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PGSFR BOP Design Features

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1. Introduction

In Prototype Gen-IV Sodium-cooled Fast Reactor (PGSFR) project, KEPCO E&C has developed the conceptual and basic BOP system design with containment, seismic isolation system, passive safety systems, sodium fire protection system, auxiliary sodium systems, power conversion system and other system based on the NSSS interface requirements.

PGSFR nuclear island composing of the containment and auxiliary buildings is installed on top of the seismic system as a single foundation, as shown on Figure 1. The containment is a reinforced concrete shell structure consisting of a cylindrical wall and a partially hemispherical dome supported by mat foundation. The auxiliary building is designed in the shape of a rectangle surrounding the containment. The building has two divisions based on two symmetrically positioned steam generators. The four decay heat removal loops are separated by quadrant in the auxiliary building. The floors, walls, and ceilings of all compartments housing sodium components or sodium piping segments are lined and covered with steel liner plates. Water pipe shall not be located in structures or compartments containing sodium to minimize the adverse effect such as sodium-water reaction. The containment and auxiliary buildings are designed to withstand an appropriate aircraft impact in accordance with the regulatory requirements of the Republic of Korea.

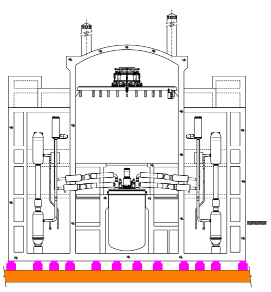
Fig. 1 PGSFR Nuclear Island


Fig. 2 LRB

The overview of the BOP system design features are presented in this paper.

2. Containment

The containment is designed to establish an effective barrier against the uncontrolled release of radioactivity to the environment and to assure that the functional containment design conditions important to safety are not exceeded for as long as postulated accident conditions require. The PGSFR design incorporates a reinforced concrete containment that is steel-lined on its inner surfaces that is an essentially leak-tight barrier against uncontrolled release of radioactivity. The containment is designed with margin to withstand pressures and temperatures resulting from a postulated sodium leakage. The containment isolation system is provided to isolate the containment atmosphere from the environment during a postulated accident.

3. Seismic Isolators

An earthquake would be major contributors to the total risk of core damage and large radiological releases in nuclear power plant. In the event of an earthquake, seismic isolators can significantly reduce the response of a structure to horizontal ground motion through the installation of a horizontally flexible and vertically stiff layer of seismic isolators between the lower and upper basemats in PGSFR, as shown on Figure 1 and 2. It is used to, with high confidence, limit the inertial forces and the vibrations transmitted from the ground to the isolated nuclear facility. 290 LRBs (lead rubber bearings) are installed to reduce seismic forces transmitting to the structures, systems, and components important to safety.

4. Passive Safety Systems

PGSFR safety systems rely on natural forces such as pressurized gas and natural convection flow to improve its safety. This concept is applied in passive decay heat removal system, passive spent fuel cooling system and passive MCR habitability system. The passive decay heat removal system is described in reference 4.

The passive spent fuel cooling system uses natural convection for cooling as shown on Figure 3. There are several rows of silos located below grade. Each row is separated by a hardened steel wall for criticality and safety and connected to an air supply duct below the fuel assembly canister and a hot air exhaust duct above the canister. The exhaust duct is actually the bottom of the concrete storage area floor. The silo is a perforated stainless steel tube with a damper door at the bottom. When the silo is empty this door is closed, when an assembly is inserted it opens the door for cool air flow. Shield plugs centered over each silo are located on the top of the shielded floor.

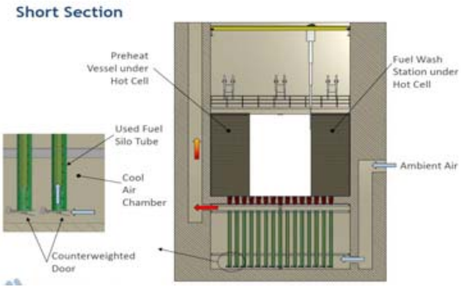

Fig.3 Passive spent fuel cooling system in PGSFR

The MCR passive habitability system provides fresh air, cooling, and pressurization to the MCR following a postulated accident. This system is passively operated and then a fresh air is supplied by air storage tanks during accident periods. A passive cooling method, which eliminates the need of an active emergency cooling, is developing for the MCR HVAC system in order to enhance the reliability of the system.

5. Sodium Fire Protection System

Sodium fire protection system consists of prevention features (e.g., double-walled pipe), mitigation features (e.g., steel liner, catch pan, suppression deck) and extinguishment features (e.g., dry powder) to reduce a potential risk of sodium fire and to protect structures, systems, and components important to safety, in the event of a sodium leak.

For the prevention of sodium fire, the specific sodium leak collection provisions using double-walled pipe and/or jacket are applied to reduce the possibility of sodium fires from the postulated sodium leaks. The sodium piping located in the containment is double-walled, the released sodium is collected from the gap between an inner and outer pipe and delivered to a sodium collection tank. Outside of the containment, the sodium is collected in the gap between the pipe and the inner steel jacket of its surrounding thermal insulation and drained into the underlying sodium fire suppression deck.

For the mitigation of sodium fire, the compartments are designed with steel liner plates on the floor to prevent the direct contact of sodium with the underlying concrete in order to preclude sodium-concrete reactions. Sodium catch pan and suppression decks are also incorporated into these compartments for reducing the long-term compartment temperature and pressure after sodium fire.

PGSFR includes sodium fire extinguishing system using a dry powder for the suppression of a sodium fire.

6. Auxiliary Sodium Systems

PGSFR includes the specific auxiliary sodium systems such as primary sodium purification system (PSPS) and primary inert gas purification system (PIGPS), which are different from PWR.

The PSPS provides the function to control the concentration of oxygen and hydrogen and the contents of impurities in sodium from the primary heat transfer system and purify the radioactive cesium in the sodium. It consists of an electromagnetic pump, a sodium buffer tank, a vacuum pump, two cold traps, an economizer, a plugging meter, a cold trap cooling loop, and a radionuclide trap.

The PIGPS provides the functions to purify the radioactive gas, sodium vapor and impurities, etc. in the reactor cover gas to control the radioactivity and the impurities in reactor cover gas. It consists of a sodium removal subsystem, a compressor subsystem, a radioactive argon purification subsystem, and a reheater.

7. Power Conversion System

The power conversion system is designed to supply the steam generated from the steam generator to turbine and maintain the heat balance between the primary and secondary system by transferring the heat generated from the NSSS to the condensate system via the turbine bypass. In addition, MS system has a recirculate system to be operated when the NSSS power is less than 30% at the plant startup and shutdown operation period. At the startup operation mode, the main feed water pump and the flash tank in the startup recirculation system are operated until the superheated steam is generated.

8. Acknowledgement

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