Conceptual Design of Spent Fuel Storage and Handling System for SMART-P Plant

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1. Introduction

A conceptual design of the spent fuel assembly (SFA) storage and handling systems for SMART-P plant was developed. This conceptual design is a part of fuel handling system of SMART-P plant. In this paper, we introduce the operation sequence, design requirements and design feature of major subsystems in the spent fuel storage and handling systems for SMART-P plant.

2. Sequence of SFA Storage and Handling

The sequence of spent fuel storage and handling subsystem equipment operations within the fuel building is as follows:

- With the spent fuel handling machine, unload SFA from the fuel transfer mechanism(FTM) carriage seat and install into the leaky SFA detection system equipment;
- With the spent fuel handling machine unload SFA from the leaky SFA detection system equipment and install into the spent fuel storage rack seat in the spent fuel storage pool or into canisters for leaky SFA arranged in the spent fuel storage racks

Procedure for loading SFA and canisters with leaky SFA into spent fuel shipping cask (SFSC) is as follows:

- With the gate valve installed in decontamination pit, use the overhead crane to install SFSC into the decontamination pit;
- Wash and dry SFSC inner and outer surfaces;
- Unfix and remove the SFSC cover;
- Install the gate valve into the channel that connects SFSC loading pit with spent fuel storage pool;
- Drain SFSC loading pit;
- Remove the gate valve out of the transport channel that connects the decontamination pit with the SFSC loading pit;
- Install SFSC into SFSC loading pit;
- Install the gate valve into the channel of the decontamination pit;
- Fill the SFSC loading pit with water and remove the gate valve out of the transport channel that connects SFSC loading pit with spent fuel storage pool;
- Use the spent fuel handling machine to install leak-tight SFA or canisters with leaky SFA into SFSC;
- Re-install the SFSC cover;
- Install the gate valve into the transport channel that connects SFSC loading pit with spent fuel storage pool and drain the SFSC loading pit and drain water from SFSC inner cavity;
- Fix the SFSC cover;
- Remove the gate valve out of the channel that connects decontamination pit with SFSC loading pit;
- Use the overhead crane to unload SFSC from the SFSC loading pit and to install it into the decontamination pit;
- Install the gate valve into the channel that connects decontamination pit with SFSC loading pit;
- Dry SFSC inner surface and implement decontamination of its outer surface;
- Check SFSC inner cavity seal leak-tightness using a special system;
- Remove the SFSC to the place of loading into wagon for further transportation to the place of long-term storage.

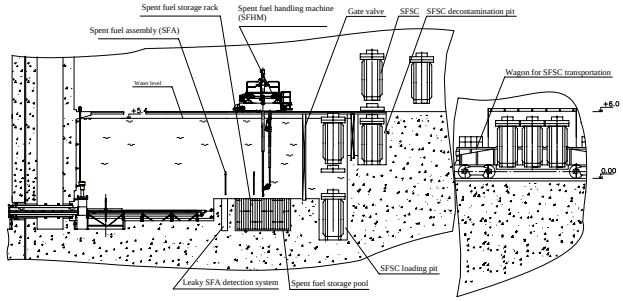

Figure 1. Spent fuel storage and handling scheme

3. System Descriptions

In this section the system description and design feature of the major subsystems in the spent fuel storage and handling system are introduced.

3.1 Spent Fuel Storage Pool

The following was taken into account during design when selecting the parameters and dimensions of the spent fuel storage pool:

- Total required pool capacity;
- Necessary SFA storage conditions;
- Design and dimensions of fuel handling mechanisms used for SFA handling in the storage pool;
- Required strength of structures in view of possible operational and emergency effects.

Spent fuel storage pool is a ferroconcrete rectangular cavity filled with water, where the walls and bottom are faced with stainless steel. The pool houses eight identical racks. Water column height up to SFA active part during transportation shall be 2.5m minimum.

3.2 Spent fuel storage rack

The rack is intended for installation and storage of SFA, canisters for leaky SFA, canisters with spent CEA and ICI.

The rack design provides for:

- Vertical installation of SFA and canisters in it;
- Alignment and fixing of SFA installed in the racks;
- Prevention of mechanical damage of SFA and canisters during their installation and withdrawal from the racks;
- Subcriticality of not less than 0.05, when SFA and canisters are stored in the rack;
- Cooling of SFA and canisters due to cooling water circulation (when spent fuel storage pool cooling system is operating) inside SFA, between SFA and between the SFA and canisters.

Tubes in the rack are arranged in a triangular grid with 125 mm pitch that allows meeting the requirements of nuclear safety during spent fuel storage with a huge margin and locating 295 leak-tight SFA, five canisters with spent CEA and ICI and six canisters with leaky SFA in a rack.

3.3 SFSC loading pit

SFSC loading pit is intended to arrange SFSC during spent fuel loading into it and is used to store the equipment of spent fuel handling machine setup facility between operations of SFA loading into SFSC. SFSC loading pit is a rectangular ferroconcrete cavity with walls and bottom faced with stainless steel. The lower part of the pit has seat, providing corresponding arrangement and positioning of SFSC in the pit, as well as the space for installation of spent fuel handling machine setup facility equipment. SFSC loading pit is connected by a transport channel with the spent fuel storage pool, so as to ensure loading into SFSC. The upper part of SFSC loading pit is connected by a transport channel with the decontamination pit to ensure SFSC transportation into the pit.

3.4 Spent fuel shipping cask (SFSC)

Spent fuel shipping cask is intended to arrange and transport SFA and canisters with leaky SFA to the place of their long-term storage. The main elements of SFSC are cover, casing and removable part.

SFSC casing is a thick-walled welded cylindrical vessel made of corrosion-resistant steel and fitted with journals for SFSC transportation by overhead cranes. Evaluation analysis of SFSC for impact load when falling from 9m height shows that SFSC is not getting depressurized. Removable part is a welded structure consisting of upper and several intermediate plates with tubes welded to them. There are two removable part design options to arrange leak-tight SFA, and to arrange 31 canisters with leaky SFA. The pitch of triangular grid for SFA arrangement in SFSC is 100 mm, and the pitch for canisters with leaky SFA is 120 mm, that ensures considerable margin to meet nuclear safety requirements.

3.5 Spent fuel handling machine (SFHM)

Spent fuel handling machine is intended to handle SFA within the fuel building and fulfills the following operations:

- Removes SFA from FTM carriage seat, transports them under water and installs into leaky SFA detection device or into spent fuel storage racks in the spent fuel storage pool;
- Removes undamaged FA from the spent fuel storage rack, which might be reloaded from reactor off schedule, and transports them to FTM carriage seat to be loaded back into the reactor;
- Removes SFA from the spent fuel storage rack seats, transports and installs them into SFSC.

SFHM bridge and SFHM carriage are intended to align the spent fuel handling mechanism with the coordinate of FTM carriage seat and transport SFA to be reloaded from the seat to the spent fuel storage pool, aligning the spent fuel handling mechanism with the coordinate of SFA seats in storage racks.

3.6 Wagon for SFSC transportation

SFSC are assumed to be transported in a Russian TK-VG-18 container wagon, which houses three SFSC. Total weight with SFA loaded into them is 96.7 t. TK-VG-18 container wagon is an eight-axis wagon with a body installed on it; load-carrying capacity is 120 t. The exposure dose rate during spent fuel transportation with decay storage time of 3 and more years on the wagon surface is max 2 mSv/h, and 2 m away from the wagon it amounts to max 0.1 mSv/h, and in any place for a passenger – max 0.02 mSv/h.

3. Conclusion

The results of conceptual design for spent fuel storage and handling system for SMART-P plant is introduced. The subsystems of spent fuel storage and handling system have their own design characteristics and design features. The basic design for spent fuel storage and handling system should be performed to upgrade the operability and the maintenance based on this conceptual design.

Acknowledgement

This work has been performed under the nuclear research and development program sponsored by the DOOSAN Heavy Industries Construction Co., LTD.

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