SAFETY OPTIONS FOR THE PROJECT OF A FUTURE CENTRALIZED INTERIM WET STORAGE FACILITY FOR SPENT FUEL ASSEMBLIES

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Abstract

The French nuclear fuel cycle includes in particular the manufacture of uranium-based fuels, the reprocessing of the spent fuels, the fabrication of MOX fuels and of ERU fuels (enriched reprocessed uranium) and the interim storage of spent fuels which are not currently reprocessed (MOX and ERU).

Regarding the used MOX and ERU fuels which are currently not being reprocessed, the strategy consists in keeping them under safe storage conditions while waiting for their future reprocessing and potential use in future generations of reactors, such as fourth-generation reactors (GEN IV).

The quantity of non-reprocessed spent fuel slightly increases every year leading to the need of extended interim storage capacities. In this regard, the French National Plan for the Management of Radioactive Waste and Materials (PNGMDR 2016-2018) provides that, given the prospect of saturation of spent fuel storage capacities between 2025 and 2035, the french nuclear power plant operator, called the operator in the following text, shall submit to the Minister of Energy by March 31, 2017, its strategy for managing storage capacity of spent fuel from NPP and the timetable associated with the creation of new storage capacities. In response to this point, the operator submitted the safety option file for a new spent nuclear fuel wet storage facility, so-called the centralized interim storage pool. As requested by the French nuclear safety authority (ASN), IRSN reviewed these safety options. The IRSN assessment focused on the safety approach at the preliminary design stage and the structuring design choices such as:

— the civil engineering structures, including storage pools (number, dimensions, storage capacity, subdivision) and the building shell;
— the methods of unloading, loading and handling of spent fuel assembly transport casks as well as the methods to store the spent fuel assemblies;
— the consideration of scenarios of loss of "support functions" identified by the operator, in particular the duration of autonomy retained in the event of a prolonged loss of electricity or cooling function;
— more generally, the accident situations to be taken in the design of the installation.

Special attention was paid on the one-hundred-year operational lifetime of this facility with regard to the surveillance of spent fuel assemblies, the control of the facility ageing, in particular through maintenance and monitoring, and the inspectability and possible replacement of systems, structures and components important for safety.

1. INTRODUCTION

The French nuclear power operator transmitted in April 2017 to the French nuclear safety authority a file presenting the safety options for the project of a new centralized interim wet storage facility for spent fuel assemblies. The project provides that it would be operated for a period of one hundred years, starting in 2030.

2. DESCRIPTION OF THE MAIN FEATURES OF THE FUTURE FACILITY

Total capacity of the storage facility would be 10,000 tons of heavy metal. This is equivalent to about 21,000 spent fuels assemblies, mainly MOx fuels and reprocessed uranium fuels.

The facility would be composed of two pools with a water height greater than twice the length of SF assemblies. The building would be semi-buried and construction could be modular.

This facility has to perform five main industrial functions:

- SF package reception.
- SF package preparation and dry unloading.
- Storage of SF and removal from storage.
- Water cooling and treatment.
- Utilities.

3. SAFETY PRINCIPLES AND OPTIONS

The operator defined three main safety functions for this facility:

- Containment of radioactive materials.
- Prevention of criticality.
- Cooling.

The defense-in-depth principles will be applied.

Two containment barriers will separate the radioactive material and the environment: the SF element cladding and the concrete structure. It will be completed by a dynamic containment ensured by a nuclear ventilation system. The pool concrete structure will be coated by a metal liner and there will be no penetrations under the water level. Chemical and radioactive characteristics of the fresh pool water will be monitored and manage by specific treatments. The external containment barrier will be designed for resisting to external aggressions. In order to avoid any SF damages, handling operation will be performed by high security means and no handling routes over the stored SF.

Prevention of criticality accident will be performed by controlling the geometry and the material of SF storage basket (poisoning). Thermal load evacuation will be performed by redundant cooling system; part of them immerged in the pools. The chosen design limits the risk of leakage or siphoning of the water from the pools. Regarding external aggressions, earthquake, flooding, “global warming” evolutions, aircraft crash, tornadoes are taken into account within the design. To take into account the lessons learned from the Fukushima accident, extreme external aggressions are considered in the design extension conditions.

4. IRSN ASSESSMENT

IRSN has assessed the safety option file, in particular the safety approach to design, the main design choices, such as the method of unloading the assemblies, the design of the structure of the installation, the choices for the water cooling systems and provisions for protecting against external aggressions. IRSN’s assessment also focused on the safety options selected with regard to long term duration of operation in particular for monitoring the aging of systems, structures and components as well as for maintenance and refurbishing.

Following its assessment, IRSN considered that the design options selected by the operator provide this facility with a higher safety level than existing facilities. Concerning the operator's general design approach,

IRSN considered that it needs to be completed in order to explicitly integrate the protection of people and the environment against ionizing radiation. Moreover, the safety options relating to risk control provisions in the field of operation are broadly adapted. Sub-criticality control provisions, based on the use of storage baskets made of borated materials, are appropriate. IRSN considered that the containment provisions for radioactive substances must be supplemented in order to manage the reception of any leaky assemblies.

Concerning the design options, IRSN considered that the dry unloading of transport casks method chosen allows to minimize the risks of falling during handling inducing aggression of the basin, as well as a reduction in the production of effluents. Furthermore, the feedback of the La Hague plants about this method is satisfactory. In addition, the water-cooling systems, similar to those provided for the pools at La Hague plants, minimize the risk of leakage from the pool due to the absence of pool's walls crossings. For IRSN, this system is well adapted for the future storage pool.

The leak tightness system chosen for the pools, made up of reinforced concrete basin coated with a metal liner, is a sensitive point regarding safety, considering the potential difficulties of design, construction and monitoring. In this regard, IRSN considered that the operator should continue to study this point in the next phases of the project. This subject will be further studied in the next phases of the project. Regarding the uncovering of fuels, the operator considers that the design and operating provisions it has adopted practically eliminate this situation. The operator's safety demonstration is based on the absence of this kind of event. IRSN considered that these technical provisions allow to greatly reduce the risks of leakage of the pool and that they are adapted. Despite these considerations, IRSN considered that such a scenario of non-compensable massive leakage of water should be taken into account to further improve the level of safety of the facility. This should lead to implement provisions regarding the loss of the water inventory of the basins, which IRSN considers reasonably achievable at this stage.

Concerning the risks associated with external aggression of the pool, IRSN considered satisfactory the design choices of the pools, in particular the choice of semi-buried buildings, the protection of basins from an aircraft crash, as well as the geographical redundancy of the cooling systems.

In case of extreme earthquake, although the cooling system is sized to the earthquake, it is considered a total loss of cooling of the water causing its boiling. For IRSN, this implies taking into account for the design of the pools, successively solicitations related to an extreme earthquake and then thermal stresses induced by the boiling of water. In this situation, aftershocks following the initial earthquake could occur after the boiling of the water. That's why this situation must be taken into account in the design of basin support system.

For the study of the extended design domain, IRSN considered that the restart of operations after a defined situation of this domain, must allow to have, within a reasonable period of time, appropriate handling equipment in order to be able to ensure if necessary the recovery and transport of assemblies.

Lastly, with respect to the planned operating life of the facility, the operator presented a monitoring program for stored fuel assemblies. IRSN considered that the operator has to establish an assembly inspection program in order to complete the knowledge on the impact of transport on the integrity of the fuel element cladding. Otherwise the operator has provided that all the equipment and structures of the facility are replaceable, except for the pools and the metal liner. For the latter, a periodic verification of the concrete structure of the pools and the liner is planned by visual controls. In this regard, IRSN considered that the operator surveillance programme must be complemented by other control provisions, in addition to visual inspections, of the conformity of the concrete structures and the liner.

5. CONCLUSION

In December 2018, IRSN presented the conclusions of its assessment to the permanent group of experts mandated by the French safety authority, which will soon forward to the French nuclear power plant operator its decision on safety options for its project of a new centralized interim wet storage facility for spent fuel assemblies.

REFERENCES

[1] Programme Act No. 2006-739 of 28 June 2006 on the Sustainable Management of Radioactive Materials and Wastes.

[2] Decree 2007-1557 of 2 November 2007 concerning basic nuclear installations and the supervision of the transport of radioactive materials with respect to nuclear safety.

[3] ASN Guide No. 13: Protection of Basic Nuclear Installations against external flooding.

[4] Report WENRA Safety Reference Levels for Existing Reactors – Update in relation to lessons learned from TEPCO Fukushima Dai-ichi accident - 24th September 2014.