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AGEING MANAGEMENT AND POST-STORAGE TRANSPORT OF DUAL PURPOSE CASK FOR SPENT FUEL

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ABSTRACT

Ageing management of spent fuel storage facility may follow lessons learned from literature for nuclear power plant and a review for spent fuel dry cask storage system by US NRC, DOE, by German BAM, that by Japan NISA, etc. Namely, the essence of systematic approach to ageing management includes Understanding ageing, Plan (Development and optimization of activities for ageing management), Do (Managing ageing mechanisms), Check (Monitoring, inspection and assessment), and Act (Maintenance). The PDCA cycle will optimize the systematic approach to the ageing management.

An ageing management programme (AMP) for the storage system over the period of extended storage will address uncertainties in the safety-relevant functions of the system that may otherwise be impaired by ageing mechanisms. The AMP identifies SSCs (System, Structure and Components) that need specific actions to mitigate ageing and ensures that no ageing effects result in a loss of their intended function of the SSCs, during an intended licensed period.
AMPs generally include Prevention, Mitigation, Monitoring, Inspection, and Maintenance programmes.

Ageing management plans should ensure compliance with transportation requirements after extended storage. Potential issue would be a significant change of the transport regulations in the future. If the regulations changed significantly, a gap analysis should be performed to identify any impact to the cask safety. Compensating arrangements, if necessary, should be proposed at that time. Assuming that the regulations will not change significantly after long-term storage, we will be able to renew the license both for transport and storage of the cask during the storage period. For example, in Japan, a holistic approach was established for the license of a 50-year storage and transport. In this approach, we can evaluate integrity of spent fuel, basket, etc. with respect to chemical, thermal, mechanical, and radiation factors. With this approach we will not have to open the cask lid for visual inspection of the spent fuel, basket, etc. prior to the post-storage transport.

INTRODUCTION

Ageing management has been extensively developed for nuclear power plants (IAEA Safety Guide NS-G-2.12 (2009)[1]). The principle and the approach should be applied also to spent fuel storage (SFS) facilities. Fig. 1 shows an adaptation of the “Plan-Do-Check-Act” cycle to the ageing management SFS facilities. A properly executed ageing management program will preclude unplanned and/or unanalyzed conditions that could reduce safety or security margins or result in unnecessary remediation costs during extended storage.
After the Fukushima accident in Japan, future strategy on the nuclear fuel cycle is being discussed by the Atomic Energy Commission of Japan. On top of that, future capacity of

nuclear power generation is being discussed by the Japanese government. Whatever fuel cycle option may be chosen, spent fuel storage is an essential process in Japan. Currently, an interim storage facility of spent fuel is being constructed. The interim storage facility is being constructed at Mutsu city of Aomori prefecture. The spent fuel will be stored for 50 years and shipped out to a reprocessing facility. The same casks will be used for transportation and storage. The transport casks shall be inspected annually and the transport license shall be renewed every 5 years. For post-storage transport, the metal casks shall be inspected to secure the integrity including of the internals. However, some of the inspection may not be conducted by the conventional method, because the Nuclear Safety Commission of Japan does not require opening the casks for visual inspection of the contents and fuel basket[2]. Because the opening the casks is to break the containment boundary of the metal casks. This action is undesirable not only from the viewpoint of reduction of workers' exposure or leak prevention of radioactive materials, but also may increase risks. The inspections prior to the transport after the storage could be substituted by confirmation of monitoring data of the casks during storage, etc.
The Nuclear and Industrial Safety Agency developed a document "Long-term Integrity of the Dry Metal Casks and their Contents in the Spent Fuel Interim Storage Facilities" in the response to the request by the Nuclear Safety Commission[3]. This paper introduces the intent of the document, which is "Holistic Approach" for Licensing Transport/Storage Metal Casks for Spent Nuclear Fuel.

AGEING MANAGEMENT OF SPENT FUEL STORAGE

General Approaches to Ageing Management

Ageing management has been extensively developed for nuclear power plants (IAEA Safety Guide NS-G-2.12 (2009)). The principle and the approach should be applied also to SFS facilities. Figure 1 shows an adaptation of the "Plan-Do-Check-Act" cycle to the ageing

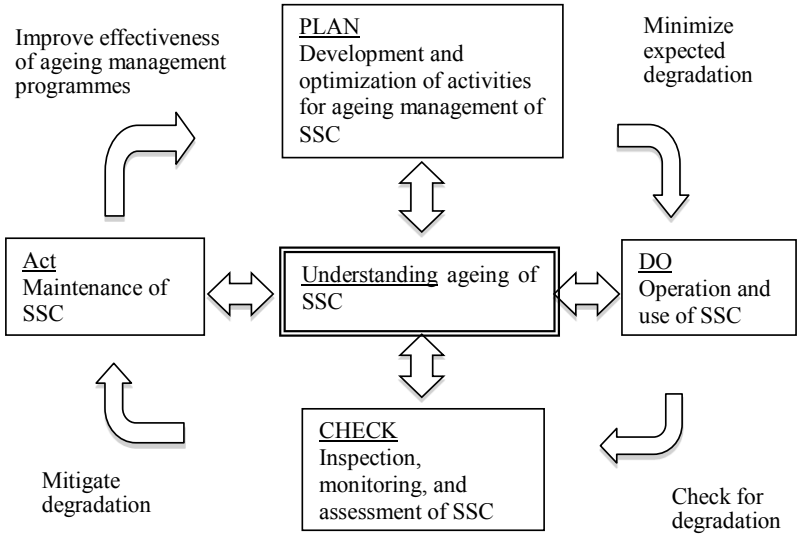

Figure 1 Systematic approach to managing ageing of a structure or component

management SFS facilities. This is a well-known and accepted practice used widely to ensure continuous process improvement. The iterative approach utilizes feedback from relevant operating experience along with results from research and development, self-assessment and peer reviews to help ensure that any emerging ageing issues will be identified and addressed. In addition to materials degradation, ageing management should also consider changes to policy and/or regulatory requirements relevant to extended storage.
A properly executed ageing management program will preclude unplanned and/or unanalyzed conditions that could reduce safety or security margins or result in unnecessary remediation costs during extended storage. Information resulting from ageing management activities also serves as a baseline for prioritizing technical considerations and associated research and development objectives. It also provides context for the public and policy makers to properly understand the relative risks.

Ageing Management Programme for Spent Fuel Storage

Key elements of the systematic approach to ageing management of SFS facilities as illustrated in Figure 1 are described as follows.

Understanding
Effective ageing management requires an understanding of potential degradation mechanisms. This may require research, development, and testing to understand consequences and identify methods to preclude, reduce, and/or mitigate degradation of SSCs during operation of the SFS facilities. Regulatory change during the extended storage is also taken into account.

PLAN
Operation, monitoring, inspection, and maintenance activities for ageing management of SSC should be developed and optimized to effectively manage ageing effects. The plan should include a "Prevention Programme" that minimize or slow the ageing effect.

DO
Operate the SFS in accordance with the procedures and programme plans developed in the previous step.

CHECK
Ongoing monitoring and inspection are required to ensure early degradation is detected and addressed before any loss of safety function. A Monitoring Programme and an Inspection Programme should be developed to detect and assess any degradation of SSCs during extended storage. Monitoring means continuous measurements. Inspection means an examination, observation, measurement or test. Examples of the content of monitoring and inspection programmes for SFS facilities are provided below.

"Monitoring Programme" consists of condition monitoring and performance monitoring
(1) Condition monitoring will search for the presence and extent of ageing effects (e.g., visual inspection of spent fuel, SFS racks, and concrete structures for cracking): Examples for dry SFS include determining the condition of concrete structures and pads, external coatings and housings, and instrumentation and cables.
(2) Performance monitoring will verify the ability of the SSCs to perform their intended functions as shown below.

Comment [WU1]: Should we say '….. tha minimizes or slows ageing effect…' ?

I don't think we can ever 'keep ageing effec from occurring.'

Comment [WU2]: This description of 'Do sounds very much like the description of 'Pl above.

And it seems like development of bot h the prevention and the mitigation programmes would be part of planning.

Should we develop both programmes as part the 'Plan' step and then say that the 'Do' ste ise, "Operate the SFS in accordance with the procedures and programme plans developed the previous step'?

- Shielding: A storage cask operator will obtain historic radiation survey data and evaluate the trends. Either through measurement or analysis, one can adequately assess trend of historical measurements or deviations from calculated radiation levels, which would indicate shielding degradation.
- Containment: For metal cask storage, metallic gasket may degrade during the extended storage. In order to confirm the containment function of the gasket, one can check the Helium gas leakage through pressure monitoring between cask lids.
- Spent fuel integrity: A penetration into the canister/cask for cavity gas sampling may be required. A non-destructive method has been proposed to detect SFA failure by measuring gamma ray from Krypton-85 released from the damaged SFA in the canister.
- Structural integrity: Schmidt hammer test may be employed to detect any degradation of concrete structure in SFS facilities.

"Inspection Programme" will assess and detect degradation that may affect performance of safety-related components (or that may jeopardize transportability). Inspections may be performed periodically or at random. Periodic reassessments of the condition of the SFS system with respect to evolving regulations and technology should be performed to ensure that the storage licensing basis remain in compliance throughout the storage period.
Inspection for a license renewal of a SFS facility may be accepted through inspection of representative SSCs.
Inspection intervals are established to ensure degradation is detected before it affects the safety function of the SSCs. During the extended storage, the time span for inspections is revised based on the history of operation, the results of the past inspection, etc.

ACT

"Maintenance Programme" should ensure that all components with a time-dependent operating life are assessed based on an understanding of the degradation mechanism of the SSC's with operating history, including corrective actions and design modifications to the SFS facilities. At the end of the identified operating life, the component will be replaced or renewed. Although maintenance must focus on safety related SSCs for technical reasons, it should also be considered that public may be concerned with the condition of more "visible" non-safety related SSCs as well (e.g. deteriorated paint).

"HOLISTIC APPROACH" FOR LICENSING TRANSPORT/STORAGE METAL CASKS FOR SPENT NUCLEAR FUEL

Scenario of Transport and Storage

Conventionally, licenses for transport and storage have been issued separately through independent review process and for different licensing period. The "Holistic Approach", however, enables licensing of off-site transport after the storage by activities of competent authorities and operators relying on and utilizing the safety records on transport and storage each other including those during the preparation of the casks at nuclear power plants. Based on the scenario, the "Holistic Approach" is proposed as follows.

Safety of Post-Transport Storage

The safety of post-transport storage relies on the proper preparation of the casks and safe transport of the casks to the storage facility.

Comment [WU3]: \
Toshi,

Please insert a reference explaining this technique (in lieu of the appendix)

Comment [WU4]:
Toshi,

Please insert a reference explaining this technique (in lieu of the appendix)

Comment [WU5]: Suggest deleting this sentence as it is not really necessary here an in any case, will be up to the regulator to decide what will be accepted for license renewal.

Comment [WU6]: Are there any compone that do not have a 'time-dependent operating livfe'?

Comment [WU7]: This is an excellent poi

It may be better placed in section 7 with 'nontechnical considerations'

Lets revisit after we see what Arturo comes with for section 7.

- The integrity of spent fuel contained in the casks is assured by confirmation of its integrity at the nuclear power station before loading, and properly emplaced in the casks, and safely transported to the storage facility.
- The nuclear power plant operator is required to conduct proper preparation of the casks including spent fuel loading, to provide the record of the operation, and to deliver it to the storage facility operator.

Renewal of Transport License during Storage

Maintenance and update of the transport license (design approval) of the casks during storage relies and the safe storage relies on each other.

- Transport license has to be maintained and updated (renewed) during storage.
- Safety functions of the casks as a transport package rely on the safe storage and its inspection record dealing with ageing.

To ensure this, storage facility operator is required to conduct proper monitoring and inspection of safety functions of the casks over the storage period, to prepare its record and to manage and maintain it together with the record delivered from the nuclear power plant operator.

Safety of Post-Storage Transport

Items to be confirmed before transportation of spent fuel from power plants

The stored spent fuel is to be shipped out to reprocessing facilities after the end of the storage. At present, when spent fuel is transported from power plants, generally the following 10 items are inspected[4]. (Specific items and methods of inspection shall be stated in the application for design approval of nuclear fuel transportation casks as the items related to handling.)

- External appearance inspection
- Leak tightness inspection
- Pressure retaining inspection
- Dose rate inspection
- Subcriticality inspection
- Temperature measurement inspection
- Lifting inspection
- Weight inspection
- Contents inspection
- Surface contamination inspection

Inspection items which cannot be conducted by visual checks etc.

In the above listed inspection items (which are generally carried out), inspections which need visual check of inside the metal casks are included. Therefore, in interim storage facilities which are not equipped with fuel refilling system, it includes the inspection items which cannot be conducted exactly the same as the above, for transportation after the end of storage.

Among those general inspection items for shipment from power plants, the following three inspection items can be specified which cannot be conducted visual checks the same manner for shipment from the interim storage facilities which have no the fuel refilling system, like these inspection items include visual check of the contents and measurement of the interior environment of the containers.

- Subcriticality inspection

This confirms that there is no deformation or breakage of baskets, which may affect the function to prevent criticality.

In case shipping out from power plants, the inspection is carried out as visual check of the basket structure appearance.

- Contents inspection

This confirms that spent fuel assemblies satisfy the requirements specified at the time of design (specification, quantity and layout when contained in the containers).

In case shipping out from power plants, the inspection is carried out confirmation of the specification and quantity by the check of operation records, and also visual inspection of the layout and appearance of the contents.

- Pressure retaining inspection

Inspection to confirm that atmosphere inside the metal casks is maintained within design requirements.

In case shipping out from power plants, inspection are carried out in such a way that remaining moisture is checked by the degree of vacuum after vacuum drying or by humidity after refilling gas into the casks while constituents and refilling quantity of gas and pressure are checked by the record of the metal cask preparation work.

Concept of alternative inspections

In order to confirm safety of transportation at the end of storage, integrity of the metal casks and contents should be checked, for example, by visual check of the condition of the contents and baskets by opening the lid of the metal casks, or by inspecting atmosphere inside the metal casks before shipment in the interim storage facilities. On the other hand, following facts should be considered: a) Interim storage facilities are very stable and static (For example, Paragraph 5.23 of the IAEA Safety Series Specific Safety Guide SSG-15 states, “In normal operation, for spent fuel storage facilities, there should be nothing that will cause a rapid increase in reactivity in the stored fuel, and thus relatively few credible mechanisms for such a sudden excursion followed by a release of radioactive material.”); b) Radioactivity of spent fuel contained in the metal casks gradually decays by releasing heat; c) Visual inspection of internals requires that the containment boundary of the metallic casks be opened. (At the end of storage, if it is decided to actually measure the pressure in the atmosphere inside the metallic cask, a vent valve installed in the primary lid must be opened after opening the secondary lid. This action is regarded as an operation to break the containment boundary of the cask, just like opening of the primary lid.) This action is undesirable not only from the viewpoint of reduction of workers’ exposure or leak prevention of radioactive materials, also may increase risks. Consequently, when the same level of safety can be assured as visual check, it is more desirable to perform inspections based on alternative approaches. The following are the alternative inspection methods related to the above-mentioned inspection items.

- Subcriticality inspection

Baskets are exposed to decay heat and radiation of the contained spent fuel, and also to external forces caused by vibration due to earthquake and transfer etc.

Therefore, the Safety Review Guidelines[5] demands that baskets must be designed (especially selection of materials) and manufactured so as to achieve long-term integrity during storage. The environment that is presumed to be achieved at the time of sealing should be retained by the following way: when metal casks are prepared in the power plants, moisture in the space (where a basket with spent fuel is installed) must be completely removed, and then the space is filled with inert gas, and finally sealed by multiple lid structure.

The basket, which is treated and managed as above by design and manufacture, is exposed to the same environment as spent fuel. Therefore, the subcriticality can be assured if the following points are confirmed:
(a) The basket is manufactured following the design in the factory.
(b) Moisture is removed and inert gas was filled according to the design requirements during preparation of the metal casks in the power plant.
(c) Casks pass subcriticality inspection for transportation from the power plant to the interim storage facility, and there is no abnormal external force during transportation.
(d) The inert atmosphere of the basket (neutron absorbing material) has been maintained during storage.

As a consequence, when the metal casks are shipped out from the interim storage facilities which have no fuel reloading equipment, subcriticality inspection during the pre-shipment inspection can be substituted by the documents which proves above listed items from (a) to (d) .

- Contents inspection

The specification, quantity and layout in the cask for the spent fuel (the contents of the cask) have been already confirmed by operational records, etc., when the casks were originally shipped out from the power plant to the interim storage facility. As there exists no factor that will change these conditions, the above-mentioned items can be reconfirmed by using the same records for the shipping of the casks from the interim storage facility.

Concerning the appearance, although the contents cannot be visually checked, as they are contained in the metal casks which have necessary heat removal function during storage, and sealed with inert gas, they are considered that integrity of spent fuel is not impaired due to chemical, thermal and radiological degradation.
Specifically, if the following points are confirmed, spent fuel integrity can be assured:
(a) Moisture is removed and inert gas is filled in the way which satisfies the design condition during preparation of the metal casks in the power plant.
(b) Casks pass the inspection of contents for transportation from the power plant to the interim storage facility, and there is no abnormal external force added during transportation.
(c) There have been no incidents that may damage integrity of contained spent fuel during storage.
(d) The inert atmosphere of the spent fuel has been maintained during storage.

As a consequence, when the metal casks are shipped out from the interim storage facilities, especially if there is no fuel reloading equipment, the inspection of the contents during the pre-shipment inspection can be substituted by the documents that confirm the listed items above from (a) to (d).

- Pressure retaining inspection

It should be confirmed by pressure measurements that atmosphere inside the metal casks is within the range of design requirements. However, as the internal cavity of the metal cask is sufficiently dried, filled with inert gas and sealed by the multiple lid structure, it can be

assumed that as long as the containment function is maintained throughout the storage period that the original atmosphere is preserved.

Specifically, if the following points are confirmed, the atmosphere inside the metal casks is assured within the range assumed at the design stage:
(a) Moisture is removed and inert gas is filled in the way that satisfied the design requirements during preparation of the metal casks in the power plant;
(b) Casks pass the pressure measurement test for transportation from the power plant to the interim storage facility and there is no abnormal external force acted during transportation;
(c) Containment function of the metal casks is confirmed by the acceptance test in the interim storage facility;
(d) Containment function of the metal casks has not been lost during storage.

As a consequence, when the metal casks are shipped out from the interim storage facilities, especially if there is no fuel reloading equipment, pressure retaining inspection during the pre-shipment inspection can be substituted by the documents that confirm items from (a) to (d).

CONCLUSIONS

Ageing management plans should ensure compliance with transportation requirements after extended storage. Potential issue would be a significant change of the transport regulations in the future. The "Holistic Approach" enables licensing of off-site transport after the storage by activities of competent authorities and operators relying on and utilizing the safety records on transport and storage each other including those during the preparation of the casks at nuclear power plants. Integrity of the casks and the internals would be ensured without opening the cask lids during and after the storage.

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