchronised with the reference clock of the station.
- (v) Operation logs should be created by a computer-based system to facilitate analysis of malfunctions and performance deterioration of mechanical and hydraulic systems.
- (vi) The response time of the computer system should ensure that inconsistent outputs are not issued and positioning of all moving devices in the fuel handling system is achieved within the specified accuracy.

11.QUALITY ASSURANCE & IN-SERVICE INSPECTION

11.1. Quality Assurance

11.1.1. The design of the system should be subjected to a quality assurance programme to cover the activities, systems, components and material specified in this guide. It should be in accordance with the principles and objectives of the AERB Safety Code of Practice on Quality Assurance for Safety in Nuclear Power Plants' (AERB/SC/QA, Rev.1).

11.1.2. The design of safety related systems and system components should be subjected to QA requirements commensurate with their importance to safety.

11.1.3. Documentation

11.1.3.1. The design specifications, analyses, the 'as built' data and pre-service and in-service inspection data for all equipment should be documented. The documentation should be maintained in accordance with an established QA programme and made available to the operators.

11.1.3.2. The design should incorporate features, which are necessary for verification of the records on

- (a) the number and identification of fuel;
- (b) the location of each fuel; and
- (c) the number and identification of major fuel handling equipment/components.

11.1.3.3. Identification features should be sufficiently durable as to remain effective during entire operation, handling and storage.

11.2. In-Service Inspection (ISI)

11.2.1. Design provision should exist for carrying out ISI of Fuel handling, storage and transfer systems as per the requirements and philosophy of AERB Safety Guide on 'In Service Inspection of Nuclear Power Plants (AERB/NPP/SG/O-2, Rev.1).

11.2.2. The design of the system should provide for ISI of safety-related components and systems, which include safe and adequate access to all systems, areas and components requiring periodic inspection. In case of fuel handling, the ISI should consist of pressure test and visual examination of the fuelling machines and other equipment, as applicable.

11.2.3. Handling and storage area should be leak-tight to an appropriate degree so that the consequences of leakage of water or gaseous coolant are within acceptable limits in terms of release of radioactivity and of maintaining the inventory. In all designs, it should be possible to test and monitor the leak tightness and locate the leak, if any.

11.2.4. Design provisions should exist for verification of calibration of various actuators, which apply force on the fuel.

11.2.5. Design provisions should exist for carrying out ISI of components and systems of containment isolation related to fuel handling systems.

12.ADDITIONAL DESIGN CONSIDERATIONS FOR STORAGE OF SPENT FUEL: AWAY FROM REACTOR (AFR) FACILITY

12.1. General

Away From Reactor facilities are interim storage facilities designed for preserving the spent fuel. The guidelines specified, as relevant, in this document are applicable to these facilities. The main nuclear safety issues of an AFR facility are protection of fuel integrity; decay heat removal; radiological shielding; containment integrity; environmental protection; assurance of subcriticality, and safe management of radioactive waste.

Since storage at AFR facility is not the final stage in the disposition of spent fuel, retrieval is important at any time during the storage period and in particular at the end of the lifetime of the storage facility. To this end, fuel handling equipment would be an integral part of the facility. The lifetime of the AFR facility should be determined based on the necessary storage period prior to any future disposition, be it reprocessing or disposal.

In cases where such a period is undefined or very long, one may be constrained by the achievable design life of the facility, the spent fuel may have to be transferred from one facility to another during the storage period. Transferring of stored spent fuel from one facility to another may take considerable time depending on the amount of fuel and loading and handling constraints at the facility. Such limitations would have to be given consideration in the design of AFR facility.

Specific issues that should be given particular consideration in the safety case for AFR facility include the anticipated lifetime of the facility, retrievability and management systems. Consideration should also be given to the provision of support services when the AFR facility remains in operation after other facilities at the site have been closed, in particular for storage facilities at reactor sites.

AERB Safety Code on Site Evaluation for Nuclear Facilities (AERB/NF/SC/S, Rev.1) should be used towards siting of AFR facility.

12.2. Additional Design Considerations

The guidelines specified, as relevant, in this document are applicable to AFR facilities. In addition, the following design considerations should be taken into account:-

The storage conditions of spent fuel should be designed such that the condition of fuel, fuel racks, or storage pools will not significantly deteriorate during the storage period. By controlling the choice of materials and the chemistry of the cooling water, corrosion of fuel, storage racks, and storage pool liners should be kept low.

The AFR facility should have the necessary arrangements in place for ensuring sufficient cooling of the spent fuel in fuel storage facilities in the event of rare external events. These arrangements should enable monitoring of the water level and water temperature in fuel storage pools containing spent fuel. Additionally, reliable capability should exist to keep the spent fuel underwater in the event of the loss of the facility's AC power distribution systems and their permanently installed on-site and off-site power sources.

Furthermore, a sufficient inventory of water should exist at the plant site in order to enable these arrangements as specified in AERB Safety Code on Site Evaluation for

Nuclear Facilities (AERB/NF/SC/S, Rev.1). Also, capability to recharge the DC batteries should exist.

AFR facility should be designed so that at the time it is to be decommissioned, the decontamination and dismantling of structures and equipment together with the removal of waste can be facilitated, the quantities of waste arising should be minimized and occupational exposure should be reduced to as low as reasonably achievable.

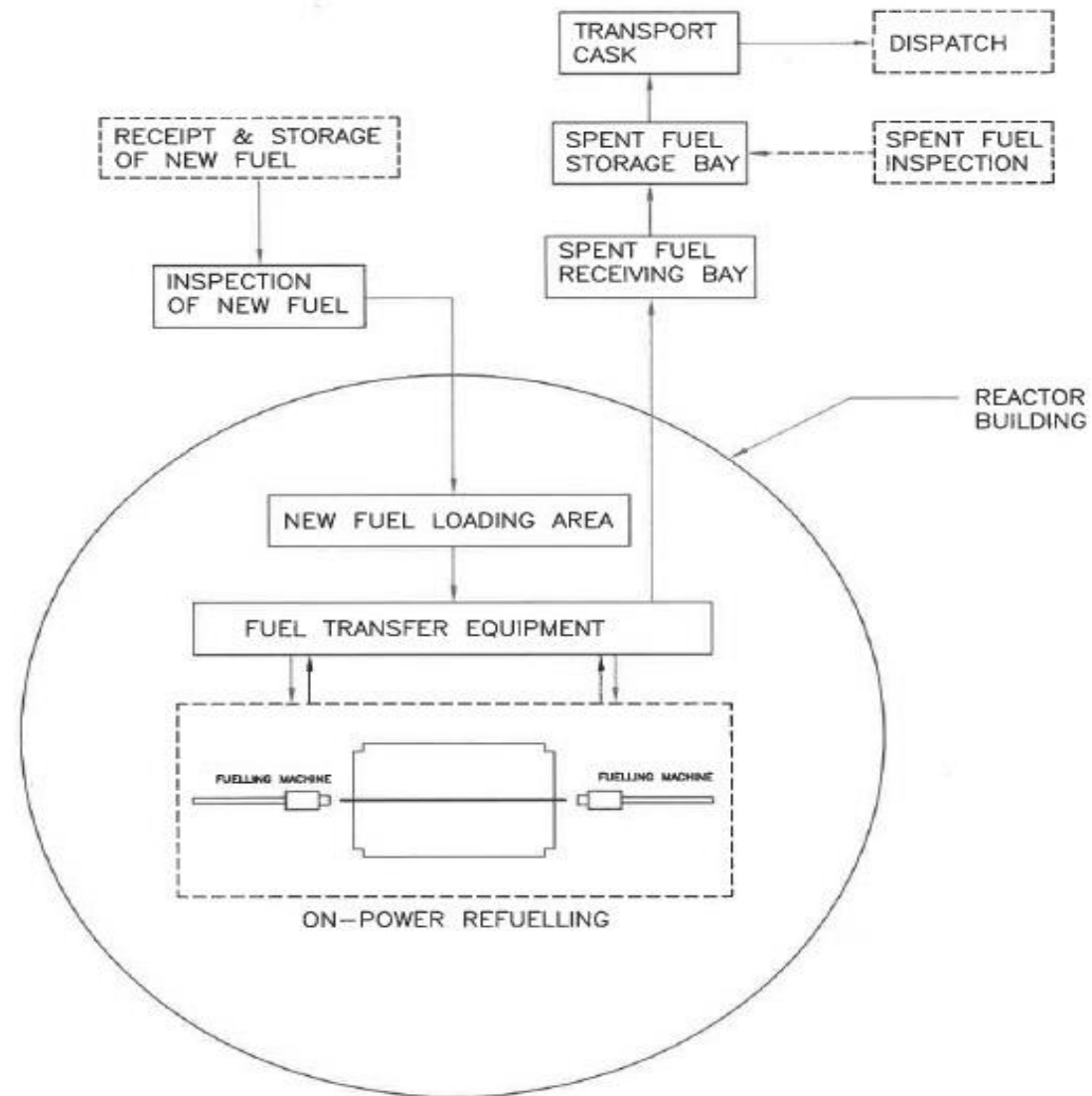


Figure-1: Typical Arrangement of Fuel Handling System in PHWRs

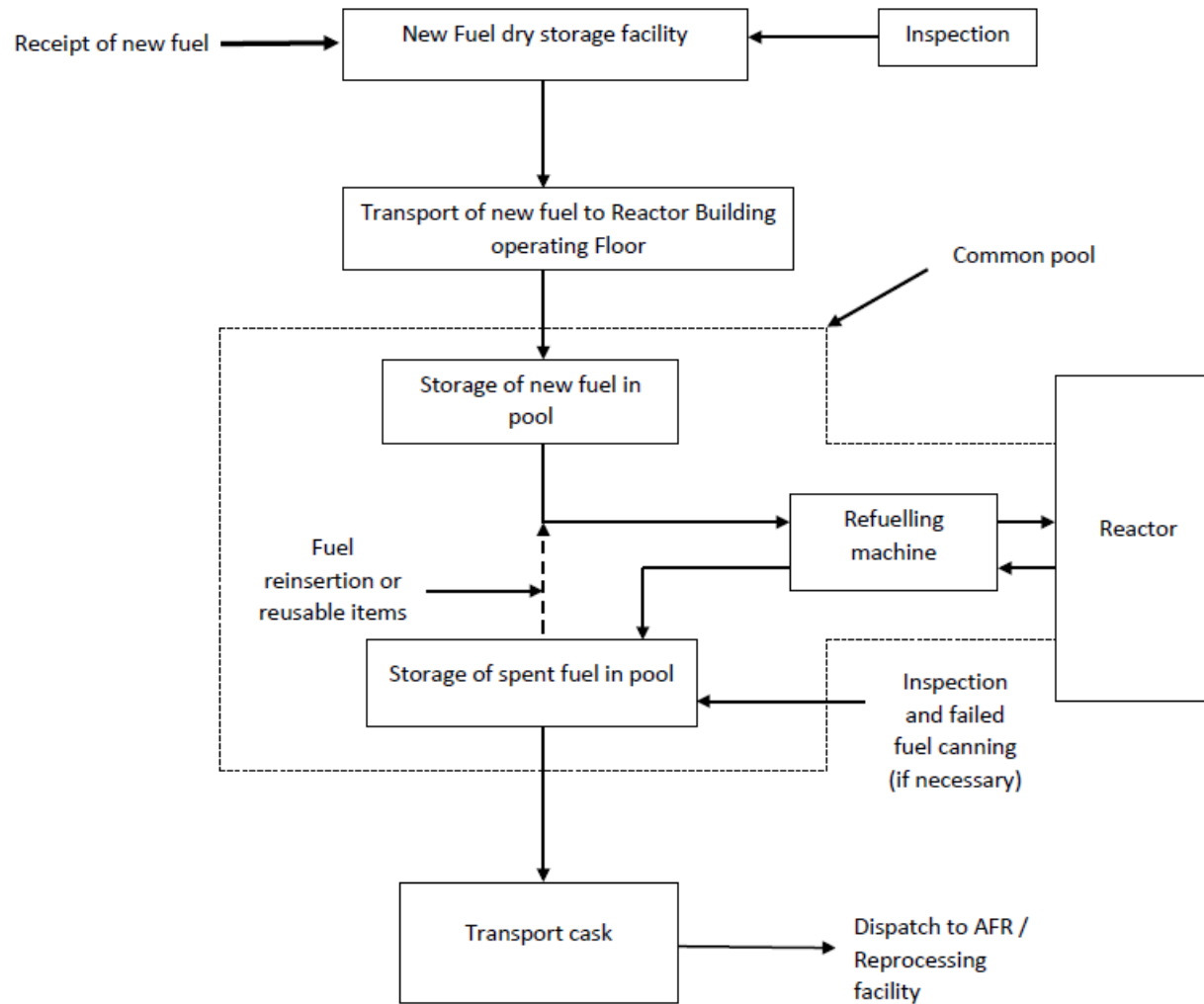


Figure-2: Typical Arrangement of Fuel Handling System in LWRs

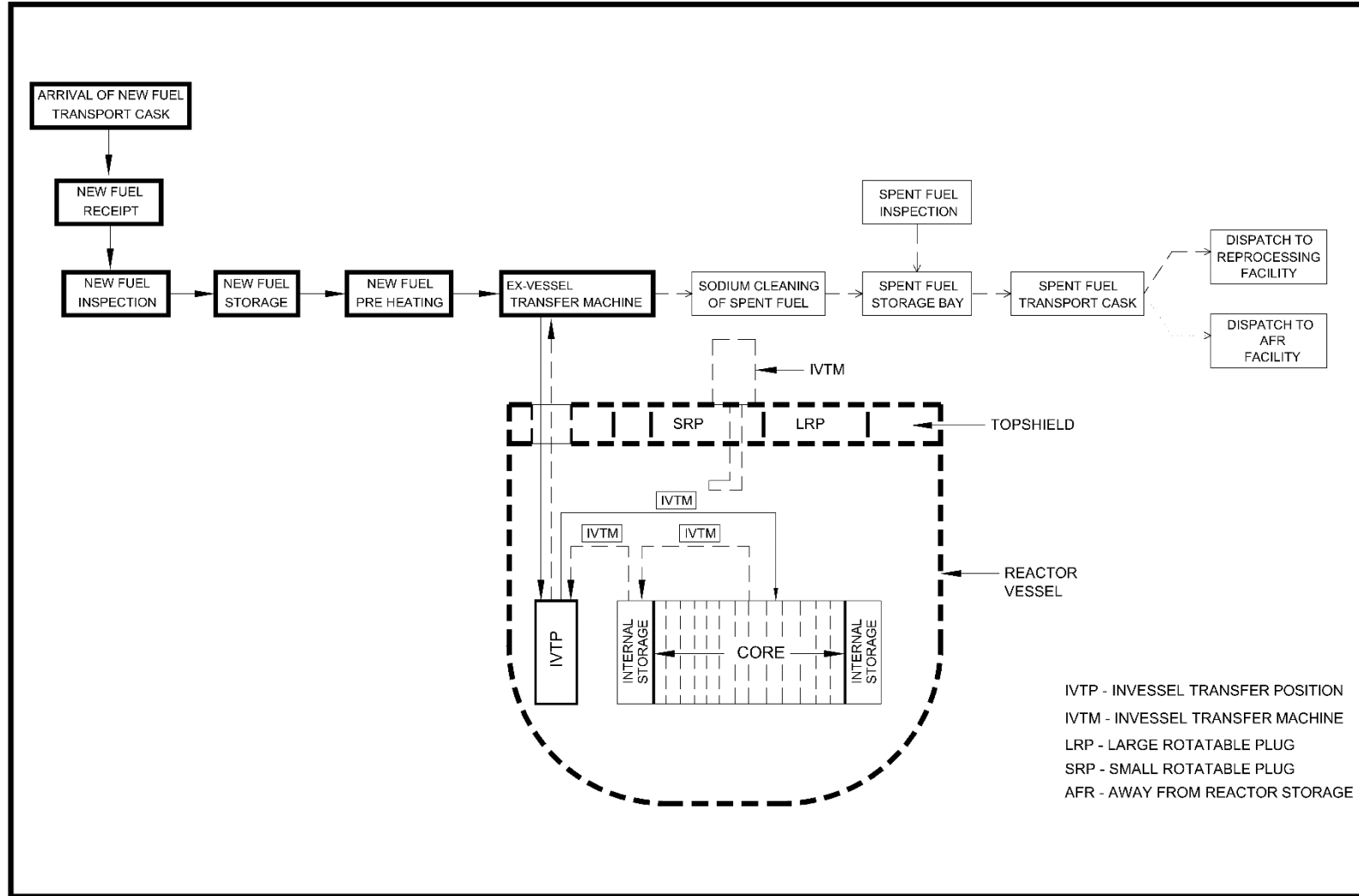


Figure-3: Typical Arrangement of Fuel Handling System in SFRs

APPENDIX

Specific Design Considerations for Dry Storage of Spent Fuel

A.1 Subcriticality

Fuel baskets and containers for dry 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.

Dry spent fuel storage facilities should be designed either to exclude the introduction of a moderator or the 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.

A.2 Heat removal

The storage facility should be constructed in a location for which there has been due consideration of changes associated with potential increase in ambient temperatures (including climate changes) 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 such storage facility.

To the maximum extent practicable, heat removal for dry spent fuel storage should be passive and should require minimal maintenance. In case of forced cooling, it should be demonstrated to be sufficiently reliable during normal operation and accident conditions, with no adverse effects on systems, structures and components that are important to safety.

Where the integrity of spent fuel relies on a storage cask's internal gas medium, the design of the associated spent fuel storage cask should ensure that the medium is maintained. It should include provisions for the monitoring and maintenance of required quality of such medium.

A.3 Containment of radioactive material

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 feasible, other means like 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 also include monitoring of seal integrity for bolted closure designs.

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

A.4 Radiation protection

Dry spent fuel loading and unloading operations should be carried out using equipment and methods that limit 'sky shine' and reflection of radiation to radiation workers and the public.

The dry storage facility should be provided with adequate monitoring provisions to detect increase in gamma and neutron fields in order to assess any degradation of containment or shielding.

Closed dry spent fuel storage facilities should be maintained at sub atmospheric pressures or filter ventilated in order to maintain concentrations of airborne radionuclides within acceptable levels.

For open dry storage facilities that do not use an over structure or building area radiation monitoring should be provided at the storage and site boundary to detect any abnormal levels of airborne radionuclides.

A.5 Structure and layout

Storage casks equipped with liners should be designed in such a manner to prevent accumulation of water between liner and body of the cask.

Storage vaults and silos should be provided with features to facilitate drainage of any accumulated water. Further, storage vaults and silos should be designed to ensure that decay heat generated by the stored spent fuel would be sufficient to evaporate and drive off accumulated water, if any.

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, the load of a full stack without unacceptable structural deformation. Further, in such configuration, static, impact and seismic loads should also be considered in the design of spent fuel and casks or baskets.

The foundations of the dry storage area should be capable of withstanding the weight of the loaded spent fuel casks and the handling equipment without excessive settling and degradation.

Ease of access should be considered in the design to facilitate the transfer of spent fuel to or from storage positions in normal operation. Access should also be considered for recovery operations after anticipated operational occurrences or accident conditions.

Sufficient clearances should be provided in all directions and on all sides so as to provide the necessary access. Casks should be designed in such a way as to provide stability and prevent them from tipping over.

The dry storage system should be designed for effective sealing to prevent any unacceptable leakage of radionuclides including inert gases and any ingress of water (moderator) and/or air.

The design of an open dry spent fuel storage facility should be such as to provide for appropriate collection, monitoring and processing of surface runoff water.

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 repackaging of the fuel or repairs. If a hot cell are not considered in design of such facility, the casks should be designed for maintenance or repair. Alternatively, arrangements should be ensured for their transport to a location where such facilities are available.

A.6 **Materials**

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

A.7 **Handling**

The design of dry spent fuel casks intended to be portable should include provision for lifting and handling 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 mechanisms should be able to withstand anticipated loadings and usage during the design lifetime of the casks.

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

For multipurpose casks intended for storage, transport and potential disposal after storage, the means for appropriate handling at the end of the storage period should be considered in the design.

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LIST OF PARTICIPANTS

In-House Working Group of AERB (TF-IHWG/D-24) for preparation of R0-Draft of Safety Guide on ‘Design of Fuel Handling and Storage Systems for Nuclear Power Plants [AERB/SG/D-24 (Rev. 1)]’

Duration of Working Group: September 18 – December 31, 2019

Shri Rajnish Kumar, NPSD	Convener
Shri Milind S. Mestry, NPSD	Member
Shri Anuj Kumar Deo, NSAD	Member
Shri Purushottam Patel, OPSD	Member
Shri Gopal Grandhi, NPSD	Member-Secretary

Task Force (TF/SG/D-24) for Review of R0-Draft of Safety Guide on ‘Design of Fuel Handling and Storage Systems for Nuclear Power Plants [AERB/SG/D-24 (Rev. 1)]’

Dates of meeting(s):

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December 15, 2021	August 29, 2022	September 6, 2022
January 20, 2023	February 14, 2023	April 25, 2024

Shri R. J. Patel Former Director, RDDG, BARC	Convener
Shri S. B. Chafle Executive Director, AERB	Co-Convener
Shri Kunal Chakraborty Head, ROD, BARC	Member
Shri N. Rama Mohan ED (Engg-LWR), NPCIL	Member
Shri Jose Varghese AD, NSDG, IGCAR	Co-opted Member
Shri Jaipal Singh ED (Engg.), NPCIL	Member
Shri Diptojoyoti Bhattacharya OPSD, AERB	Member
Shri Rajnish Kumar OPSD, AERB	Member
Shri Parikshat Bansal IT&RDD, AERB	Member
Shri Milind S. Mestry Former NPSD, AERB	Member
Shri Ravindra Gupta DCE (Engg-LWR), NPCIL	Co-opted Member
Shri Soumen Koner NSAD, AERB	Member
Shri Gopal Grandhi NPSD, AERB	Member Secretary
Shri Eapen P. Joseph ACE (FMH), NPCIL	Invitee
Shri Ajey Bhoge ACE (FMH), NPCIL	Invitee

Advisory Committee for Nuclear and Radiation Safety (ACNRS)

Date of meeting: August 24 & 25, 2018 and June 27, 2024

Shri S.S. Bajaj Former Chairman, AERB	Chairman
Shri S. B. Chafle, Executive Director, AERB	Member
Dr. N. Ramamoorthy Chairman, SARCAR, AERB	Member
Shri. K. V. Suresh Kumar CMD, BHAVINI	Member
Shri. V. Rajesh Director (T), NPCIL	Member
Shri S. Jayakrishnan Director (T-LWR), NPCIL	Member
Prof. C.V. R. Murty Chair Professor, Dept. of Civil Engg., IIT, Madras	Member
Dr. Kallol Roy Former CMD, BHAVINI	Member
Shri. H.S. Kushwaha Former Director, HS&E group, BARC	Member
Shri. K.K.Vaze Former Director, RDDG, BARC	Member
Dr. (Smt). Sadhana Mohan Former Group Director, Chemical Engg. Group, BARC	Member
Dr. A.N. Nandakumar Former Head, RSD, AERB	Member
Dr. R. B. Solanki, Head, RDS, IT&RDD IT&RDD, AERB	Member Secretary

TECHNICAL EDITING

Shri R. S. Parvatikar, Former AD (FHS), NPCIL

COPY EDITING

Shri K. Srivasista, Former, Head, R&DD, AERB

LIASON OFFICER

Shri P. Bansal, RDS, IT&R&DD, AERB

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