Design of a Fuel Handling System in a Reactor Vessel for a Large Capacity SFR

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1. Introduction

An economic improvement of a Gen IV SFR (Sodium-cooled Fast Reactor) plant is important to compete with other reactor system. One way to improve its economics is an increase of its capacity with the minimum number of components and loops. That is a large-size scale effect obtained by reducing the plant maintenance, repair, and construction costs [1].

The NSSS arrangement design has been developed with two heat transport loops. As shown in Fig.1, it has large size NSSS primary and secondary components. The reactor vessel is 14.5 m in outer diameter, 0.05m in thickness. There are 4 IHXs, 4 primary mechanical pumps, and 4 decay heat removal heat exchangers inside the reactor vessel. The two IHTS loops outside of the reactor vessel have 2 mechanical pumps and 2 SGs. The component number and the reactor internal and vessel sizes were determined based on the core and fluid system design information [2,3].

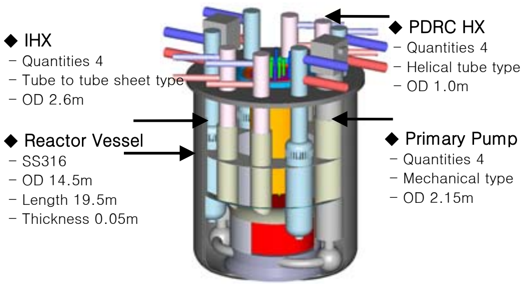

Fig. 1 Component arrangement in the reactor vessel for the two loop system of a pool type SFR of 1200MWe

The in-vessel fuel handling system is one of the key issues for designing a 1200MWe large capacity of a sodium-cooled fast reactor due to a large core diameter. It should access all the 1177 core assemblies from the center to the outside ones, which has a maximum diagonal length of 6.74m. One candidate of the several core designs is represented in Fig.2.

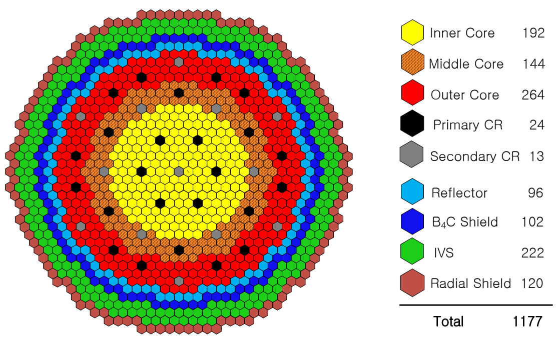

Fig. 2 Core section view of a pool type SFR of 1200MWe[3]

2. Fuel Handing System Arrangements

Through the conceptual design experience of a refueling system for the KALIMER-600 as shown in Fig.3 [4], the fuel handling system for a large capacity SFR has been designed with a two-rotatable plug system. The system consists of two in-vessel transfer machines (FACM, DLCM), large and small rotatable plugs, and fuel transportation ports.

The fuel handling system is directly interfaced with an upper internal structure (UIS), which is attached to a small rotatable plug. So the maximum diameter of the UIS can be limited by the accessibility of the core assemblies by the two transfer machines.

Several design parameters should be determined for the fuel handing system. One is the center positions of the LRP & SRP, and the locations of the FACM and DLCM on the SRP. Another is the arm length of the FACM and the locations of the fuel transportation ports. Usually, the centers of the SRP and LRP are located in opposite directions on the x axis. The fuel transportation ports are positioned in the upper region close to the reactor support barrel.

There are basic requirements for obtaining the feasible parameters. At first, the outer core assembly on the x-axis should be reached by the sum distance of the arm length of the FACM and the x-axis coordinate of the FACM. Secondly, the distance from the origin to the fuel transportation ports should be less than the summed length of the offset length of the LRP, the arm length of the FACM and the x-axis coordinate of the FACM. Thirdly, the common positions accessed by both the FACM and DLCM are required to transit for the in-core and outer-core assemblies. Many computer simulations have been performed to obtain feasible design values. Among the several designs satisfying the accessibility of the whole core assemblies, the most feasible design is represented in Fig.4 & Table 1.

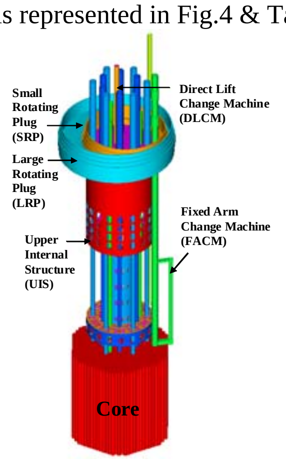

Fig. 3 Concept of a refueling system with two rotating plugs

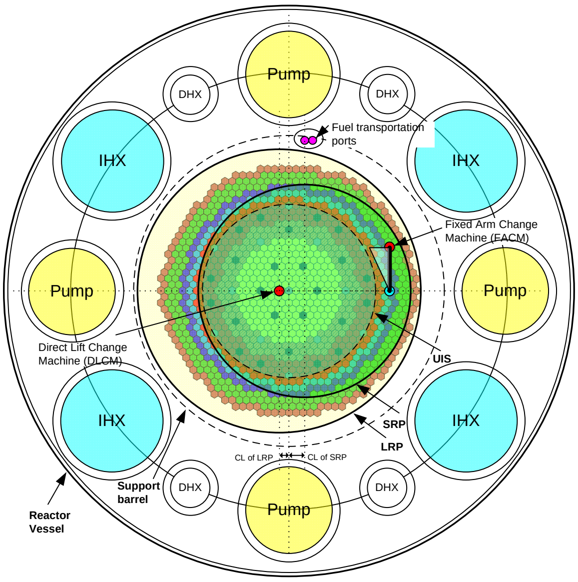

Fig. 4 Fuel handing system arrangement in the RV of a SFR of 1200MWe

Table 1. Fuel handing system design features

Dimension of System (unit : cm)

- Outer diameter of RV : 1450
- Inner Dia. of support barrel : 790
- Diameter of Driver Fuel : 492
- Outer Dia. of UIS : 440
- Diameter of LRP : 720
- Diameter of SRP : 540

- Center of FACM : (255.0,0.0)
  - Arm Length : 110.0
  - Rotation angle : 27 ~ -205 deg.
- Center of DLCM : (-24,0)
- Fuel transportation ports
  - Diameter : 20
  - Centers :(40,382)/(60,382)

- Offset center of LRP : (-24,0)
- Offset center of SRP : (40,0)
- Center of UIS : (0, 0)

- Fuel No. Accessed by DLCM/FACM: 182/1001
  - 4 common ports :
  (109,94), (109,-94), (0, 126), (0,-126)

3. Design Evaluation of Fuel Handing System

The outer diameters of the large- and small- rotating plugs are 7.20m and 5.40m, respectively. In that case, the UIS outer diameter is limited to 4.4m, and the FACM rotation angles are from -27 degrees to 205 degrees because the UIS outer shell stops the arm's rotation to inside of the UIS. The diameter of the UIS includes the 37 control rod drivelines (CRDLs), but does not cover all the driver fuels, which have a maximum diagonal length of 4.92m.

The principal functions of the UIS are a lateral support for the protection of the drivelines from a sodium flow induced vibration, and a support for the above core instrumentation drywells.

As shown in Fig.5, the 182 driver fuel assemblies near the center are accessed by the DLCM machine, and the 1079 core assemblies are accessed by the FACM machine. The fuel handing system can access all the core assemblies with an accuracy of a 7mm even though the rotatable plugs have a rotation accuracy of 1 degree.

This design has 4 fuel assembly positions accessed by the both DLCM and FACM for transferring the in-core assemblies to out-core positions and the reverse.

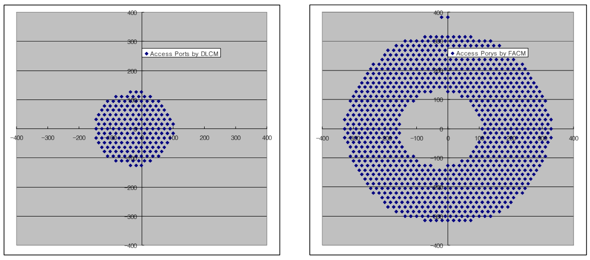

Fig. 5 Core assembly groups accessed by the DLCM and FACM

4. Conclusions

A conceptual design for an in-vessel fuel handing system accessing all the core assemblies has been obtained for a 1200MWe capacity of a SFR.

The fuel handing system can access all the core assemblies with a maximum offset of a 7mm. This design has 4 fuel assembly positions accessed by the both DLCM and FACM for transferring the in-core assemblies to out-core positions.

Further studies for this concept are required to check on the interface with the instrumentation sensors and other equipments on the reactor head.

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