EGYPTIAN SAFETY REQUIREMENT PROPOSAL FOR STORAGE AND TRANSPORT OF SPENT FUEL

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Abstract

The storage and secure of SNF should be manage in a safe manner. Egyptian Nuclear Power Plant Authority (ENPPA) is responsible for the safe management of spent nuclear fuel produced by nuclear power plant. The Egyptian nuclear power plant project consists of four Units with VVER-1200 reactors. The operation of 4 NPP units will be accompanied with the accumulation of SNF in the amount of 168 SFAs in average per year. In the course of operation of 4 units during 60 years approximately 11,532 SFAs will be accumulated. TUKs as dual-purpose casks will be used during long-term storage and transportation of the spent fuel assembly for the Egyptian Nuclear Power Plant (ENPP).

The aim of the paper is to establish a proposal for Egyptian safety requirements for safe storage and transportation of spent nuclear fuel. The proposal guided by the Egyptian law on regulation of nuclear activities and radioactivity (law no. 7 of the year 2010) and its Executive regulations, recommendations of IAEA safety standard, the joint convention on the safety of spent fuel management and on the safety of radioactive waste management and Russian nuclear safety requirements. Specific legislation has been established in the nuclear law to: identify responsibility for safety, security and safeguards, and management of spent fuel and radioactive waste (transportation, handling, and storage). Egyptian proposal cover the safety considerations for storage and transportation of spent nuclear fuel.

1. INTRODUCTION

Spent nuclear fuel (SNF) is generated from the operation of nuclear and research reactors of all types and needs to be safely managed following its removal from the reactor core. SNF is considered waste in some circumstances or a potential future energy resource in others and, as such, management options may involve direct disposal or reprocessing. Either management option will involve a number of steps, which will necessarily include storage of SNF for some period of time. This time period for storage of SF can differ, depending on the management strategy adapted, from a few months to several decades. The time period for storage of SNF will be a significant factor in determining the storage arrangements adopted. The final management option for many countries may not have been determined at the time of design of the storage facility, leading to some uncertainty in the storage period that will be necessary, a factor that needs to be considered in the design of the facility. Storage options include wet storage in some form of storage pool or dry storage in a facility or storage casks built for this purpose [1]. Storage casks can be located in a designated outside area on a site or in a designated storage building. A number of different designs for both wet and dry storage of SNF have been developed and used in different countries. SNF is stored for cooling at the reactor fuel storage pool for a period of time and then may be transferred to a designated wet or dry SNF storage facility, where it will await reprocessing or disposal. The fuel storage pools of some reactors have sufficient capacity to accommodate all the SF that will be generated during the lifetime of the reactor.

2. EGYPTIAN NUCLEAR PROGRAM

Egypt's nuclear program, which began in 1954, features two research reactors and a hot-cell laboratory, all located at Inshas. They are used for peaceful purposes and are under IAEA safeguards.

On the 19th of November 2015 the Intergovernmental Agreement (ING) between the Government of the Russian Federation and the Government of the Arab Republic of Egypt on cooperation in construction and operation of the Nuclear Power Plant on the territory of Arab Republic of Egypt was signed. The NPP will be built on site located in the territory of the El-Dabaa area on the Mediterranean coast 150 km away from Alexandria. Nuclear power plant use uranium fuel rods bundled into fuel assemblies. After about 5 years, the fuel is no longer

useful and is removed from the reactor. Reactor operators have to manage the heat and radioactivity that remains in this SNF.

Each reactor has at least one pool for SNF storage. Plant personnel move the SF underwater from the reactor core to the pool. Over time, SNF in the pool cools as the radioactivity decays away. These pools were intended to provide temporary storage. The idea was that after a few years, the SF would be shipped offsite to be reprocessed, and fissile materials recycled into new fuel.

2.1. El Dabaa nuclear power plant

El Dabaa NPP is the first nuclear power plant planned for Egypt and will be located at El Dabaa, Matrouh Governorate, Egypt, which is about 130 Kilometers northwest of Cairo. El Dabaa NPP, consisting of four Units with VVER-1200 reactors is being built based on the terms and conditions of the EPC contract, which was signed between JSC Atomstroy export and ENPPA on 31 December 2016 and came into force on 11 December 2017. The Project provides for the construction of four Power Units with a capacity of 1.2 GW based on VVER -1200 MW reactor (pressurized water reactor) of the Russian design. Russian Side shall assist Egyptian partners in the development of nuclear infrastructure, shall supply Russian nuclear fuel for the entire life cycle of the Nuclear Power Plant, shall build a special storage facility and supply containers for storing SNF, translate the document from Russian language to English, provide training for national personnel, and support Egyptian partners in operation and maintenance of El Dabaa NPP during the first 10 years of operation. In accordance with EPC contract Unit 1 of El-Dabaa NPP will be commissioned in 2026.

2.2. Interim storage and transport

For several years after unloading, while the SNF is kept in water-filled pools, the principal risk is that a loss of cooling water could result in the fuel heating to a temperature high enough to ignite the zircalloy cladding of the fuel, resulting in a release of volatile radioactive fission products and in radiation protection concerns. One way to lower this risk is to move SNF to dry-cask storage once the heat output from the SF has decreased adequately. This could be done easily 5 years after unloading. In dry-cask storage, SF assemblies are typically placed in steel canisters that are surrounded by a heavy shielding shell of reinforced concrete, with the shell containing vents allowing air to flow through to the wall of the canister and cool the fuel. A typical dry-cask for pressurized water reactor fuel contains about 10 tons of SF, roughly one-half of an annual discharge from a 1 GWe reactor. In the USA, casks are typically stored at or close to the reactor site. Interim storage in dry casks is increasingly being employed even in countries that reprocess some of their spent fuel. There are different types and many varieties of cask types in use. Some countries store casks in buildings for additional protection against weather aggressions, accidents and attack.

2.3. Spent fuel storage & transportation

After unloading from reactor cores the SNF shall be stored in spent fuel racks in spent fuel ponds which are separate for each NPP unit. The failed fuel will be stored in special canisters. After getting cooled for at least five years, the fuel can be transferred by spent fuel transportation casks (TKC-13) to Away From Storage (AFR) facility for further storage.

2.3.1. TUKs as dual-purpose casks

The technology of dry long-term storage and transport of SF in metal concrete casks has become a commercial one. Both the technology and equipment have been tested in SF transport and process operations including container-type storage facilities at nuclear power plants and other nuclear facilities and sites. The dual-purpose cask technology ensures reliable and safe SF containment preventing any release into the environment. Creating a new type of dual-purpose cask for SF from a new generation of VVER-1200 reactor is a true to life necessity. Commissioning of such dual – purpose TUK is planned by 2020.

3. GENERAL SAFETY REQUIREMENTS

3.1. Egyptian nuclear law and its executive regulations

Nuclear Law has been established by a Presidential Decree No.7 for year 2010 (Law of Regulating the Nuclear and Radioactive Activities). State' System of Accounting for & Control of Nuclear Materials (SSAC) has been established by a Presidential Decree No. 152 of 2006 and its executive Ministerial Decrees (No. 419, 420 and 421, 2006) concerning the Egyptian System of Accounting for & Control of Nuclear Materials.

Specific legislation has been established in the nuclear law to: identify responsibility for safety, security and safeguards, specify allowable ownership of NPPs and associated rights and obligations, and provide funding for NPP programme. Specific legislation has been established in the nuclear law to identify responsibility for safety, security and management of spent fuel and radioactive waste (transportation, handling, and storage).

Article 6 of the Egyptian nuclear law stated that" Import, entry, abandonment or burial of any radioactive wastes or spent nuclear fuel into Egypt's soil, regional water, exclusive economic zone or continental shelf shall be prohibited".

Article 6 of the Egyptian nuclear law stated that "the regulatory Authority in coordination with concerned bodies designated by the Prime Minister shall set out the long-term planning criteria for the sites at which the radioactive wastes and spent nuclear fuel are handled. Such criteria shall be issue, upon a decree by the Prime Minister.

Article 47 of the Egyptian nuclear law stated that "the facility exercising an activity requiring the preservation of a nuclear fuel to be used at such facility or producing a radioactive waste shall be obtained:

- A license to preserve such fuel, during all its cycle stages, whether such preservation is in or outside the nuclear facility;
- A license for the disposal of spent nuclear fuel and radioactive wastes.

The Regulatory Authority (RA) shall define the requirements of the above stated preservation and disposal.

Article 48 of the Egyptian nuclear law stated that "the RA shall specify the rules and procedures of control, reporting and recording at the spent nuclear fuel preservation facilities and radioactive waste disposal facilities as well as the limits of safe operation of such facilities and exposure doses to such fuel and wastes for the personnel and public, in light of the tolerable levels of such exposure.

The RA shall inspect such facilities and obtained enough information and data on their performance and on the nuclear safety and security, radiation safety and environmental impact assessment related to thereto, as per the systems issued in this respect."

Article 12 of the executive regulations stated that "the licensee shall adhere to the systems, standards, rules and requirements issued by the RA, in respect to the handling, transport and storage of the following:

- Fresh nuclear fuel;
- Spent nuclear fuel;
- Radioactive waste due to operation;
- Radioisotope due to operation.

Article 13 of the executive regulations mentioned in the site approval permit phase that the licensee should submit application to the RA includes data about spent fuel storage

4. IAEA SAFETY RECOMMENDATIONS PRESENTED IN IAEA SAFETY GUIDE SSG-15

4.1. Roles and responsibilities

Storage of SNF should be undertaken within an appropriate national legal and regulatory framework that provides for a clear allocation of responsibilities [1,6], including responsibilities for meeting international obligations and for verifying compliance with these obligations, and which ensures the effective regulatory control of the facilities and activities concerned. The national legal framework should also ensure compliance with other relevant national and international legal instruments, such as the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [7]. Since SNF may be stored for long periods of time prior to its retrieval for reprocessing or disposal, the regulatory body should verify that the operating organization is providing the necessary personnel and the technical and financial resources for the lifetime of the spent fuel storage facility, to the extent that such confirmation is within the statutory obligations of the regulatory body.

The regulatory body should also provide guidance to operating organizations on how to meet requirements relating to the safe storage of spent fuel.

The regulatory review of the decommissioning plans for spent fuel storage facilities should follow a graded approach, particularly considering the phases in the lifetime of the storage facility. The regulatory body should periodically verify that the key aspects of the operation of the storage facility meet the requirements of the national legal system and facility licence conditions, such as those relating to the keeping of records on inventories and material transfers, compliance with acceptance criteria for storage, maintenance, inspection, testing and surveillance, operational limits and conditions, physical protection of nuclear material and arrangements for emergency preparedness and response. Such verification may be carried out, for example, by routine inspections of the spent fuel storage facility and audits of the operating organization.

The responsibilities of the operating organization of a spent fuel storage facility typically include:

- Application to the regulatory body for permission to site, design, construct, commission, operate, modify or decommission a spent fuel storage facility;
- Conduct of appropriate safety and environmental assessments in support of the application for a licence;
- Operation of the spent fuel storage facility in accordance with the requirements of the safety case, the licence conditions and the applicable regulations;
- Development and application of acceptance criteria for the storage of spent fuel, as approved by the regulatory body;
- Providing periodic reports as required by the regulatory body (e.g. information on the actual inventory of spent fuel, any transfers of spent fuel into and out of the facility, any events that occur at the facility and which have to be reported to the regulatory body) and communicating with interested parties and the general public.

The operating organization is responsible for the safety of all activities associated with the storage of spent fuel (including activities undertaken by contractors) and for the specification and implementation of the programmes and procedures necessary to ensure safety [3]. There should be clear and unequivocal ownership of the spent fuel stored in the facility. The interface between the responsibilities of the operating organization and the SNF owner, if they differ, should be clearly defined, agreed upon and documented. The SNF owner, namely, a body having legal title to the SF, including financial liabilities (usually the SF producer), should be responsible for the overall strategy for the management of its SF. In determining the overall strategy, the owner should take into account interdependences between all stages of SF management, the options available and the overall national SF management strategy.

The operating organization will be required to establish, maintain and implement a system for nuclear material accounting and control as an integrated part of the State system of accounting for and control (SSAC) of nuclear material. In addition, physical protection systems for deterrence and detection of the intrusion of unauthorized persons and for protection against sabotage from within and outside the facility will be designed and installed during the construction and operation of the spent fuel storage facility. The implications of such systems

and arrangements for the safety of the facility should be assessed and it should be ensured that no safety function would be compromised nor would the overall level of safety at the facility be significantly reduced on account of such systems and arrangements.

4.1.1. Management systems

The requirements on management systems for all stages in the lifetime of a spent fuel storage facility should be established. A management system is required to be established, implemented, assessed and continually improved by the operating organization [4] and it should be applied to all stages of the storage of spent fuel that have a bearing on safety. It should be aligned with the goals of the operating organization and should contribute to their achievement. The management system should make provision for siting, design, commissioning, operation, maintenance and decommissioning of the spent fuel storage facility. The management system should be designed to ensure that the safety of the spent fuel and of the spent fuel storage facility is maintained, and that the quality of the records and of subsidiary information on spent fuel inventories is preserved, with account taken of the duration of the storage period and the consecutive management steps, for example, reprocessing or disposal [5]. The management system should also include provision to ensure that the fulfilment of its goals can be demonstrated.

4.1.2. Resource management

Spent fuel management activities will require financial and human resources and the necessary infrastructure at the site where the spent fuel storage facility is located.

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

4.1.3. Safety case and safety assessment

In demonstrating the safety of the spent fuel storage facility and related activities, a safety case should be developed as development of the facility progresses and the supporting safety assessment should be carried out in a structured and systematic manner.

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

The prime responsibility for safety throughout the lifetime of a facility lies with the operating organization. This includes responsibility for both ensuring and demonstrating the safety of a facility in the safety case.

Periodically, the safety case should be reviewed to assess the continuing adequacy of the storage capacity; account should be taken of the predicted spent fuel arising, the expected lifetime of the storage facility and the availability of reprocessing or disposal options.

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

Safety assessment for a spent fuel storage facility should cover the expected operational period of the facility. The storage of spent fuel for long periods of time would require events of lower likelihood to be evaluated in the safety assessment than would storage for a shorter duration.

4.2. Federal environmental, industrial and nuclear supervision service (rostechnadzor) [2]

The basic safety justification document for nuclear fuel storage and transportation shall be the Safety Analysis Report of a nuclear facility. As regards nuclear fuel transportation and storage, the nuclear facility SAR shall contain lists of possible operational violations, initiating events of design basis and beyond design basis accidents as well as a probability and severity categorization of beyond design basis accidents. Exemplary lists of

initiating events for design basis accidents and an exemplary list of beyond design basis accidents. Components of the nuclear fuel storage and transportation system shall be categorized in terms of their impact to safety. To maintain and verify design characteristics, safety important NFSTS components shall be subjected to inspection and testing during manufacturing, assembling and aligning and undergo periodic in-service checks to verify their compliance with the design. The design shall contain a list of nuclear hazardous operations during storage and transportation of nuclear fuel. The design shall provide for engineered features for storage and transportation of damaged nuclear fuel. The nuclear fuel storage and transportation system shall be capable of performing its functions in the scope determined in the design taking account of internal and external natural and man-induced events, as assumed in the design. The NF design shall establish nuclear fuel storage and transportation standards confirmed by an independent conclusion on nuclear safety. A procedure to obtain this conclusion is set up by a body for state control of the use of atomic energy. The design shall contain lists of methodologies and computer codes used for safety justification of nuclear fuel storage and transportation and define the fields of their application. The computer codes applied shall be verified and certified in accordance with the established procedures.

4.2.1. Storage of nuclear fuel

- Nuclear fuel storage facilities shall be equipped with fire alarms, ventilation, regular and emergency lighting. The design shall indicate whether it is reasonable to equip the nuclear fuel storage facility with a CCTV system.
- Nuclear fuel storage facilities shall be equipped with automated and portable fire extinguishing devices. It is prohibited to use for fire extinguishing the media which when used can increase the effective neutron multiplication factor.
- The permissible term of nuclear fuel storage at NF shall be indicated in the design.
- It is prohibited to keep in the storage facility the flammables or toxic agents or explosives which are not a part of packaging.
- It is prohibited in nuclear fuel storage facilities to lay cables which are not directly relate to power supply of equipment for storage and transportation of nuclear fuel, and to lay pipelines containing flammable and explosive liquids and explosive gases.
- The storage facility design shall provide for automatic trip of ventilation in the event of fire.
- The possibility of using OSTP for storage of specific type of nuclear fuel shall be justified in the design.
- It is allowed to store in nuclear fuel storage facilities the reactor core components which do not contain fissile material. In this case the component types and their locations shall be regulated by the design.
- Layout of the storage facility shall provide for unimpeded personnel evacuation from the premises in the event of an accident.

4.2.2. Transportation of nuclear fuel

- On-site transportation of nuclear fuel shall be carried out in On Site Transportation Package (OSTP) on special vehicles intended for these purposes. Requirements for special vehicles intended for transportation of nuclear fuel shall be established in the design.
- The design shall establish whether in the on-site transportation of nuclear fuel it is permitted to use vehicles intended for transportation of other goods provided they are additionally furnished with special equipment and shall set up requirements for additional equipment of such vehicles.
- The possibility of transporting in OSTP the nuclear fuel which is not envisioned in the design, including new NF types, shall be additionally justified in the design.
- During transportation the packages shall be reliably fixed on a vehicle to avoid spontaneous movement and tilting at turning, bumps, braking, roll movements.
- In case of natural and man-induced events specific for the NF location site a possibility for NF fall out of OSTP or violation of NF mutual arrangements inside OSTP shall be excluded.
- During the package movements the lifting height shall be possibly minimal. The maximum permissible height for lifting the packages shall be justified in the design.

— It is allowed to lift a package at a height exceeding that defined in the design provided one of the following requirements is met:
  - Graded lifting is provided, for which technical measures exclude exceeding the value defined in the design for each step;
  - Lifting is performed above a shock-absorber or using a damping device that reduce loads to the package in case of drop down to the loads that arise from a drop from the design height;
  - Availability of an independent (of the main) back-up lifting (lowering) system that ensures lifting (lowering) of a fully loaded package.
— It is prohibited to lay routes and transport loads, if such loads are not elements of lifting or reloading devices, and nuclear fuel packages through the places where nuclear fuel is stored or is temporary placed (in case the nuclear fuel is present in these places). If this requirement is not feasible for existing storage facilities, the nuclear fuel in storage shall be protected from damages associating with drop of nuclear fuel loads and packages. Should this be the case, the capabilities of protective structures to withstand static and dynamic loads, which can arise from a drop of nuclear fuel load or package, shall be justified in the design.
— Speed of on-site movement of vehicles with nuclear fuel packages or shrouds shall be justified in the design.
— Movement of a vehicle transporting nuclear fuel shall be immediately terminated if a malfunction of driving gear, coupling or package fixing on the vehicle is detected.
— An NF shall provide for special sections and equipment for preparing transport packages and vehicles for off-site transportation.

4.2.3. Equipment for nuclear fuel storage and transportation

— While designing the safety important equipment of the nuclear fuel storage and transportation system the possibility shall be provided for its testing, maintenance and repair.
— The transportation and process equipment for nuclear fuel transfers shall ensure the speed and acceleration of nuclear fuel movement which does not exceed values established in technical specifications or other technical documentation of the nuclear fuel manufacturer.
— Nuclear fuel storage and transportation equipment shall have no sharp edges that may damage nuclear fuel.
— In normal operation conditions the design of nuclear fuel storage and transportation equipment shall exclude shocks or any other impacts that may cause damage or change of geometry of FAs or FRs.
— Designs of shrouds, OSTP, racks in nuclear fuel storage facilities shall ensure their stability to internal and external natural and man-induced events characteristic of the NF location site.
— For NF handling it is permitted to use only operable equipment, as stipulated in the design, which underwent recurrent inspections, tests and visual checks before the NF operations are performed.
— While designing the equipment for storage and transportation of nuclear fuel it is required to consider all loads arising during normal operation, operational violations, including design basis accidents.
— The equipment (for example, racks and shrouds), which structural materials contain neutron absorbing nuclides to ensure nuclear safety, shall be designed and manufactured to exclude unallowable decrease of absorption ability under mechanical, chemical or radiological impact in normal operation, operational events, including design basis accidents. The equipment structural elements' absorbing properties, as designed, shall be confirmed before the equipment installation and in service.
— There shall be foreseen engineered means to exclude uncontrolled and spontaneous movements of nuclear fuel storage and transportation equipment, nuclear fuel drops, including in the events of loss of power and when power supply is resumed.

4.2.4. Nuclear safety during nuclear fuel storage and Transportation

Nuclear safety of fresh and spent nuclear fuel storage and transportation shall be ensured, beside other measures, by means of:

- Limitations imposed on the arrangement of nuclear fuel in shrouds, racks, stacks, fresh and spent FA drums, OSTPs;
- Limitations imposed on the number of FAs and FRs in shrouds, racks, stacks, fresh and spent FA drums, OSTPs;
- Limitations imposed on the number of packages and shrouds in a group, number of packages in a stack;
- Limitations imposed on the arrangement of the groups of shrouds, racks, stacks, fresh and spent FA drums, OSTPs;
- Use of heterogeneous or homogeneous absorbers;
- Monitoring of the arrangement of FRs and FAs, heterogeneous absorbers, packages,
- Shrouds, racks, stacks;
- Monitoring of presence and/or absence of moderators in fresh nuclear fuel storage facilities;
- Monitoring of presence, condition and composition of the cooling water and presence of a moderator in SNF dry storage facilities;
- Observing process parameters of the nuclear fuel storage and transportation system.
    - The spacing of FAs arrangement in shrouds, racks, and packages, as well as mutual arrangement of shrouds, racks, stacks and tubes, shall be chosen so that during nuclear fuel storage and transportation the effective neutron multiplication factor would not exceed 0.95 in normal operation and operational events, including design basis accidents. At this, such number, distribution and density of a moderator (water, in particular) shall be considered which lead to the maximum neutron multiplication factor in case of design basis accident initiating events during storage and transportation.
    - The nuclear safety analysis shall consider a possibility of the neutron multiplicity factor increase due to fissile nuclide accumulation in case of nuclear fuel burnup. Spent nuclear fuel shall be considered as fresh if the neutron multiplicity factor in case of burnup decreases, except for the cases where burnup value is used as a nuclear safety parameter. The analysis of initiating events shall consider the following possibilities:
        (a) re-grouping of FAs inside shrouds, fresh and spent FA drums, racks and packages resulting in an increase of the effective neutron multiplication factor;
        (b) change of geometry of FR and FA, as well as spacing between FR and FA, resulting in an increase of the effective neutron multiplication factor;
        (c) boiling of water, formation of steam-water mixture, and resulting increase of the effective neutron multiplication factor and thinning of the water protection layer;
        (d) loss of efficiency of heterogeneous and homogeneous neutron absorbers;
        (e) penetration of water or steam-water mixture into a package, shroud, fresh or spent FA drum, a dry storage facility for spent nuclear fuel.
- If irretrievable heterogeneous absorbers are used in rack and shroud structural components, the nuclear fuel spacing is selected on the basis of their absorbing capacity. It is not permitted to use retrievable heterogeneous in racks and shrouds.
- When analyzing nuclear safety of nuclear fuel storage facilities, one is required to assume that:
    - The nuclear fuel storage facility is full at maximum design degree;
    - When nuclear fuel of different enrichment is present in the storage facility, all fuel has the maximum enrichment;
    - When nuclear fuel with different nuclide composition is present in the storage facility, all fuel has the composition corresponding to the maximum effective neutron multiplication factor;
    - For normal operation in snf storage facilities with homogeneous absorbers (for example, borated water) and for nuclear fuel containing removable burnable absorbers, the absorber is absent;
    - A reflector is present in the storage facility.

— Calculation methodology errors, errors in determining enrichment of fissile nuclides and nuclear fuel nuclide composition and nuclear fuel fabrication allowances shall be considered in calculations used for justification of NF nuclear safety as regards nuclear fuel storage and transportation.
— The use of burnup as a nuclear safety parameter shall be justified in the design. At this, the design shall provide for burnup monitoring installations.

4.2.5. Safety measures for spent nuclear fuel storage and transportation [2]

(a) Storage of spent nuclear fuel

— For at-reactor storage of spent nuclear fuel the storage capacity shall so that it is possible to hold-up nuclear fuel for the time sufficient for reduction of radioactivity and heat release down to levels allowing for SNF off-site shipment.
— For SNF storage and transportation the measures or devices shall be provided for to exclude a possibility of fuel clad temperature increase during storage and transportation in excess of the values established for normal operation and operational violations including design basis accidents.

(i) Storage of spent nuclear fuel in water or other liquid medium

— Cooling ponds of spent nuclear fuel shall be equipped, at minimum, with the following systems necessary for safety ensurance:
  - Heat removal from the cooling medium (except for the cases, for which it is proved that the design temperature values of the cooling medium are not exceeded when the cooling medium heat removal system is unavailable);
  - Monitoring of specific activity of the cooling medium;
  - Cooling medium clean-up system;
  - process control systems (over content of homogeneous absorbers in the cooling medium or heterogeneous absorbers in racks, should such systems be foreseen in the design;
  - Over temperature, cooling medium level, water chemistry; hydrogen content in the air, as necessary);
  - Radiation monitoring;
  - Ventilation;
  - Filling and draining of the cooling pond;
  - Leak monitoring, collection and return;
  - Make-up;
  - Emergency make-up.
— The heat removal system shall be designed so that the cooling medium temperature in the cooling ponds does not exceed design values in normal operation, operational violations including design basis accidents. In the design of the heat removal system passive devices should be preferably used.
— For at-reactor storage facilities free storage capacity shall be foreseen to ensure complete unloading of the core at any time of operation.
— Should the ponds of the storage facilities have several separate compartments or should there be several separate ponds, the possibility of independent heat removal from spent FAs in each compartment and/or pond shall be provided for.
— In the SNF storage facility a free capacity shall be foreseen for SNF unloading from one compartment of the cooling pond in case of repair or accident.
— All pipelines in the cooling pond shall be set in the upper part in order to maintain the necessary level of water above nuclear fuel, should the pipelines break and water flow from the pond through these pipes. Dumping of the cooling ponds shall be performed using immersion pumps and down to the level justified in the design.
— The possibility of dumping the ponds due to the siphon drain effect shall be excluded. Pipelines for the cooling medium supply or removal shall be made so that in case of an air block or a break (leakage) the water level does not fall below the level ensuring safe storage of nuclear fuel.
— If there is a flood gate between compartments of the cooling ponds, it shall be

— designed to withstand water pressure from any side with no water from the other one.
— SNF cooling ponds shall be equipped with devices which exclude the ponds overflow with the cooling medium.
— Requirements for the cooling medium quality of SNF storage facilities shall be justified in the design.
— When a separate cooling medium clean-up system is used it is required that the cleanup system flow capacity be less than that of the make-up system.
— The storage facility design shall exclude spills and/or leaks of the cooling medium in excess of the make-up and/or emergency make-up amount during normal operation, operational violations including design basis accidents.
— Structural materials used for lining of cooling ponds, racks, shrouds, packages, reloading equipment shall be corrosion resistant.
— The cooling pond lining shall be made as an accident confining component. The lining shall ensure the design degree of leak-tightness and stability to stresses, as envisioned in the design. The lining shall remain intact when a SFA, shroud tube with SFA, other equipment and tool falls from the maximum height possible during transport and process operations. Structural materials shall not be sources of contamination of SFAs with alien substances that may affect SFAs integrity during their design storage period and shall not be sources of contamination of the cooling medium of the storage facility.
— The cooling pond shall be equipped with devices for detecting the cooling medium leaks, identifying their locations; the CP design shall allow for their elimination. Systems for radioactive water collection into monitored water collectors shall be envisaged for cooling ponds.
— The storage facility design shall provide for:
  - Technology for leaking SNF handling
  - Criteria for leaking SNF which, if achieved, require specific tubes and other equipment and measures to exclude spread of the fission products in the cooling medium exceeding the permissible values;
  - Safety justification for faulty SNF handling, and limits and conditions of SNF safe storage.
— The storage tube design shall provide for devices which allow to remove highly radioactive medium from storage tubes without its mixing with the cooling pond medium.
— In the design the possibility of lighting of the internal cooling pond volume shall be provided. Materials of the equipment used in these lighting fixtures shall not corrode inside the storage facility environs and cause its deterioration.
— The filtering equipment of the ventilation system shall be designed and operated so as to limit a potential release of radionuclides as well as radioactive aerosols.
— The ventilation system shall provide for dilution and safe evacuation of hydrogen resulting from water radiolysis.
— In case of a drop of SFAs, tubes, shrouds on the cooling pond bottom all routine transportation operations shall be terminated until they are removed.
— The design shall provide for removal of dropped SFAs, tubes or shrouds without draining the cooling ponds and full unloading of SFAs.

(ii) Storage of spent nuclear fuel in dry storage facilities

Dry storage facilities:
— For dry storage of spent nuclear fuel the design shall identify a method of cooling (forced circulation and/or natural convection), which excludes a possibility of fuel cladding temperature increase in excess of values established in the design in normal operation and operational events including design basis accidents.
— Requirements for leak tightness of dry storage facilities shall be established in the design. The means of monitoring of gaseous cooling medium leaks and filters shall be provided for in the design that allow to keep a release of radioactive substances within permissible limits established by radiation safety standards in case of possible loss of integrity due to an initiating event.
— Requirements for leak tightness of a storage facility are not established if nuclear fuel is stored in OSTPs, which exclude loss of integrity in initiating events anticipated in the design.

— The design shall define the scope of activities related to maintenance and monitoring of OSTPs, including monitoring by instruments pertaining to the confining system, and temperature of OSTP surface.
— The design shall envisage special rooms and equipment for opening of OSTPs with SNF.
— The storage facility shall be equipped with devices and tools which use will allow resuming normal operation of the storage facility and storage and transportation of damaged SFA OSTPs after design basis accidents.
— Where forced heat removal from OSTP is used, redundant systems for heat removal from OSTPs shall be provided for.
— For dry storage facilities it is required to anticipate measures for monitoring and limitation of radioactive substance accumulation, moderator detection, and temperature monitoring.
— In the design it shall be justified whether it is possible to use OSTP and open-air pads for dry storage.

(b) Requirements for On-Site Transportation Package (OSTPs) used for dry storage

— In the designing (developing) OSTPs for dry storage all possible external and internal impacts characteristic of the storage in normal operation and operational events, including design basis accidents, shall be taken into account.
— The design of the OSTP confining system shall be calculated with the account for maximum pressure in the OSTP inner space, data on radiation, physical and chemical characteristics of SNF, temperature of the OSTP gaseous medium, and temperature of the environment in normal operation and operational events including during design basis accidents.
— Any detachable joint of OSTP shall have not less than two confining barriers, where each confining barrier shall ensure design leak tightness parameters.
— The OSTP design shall ensure the possibility of control over the confining system. The leak tightness inspection methods and frequency of SNF OSTP leak tightness shall be defined and justified in the design.
— Safe operation limits as regards radionuclide releases from SNF OSTPs shall be defined and justified in the design.
— The OSTP design shall ensure the possibility of dumping of its inner space. Duration of SNF storage in OSTP and requirements for gas composition and allowed humidity level in OSTP shall be justified in the design.
— The OSTP design shall provide for decontamination; it shall ensure that there are no stagnant zones of possible accumulation of liquid (water, including atmospheric precipitation, working media and decontamination solutions) and locations which are difficult to access for maintenance.
— Structural materials of OSTP components shall not cause electromechanical interaction with each other and the package content; shall be resistant to decontamination solutions; withstand the impact of ionising radiation corresponding to characteristics of SNF; and the impact of temperature that may arise in normal operation and operational events including design basis accidents.
— The OSTP design shall consider:
  - Chemical and physical and chemical interactions;
  - Changes in material properties due to cyclic alterations of temperature in the environment;
  - Conditions of operation (irradiation, residual heat, internal pressure, humidity, presence of fission products and the environmental conditions).
— Valves through which a leak of radioactive content is possible shall be equipped with technical devices protecting from unauthorised manipulation and leak confining devices.

(c) SNF storage and transportation equipment

— The equipment for storage and transportation of SNF shall be designed (developed) so that a possibility of excessive mechanical loads to FRs and FAs are reduced to minimum during FR and SFA storage and transportation. In designing (developing) the equipment for SNF storage and transportation it is required to consider changes in geometry of FRs and SFAs and equipment components, which occur during

operation. Mechanical damages to outer surfaces of FRs and SFAs resulted from their insertion and withdrawal from the SFA storage and transportation equipment shall be excluded.

— In designing (developing) the equipment for SNF storage and transportation it is required to ensure easiness of its disassembly or retrieval for repair and maintenance.
— The SNF storage and transportation equipment in the cooling pond shall have interlocks, which exclude lifting of SNF above the corresponding water layer that is defined from the point of radiation safety.
— Equipment and tools used for underwater process operations shall be manufactured so that hollows in these tools are filled with water during submerging to maintain water protection layer and be emptied when the tools are taken out of the pond.
— In designing (developing) the storage facility and its equipment it is necessary to consider:
  - Load arising from maximum number of sfas, CPS rods, additional absorbers, dummies, and other devices foreseen in the design;
  - Loads during seismic impacts;
  - Hydrostatic pressure of water;
  - Loads arising from thermal effects;
  - Loads arising during full OSTP loading;
  - Dynamic loads during tossing of floating storage facilities.
— The reloading machine for nuclear fuel reloading under water shall have interlocks excluding:
  - Movements of the reloading machine when sfas are inserted in (withdrawn from) the reactor and the cooling pond and shroud rack cells;
  - Collision of the reloading machine bar carrying sfas with structures of the refueling pond;
  - SFA withdrawal from the reactor or cooling pond racks when the force to the reloading machine bar exceeds the value established in the technical documentation.
— For computer-controlled reloading machines there shall be automatic record-taking of all bar and SFA movements and interlock actuations, as well as the means to verify interlock availability and performance.
— The nuclear fuel storage and transportation equipment shall include devices that exclude overheating of FRs in SFAs by residual heat in excess of permissible temperature values established by the design, and which ensure protection of the personnel from overexposure.
— The design shall provide for necessary tests to verify performance of the storage and transportation equipment, in particular, the storage facility load-bearing structures (racks, brackets), and the storage facility lining leak tightness tests.

5. EGYPTIAN PROPOSAL FOR SAFETY STORAGE AND TRANSPORTATION OF SPENT NUCLEAR FUEL

Egyptian Nuclear Power Plant Authority (licensee) is responsible for the safe management of spent nuclear fuel.

5.1. General safety considerations for storage of spent nuclear fuel

The licensee shall ensure that the storage facility was designed to fulfill the main safety functions, i.e. maintaining of subcriticality, removal of heat, containment of radioactive material and shielding from radiation and, in addition, retrievability of the fuel. The design features should at least, if possible, include the following features:

— Systems for removal of heat from the spent fuel should be driven, if possible, by the energy generated by the spent fuel itself (e.g. natural convection).
— A multibarrier approach should be adopted in ensuring containment, with account taken of all elements, including the fuel matrix, the fuel cladding, the storage casks, the storage vaults and any building structures that can be demonstrated to be reliable and competent.
— Safety systems should be designed to achieve their safety functions with minimum need for monitoring.
— Safety systems should be designed to function with minimum human intervention.

— The storage building, or the cask in the case of dry storage, should be resistant to the hazards taken into consideration in the safety assessment.
— Access should be provided for response to incidents.
— The spent fuel storage facility should be such that retrieval of the spent fuel or spent fuel package for inspection or reworking is possible.
— The spent fuel and the storage system should be sufficiently resistant to degradation.
— The storage environment should not adversely affect the properties of the spent fuel, spent fuel package or the storage system.
— The spent fuel storage system should allow for inspections.
— The spent fuel storage system should be designed to avoid or minimize the generation of secondary waste streams.

5.2. Management of SF by the licensed operator

5.2.1. Responsibilities

The licensee shall:

(a) Establish a plan for the management of spent nuclear fuel utility, based on the inventory.
(b) Ensure that spent nuclear fuel storage is managed by appropriate classification, conditioning, storage and disposal, and maintain records of such activities including inventory of SNFS facility;
(c) Report to the ENRRA the required information at such intervals as may be specified in the license.
(d) Establish and maintain mechanism for availability of sufficient fund for the management of its SFSU.
(e) Assist the ENRRA inspector in his duties by granting him access to his facilities and records.
(f) Inform ENRRA promptly if any incident or accident has been taken place, submit preliminary report within twenty-four (24) hours and submit a written report to the ENRRA on the matter and the actions which have been taken within seven (7) days.

5.2.2. Safety

The licensee shall be directly responsible for the safety of the SFSU. To this end, the licensee shall:

(a) Comply with national laws and technical standards to ensure the safety of the SNFS;
(b) Be subject to regulatory supervision of the ENRRA and to report promptly the actual safety condition in case of nuclear incidents;
(c) Seek permission of the ENRRA for transporting nuclear/radioactive material to/from a SFSU;
(d) Submit any other relevant document/information at any stage during the licensing process.
(e) Ensure that SFSU are managed in such a way that the spent fuel can be safely stored and retrieved from the storage facility. Considerations relating to safe storage shall include possible reactions within the SFSU and the effect of the environment.

5.2.3. Licensing [8]

(a) A separate license shall be required for establishment of independent spent fuel storage in case the installation is not covered under license of any operating nuclear power plants or a research reactor.
(b) The ENRRA may also require the applicant/licensee to submit any other relevant document/information at any stage during the licensing process.
(c) No licensee shall transfer or assign a license to any other person without the prior approval of the Authority.
(d) The authorization/licensing process shall consist of the following stages:
    (i) Site Registration
    (ii) Construction License
    (iii) Permission for Commissioning

(iv) Permission to Introduce Nuclear Material into the Installation
(v) Operating License
(vi) Revalidation of Operating License
(vii) Licensing Beyond Design Life
(viii) License for Decommissioning of a Nuclear Installation or Closure of a Waste Repository
(ix) Removal from Regulatory Control

5.2.4. Security

The licensee shall ensure that all necessary means are taken to prevent unauthorized persons gaining access to the SNFS facility.

5.2.5. Transporting

The licensee shall ensure that the spent fuel is prepared for transport to a storage or disposal site. For this purpose, it shall be regarded as a radioactive source for transport in accordance with all applicable regulations. The licensee shall not transfer the SFS without confirmation that the organization to which it is to be transferred has the necessary authorization to hold/use/ recycle that material.

5.2.6. Storage

The licensee shall:

— Store and manage SFS in a storage facility licensed according to ENRRA regulations clearly demarcate and control access to the SFS storage area.
— Design the storage facility in such a way that the DSRS can be retrieved whenever required, without exposing workers to significant radiation exposure.
— Design the storage facility on the basis of the assumed conditions for its normal operation and all conditions assumed in the license.
— Design the storage facility for the likely period of storage, preferably with passive safety features, with the potential for degradation taken into account.
— Ensure provisions are made for regular monitoring, inspection and maintenance of the SF and the storage facility to ensure continued integrity.
— Protect human health and the environment and in particular SFSU shall not be stored in the vicinity of corrosive, explosive or easily flammable materials.

5.3. Responsibilities of the regulatory body

Egyptian Nuclear and Radiological Regulatory Authority shall:

— Assess periodically the safety of SFS facilities until termination of the license
— Follow-up on the management of SFS facilities by the licensed users.
— Review all the documents that are required to be submitted by licensee users according to the regulations.
— Contribute to the technical input for the establishment of the policies, safety principles and regulations and provide guidance to operating organizations on how to meet requirements relating to the safe storage of spent fuel
— Verify that the operating organization is providing the necessary personnel and the technical and financial resources for the lifetime of the spent fuel storage facility, to the extent that such confirmation is within the statutory obligations of the regulatory body.
— Review the decommissioning plans for spent fuel storage facility. The initial decommissioning plan should include how financial and human resources and the availability of the necessary information from the design, construction and operational phases will be ensured when the decommissioning takes place.

— Review the updated decommissioning plan and review and approve the final decommissioning plan if a facility is shut down and no longer to be used for its intended purpose.
— Periodically verify that the key aspects of the operation of the storage facility meet the requirements of the national legal system and facility license conditions, such as those relating to the keeping of records on inventories and material transfers, compliance with acceptance criteria for storage, maintenance, inspection, testing and surveillance, operational limits and conditions, physical protection of nuclear material and arrangements for emergency preparedness and response. Such verification may be carried out, for example, by routine inspections of the spent fuel storage facility and audits of the operating organization. The regulatory body should verify that the necessary records are prepared and that they are maintained for an appropriate period of time.

6. CONCLUSION

1. Egyptian Nuclear Power Plant Authority (the licensee) is responsible for the safe management of spent nuclear fuel produced by nuclear power plant reactors.
2. Specific legislation has been established in the nuclear law to: identify responsibility for safety, security and safeguards, specify allowable ownership of NPPs and associated rights and obligations, and provide funding for NPP programme.
3. Specific legislation has been established in the nuclear law to: identify responsibility for safety, security and management of spent fuel and radioactive waste (transportation, handling, and storage).
4. Egyptian proposal covers the safety considerations for storage and transportation of spent nuclear fuel, additionally the responsibilities of licensee and regulatory body.

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