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# Design of the Down-scaled Test Vessel for a Hydrodynamic Simulation Reflecting Recent Specification of PGSFR

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## 1. Introduction

PGSFR, which denotes the Prototype Generation-IV Sodium-cooled Fast Reactor is being developed by KAERI for the advanced next generation nuclear power plant in Korea. [1] This is a pool type reactor in which the major components are installed inside the reactor vessel. Contained internals are four IHXs, four DHXs, and two PHTS pumps as principal components with others.

In such a pool type reactor, the flow distribution strongly depends on the arrangement and geometrical configuration of the components. Pressure drops along the flow paths are induced from the flow distribution determined by the arrangement of components in the reactor vessel. It is important to estimate these hydro-dynamic characteristics, the flow distribution in a reactor vessel, and the pressure drops across the major components for the optimum thermo-hydraulic design of the reactor.

For this concern, the experimental approach using a down-scaled model with water flow at room temperature was considered to predict the flow distribution in such a complex geometries of a newly designed reactor. [2]

A one-fifth model linearly down-scaled compared to the PGSFR was chosen, considering non-dimensional parameters governing the fluid dynamic behavior in a prototype reactor. This study presents the design of the down-scaled test vessel which incorporates recent dimension changes and additional components. Pivotal changes are the size of major components such as IHX, DHX and Redan, and added components of PSPS, IVTM and FTP.

## 2. Test Requirements

For the hydrodynamic similarity of the test vessel with water at 60℃, the Froude number related to the free surface of the coolant in a vessel should be conserved between the test model and PGSFR. As a result, the ratio of the characteristic velocity is decided to be 1/2, and therefore, the ratio of the Reynolds number becomes 1/16, where the flow regime in the test vessel is considered to be enough turbulent. For a simulation of the fuel assemblies and IHXs which have complex flow geometry comprising many rods inside the components, scaled single flow paths for each component have been designed to model the flow behavior of the original fuel assemblies and IHXs of the PGSFR as matching the Euler number to be identical for both, the test model and PGSFR. Table 1 summarizes the specifications of the test model.

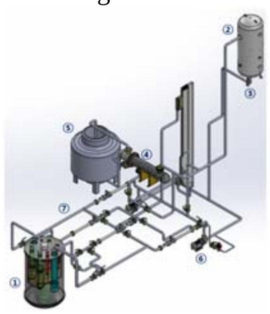
Table 1. Specifications of Test Model

| | PGSFR | Test Model | Ratio ( Model/PGSFR) |
|---|---|---|---|
| Coolant | Sodium | Water | - |
| Temp. (℃) | 467.5 | 60 | - |
| Press. (MPa) | 0.1 | 0.1 | - |
| Density (kg/m$^3$) | 839.8 | 983.2 | 1.17 |
| Viscosity (Ns/m$^2$) | 2.48x10-4 | 4.66x10-4 | 1.88 |
| Pool Dia. (mm) | 10422 | 2084 | 1/5 |
| Fr (-) | - | - | 1/1 |
| Velocity (m/s) | | | 1/2 |
| Re (-) | - | - | 1/16 |
| Eu (-) | - | - | 1/1 |

## 3. Design of Test Vessel

### *3.1 Test Facility*

Test vessel incorporates pump inventories without internal pumps inside, not the same way of PGSFR which has PHTS pumps inside. Therefore, dual loop system was designed including two external pumps, a storage tank with heater and a heat exchanger as shown in Fig. 1. The normal operating condition is 60℃, 4bar and 46.6kg/s with water as a working fluid.



| Number | Component | Specification |
|---|---|---|
| ① | Test Vessel | Φ2.08 x L3.1 m |
| ② | Storage Tank | Φ1.0 x L1.8 m |
| ③ | Heater | 125 KW |
| ④ | Heat Exchanger | 43,200 Kcal/hr |
| ⑤ | Cooling Tower | 975,000 Kcal/hr |
| ⑥ | Circulation Pump | 120 m$^3$/hr, 60 m |
| ⑦ | Piping | 4" |

Fig. 1. Schematic of the Test Facility**.**

### *3.2 Test Vessel*

The test vessel, 1/5 down-scaled reactor of PGSFR is demonstrated in Fig. 2. The size of the vessel was changed due to the modification of kinetic mechanism of IVTM; vessel I.D. from 1,730 to 2,084mm, and the length of IHX and DHX are 300mm longer than before. The additional components that should be considered, IVTM, PSPS and FTP are newly incorporated.

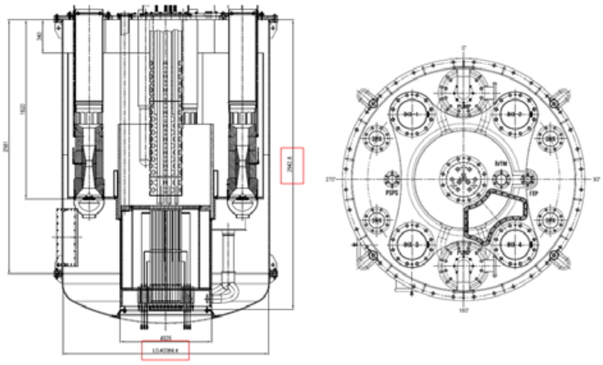


Fig. 2. Test Vessel**.**

Glass windows are embedded at the side and cover of the vessel to visualize the flow structure at the inlet and outlet of the IHXs through which the coolant is passing.

### *3.3 Fuel Assembly Simulator*

A fuel assembly which contains 217 fuel rods inside the hexagonal duct was simulated by the venturi tube with multi-hole orifices shown in Fig. 3, which can adjust the pressure drop (125.6kPa) to match the Euler number with PGSFR. The venturi throat and orifice holes were decided according to each specification of 9 group FA simulators for the flow range of 0.257 to 0.551kg/s.

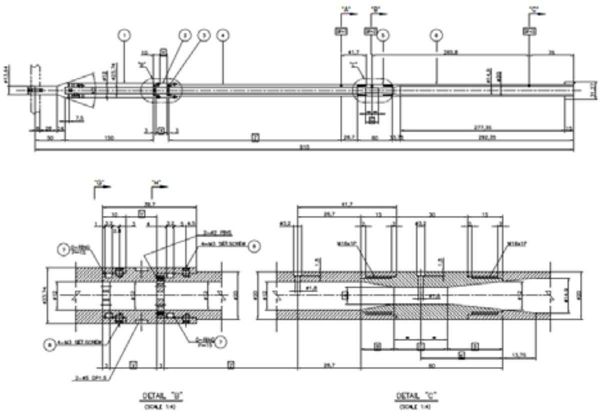


Fig. 3. Dimension of the fuel assembly simulator**.**

Three pressure sensing lines were extracted per a FA simulator. Therefore, total 336 (112x3) sensing lines should be guided to the outside through the 9 CRDM tubes not disturbing the flow at the exit of the core. Fig. 4 demonstrates the sensing line module and their combination to extract lines through the CRDM tubes.

### *3.4 IHX Simulator*

As similar to the FA simulator, the IHX was also simulated by the single flow passage in which there embedded the venturi throat and multi-hole orifices to match the Euler number with PGSFR. Fig. 5 illustrates the dimension of IHX simulator. The size of venturi throat and multi holes for four IHXs were decided according to the specified flow rate (11.6kg/s) and pressure drop (3.71kPa) conditions.

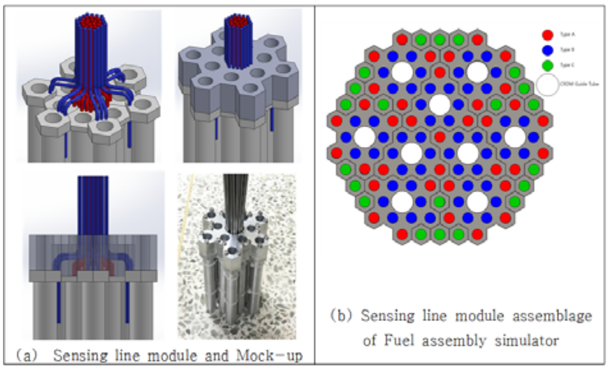



Fig. 4. Pressure sensing line extracting module**.**

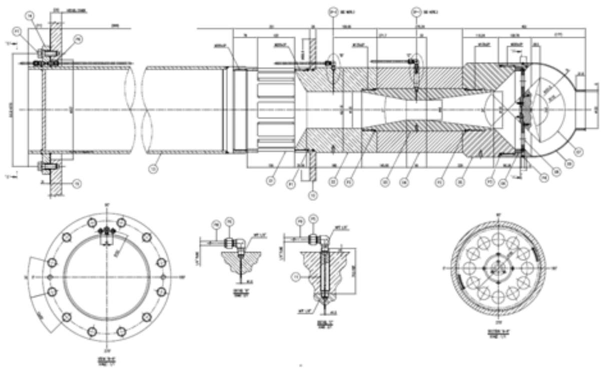


Fig. 5. Dimension of IHX simulator

Calibration processes were performed intensively for simulators of FAs and IHXs to guarantee the specified pressure drop characteristics using the CALIP test facility. Test items were quantifications of the pressure drop characteristics and discharge coefficients for 112 FA [3], and 4 IHX simulators [4], thoroughly.

## 4. Conclusions

The one-fifth down-scaled test vessel was designed reflecting the recent advances of the prototype to simulate the flow distribution of the PGSFR. The crucial changes were the size of the vessel diameter, IHX length, and addition of internal components such as IVTM, PSPS and FTP.

Presented new design includes all changes for the fabrication of the test vessel. Extraction method for the complex pressure sensing lines from 112 FA simulators was devised using sensing line modules and CRDM tubes. The calibration of the principal components, FAs and IHX simulators were successfully completed.

Fabrication and build-up of the test facility will be performed subsequently on schedule.

## ACKNOWLEDGMENTS

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