Design Improvement of the Core Inlet Flow Path for a High Temperature Gas-cooled Reactor

Churl Yoon*(cyoon@kaeri.re.kr), Sung-Deok Hong, Sin-Yeob Kim, Hyeonil Kim and Chan Soo Kim

Korea Atomic Energy Research Institute

Purposes and Ultimate Goal

Purposes : To propose a design improvement of the HECTAR MCSS(Metallic Core Support Structure) for **minimizing the CIFP(Core Inlet Flow Path) flow maldistribution**, and To validate the design improvement by using CFD(Computational Fluid Dynamics) technique.

Ultimate Goal : Validation and **improvement of the HECTAR design** under development

Core Inlet Flow Path (CIFP) of the HECTAR

HECTAR (HElium Cooled Thermal Application Reactor)

- A high temperature gas-cooled reactor (HTGR) generating 90MWt
- For industrial process heat utilization
- Fully passive cooling safety feature

HECTAR CIFP (Core Inlet Flow Path)

- Flow passages of the cold Helium fluid entering from the Cross Duct (CD or CV):
  1) Space between the Core Barrel and RV
  2) 8 separate compartments in the Metallic Core Support Structure (**MCSS**)
  3) 8 vertical Parallel Flow Channels (**PFC**), installed parallelly on the outside wall of the Core Barrel
  4) Core Upper Plenum (**CUP**)

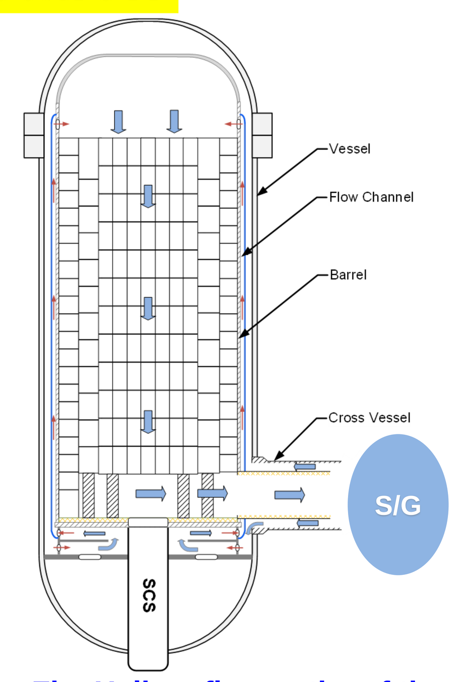
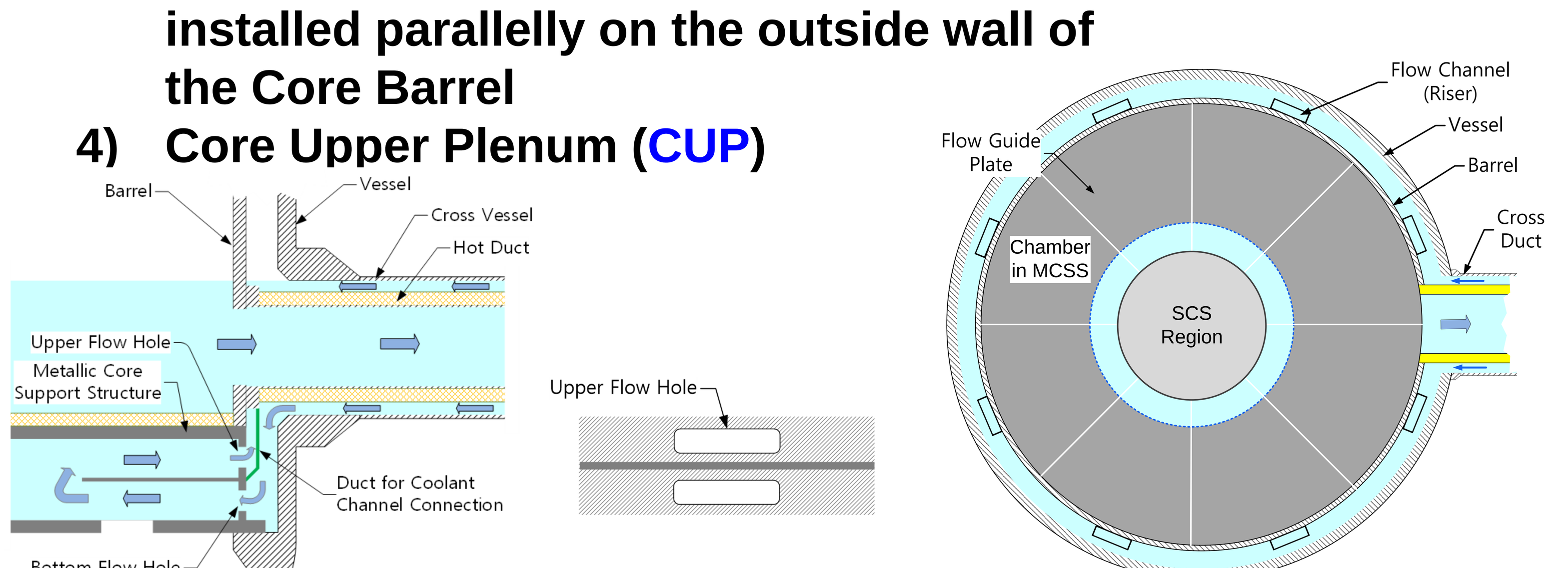


Fig. Helium flow paths of the HECTAR primary loop

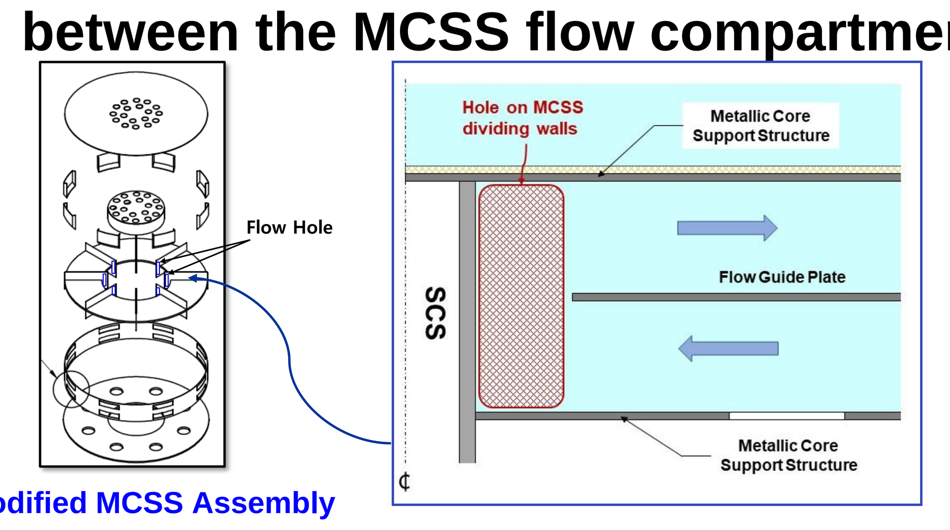


(a) Flow paths in MCSS (b) Flow holes at MCSS (c) Top view of MCSS lower compartments

Fig. Flow paths through Metallic Core Support Structure (MCSS)

MCSS Design Change (Proposal)

MCSS Design Change for Reducing Flow Maldistribution: - Adding flow holes on the dividing walls between the MCSS flow compartments



Modified MCSS Assembly

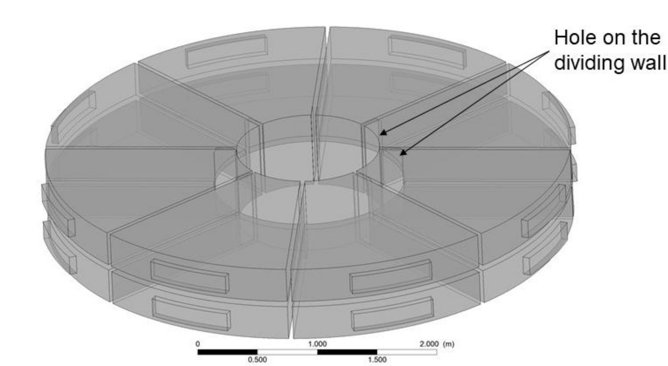


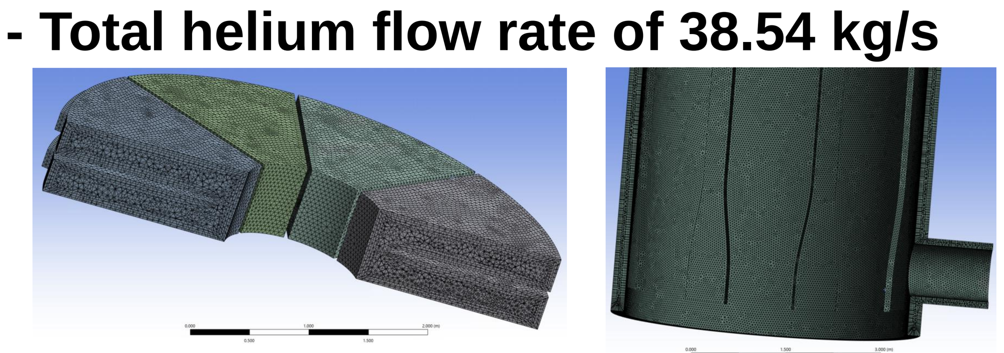
Fig. Fluid domain for modified MCSS

CFD Analysis Methodology:

- Shear Stress Transport (SST) turbulence model with Automatic wall function

Simulation Condition:

- Isothermal (300°C), High-P (6.5MPa) &
- Total helium flow rate of 38.54 kg/s



(a) MCSS (Cut View) (b) Between Core Barrel & RV

Fig. Meshes on some selected parts

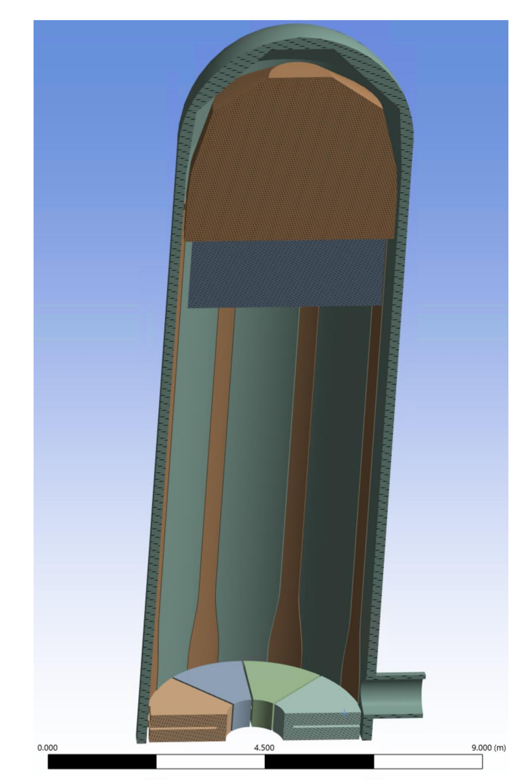


Fig. Computational domain (Cut View)

CFD Simulation Results

Fow Maldistribution for Original MCSS Design:

- **Geometric asymmetricity** of the HECTAR CIFP

→ **Flow maldistribution** in mass flowrates.

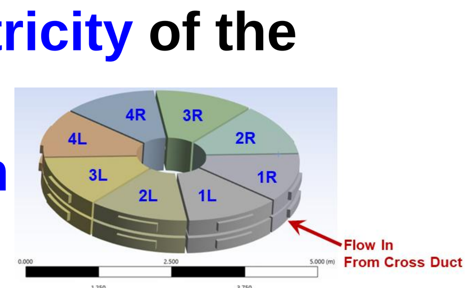


Fig. Naming of MCSS flow compartments

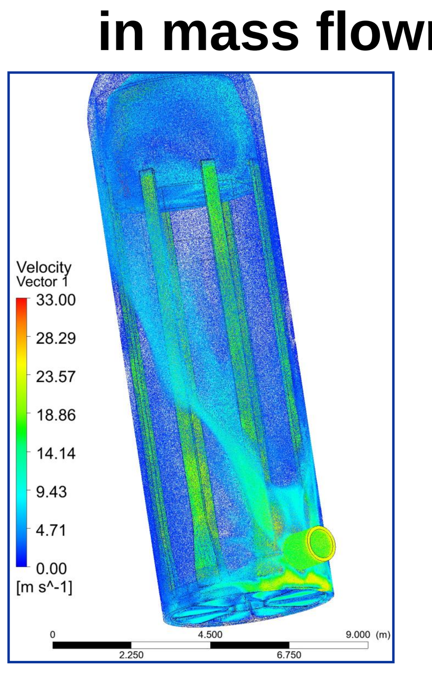


Fig. Velocity vectors

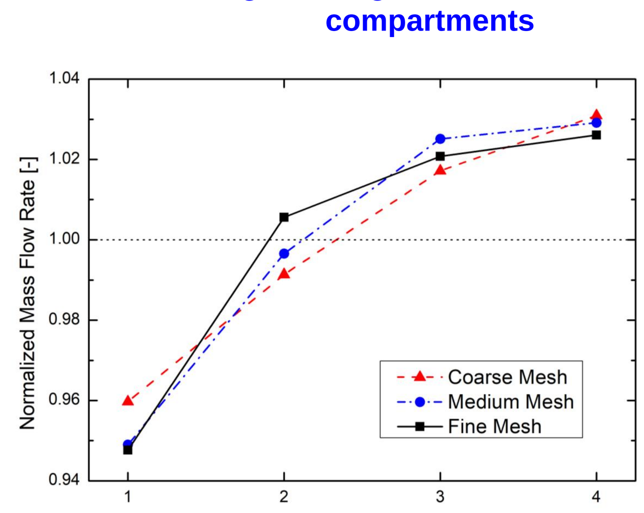


Fig. Average MFRs

Effect of the Holes on the MCSS Dividing Walls:

- **Fluid mixing** across the holes

→ **Pressure uniformization** at downstream

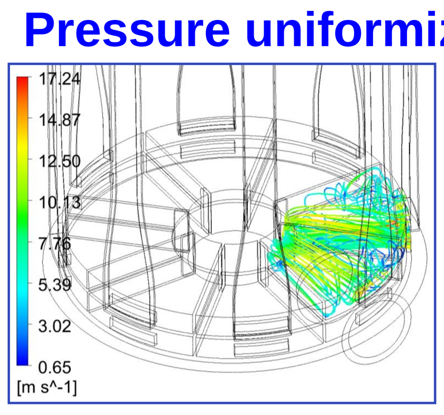


Fig. Streamlines from 2R inlet

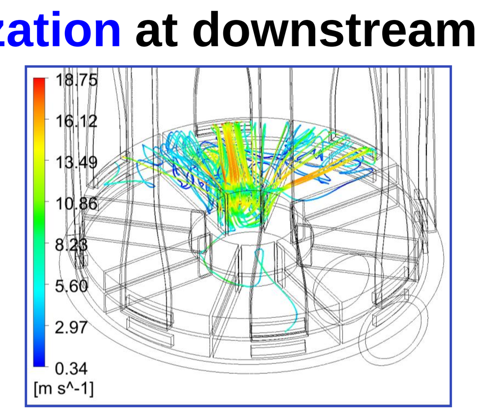
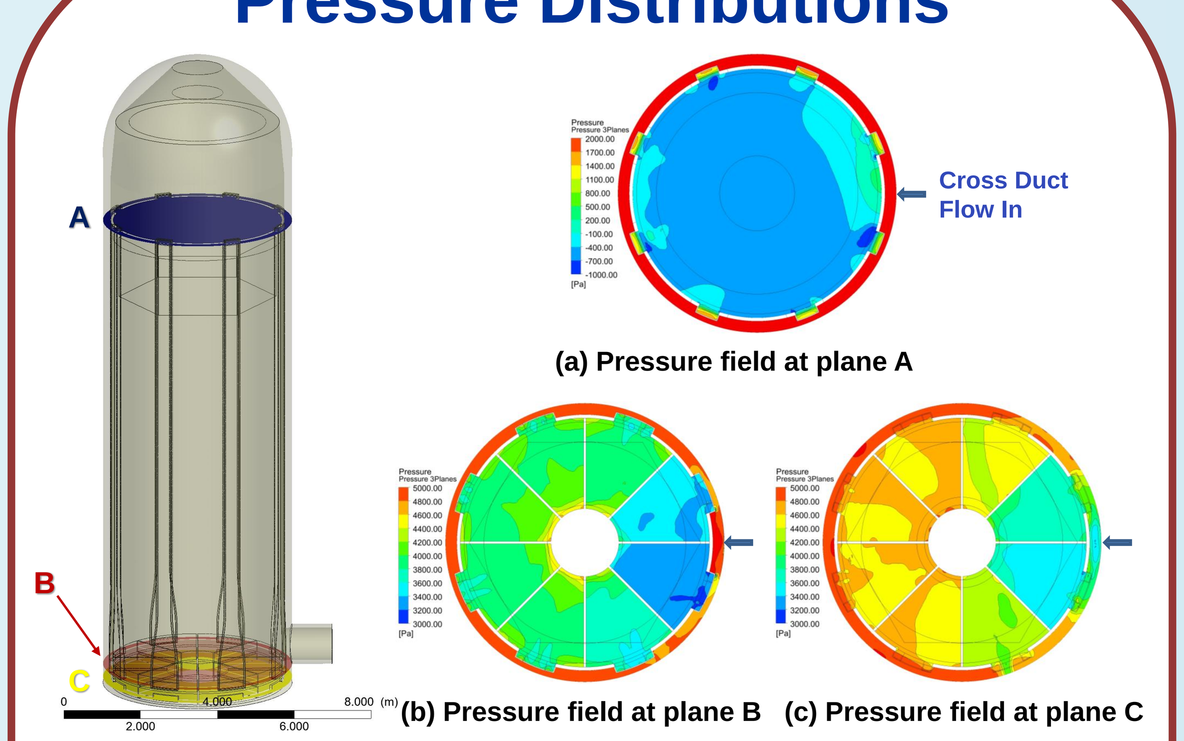


Fig. Streamlines from 4R inlet

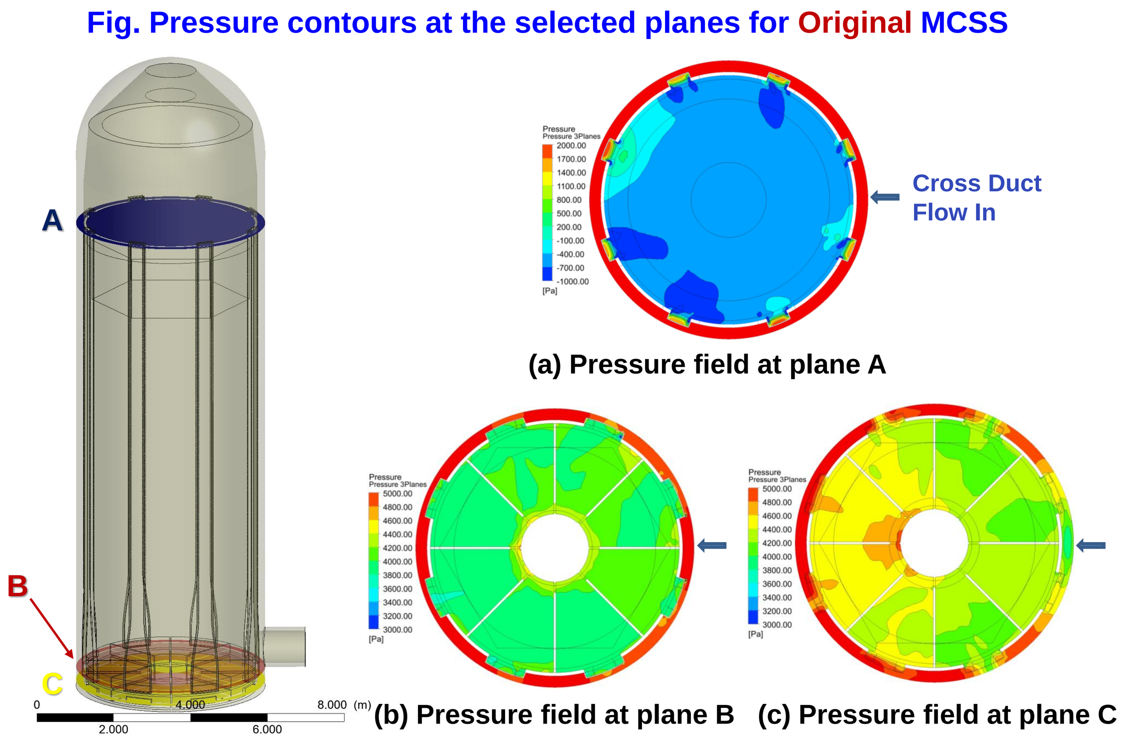
Pressure Distributions



(a) Pressure field at plane A

(b) Pressure field at plane B (c) Pressure field at plane C

Fig. Pressure contours at the selected planes for Original MCSS



(a) Pressure field at plane A

(b) Pressure field at plane B (c) Pressure field at plane C

Fig. Pressure contours at the selected planes for Modified MCSS

Pressure Distribution Results:

- Pressure on Plane B is more uniform for **Modified MCSS** case

$$\dot{m}_{PFC,i} = \rho u_{PFC,i} A \propto \Delta P_{MCSS,i-CUP}$$

→ $\dot{m}_{PFC,i}$ become **more uniform**

Conclusions & Future Works

Conclusions:

1) **Quadrilateral holes on the MCSS compartment dividing walls** were introduced,
2) which allow **fluid exchange** between MCSS flow compartments.
3) **Pressure distribution** becomes more **homogenized** in downstream section of the MCSS flow region.

→ The **flow maldistribution** tendency **is reduced**.

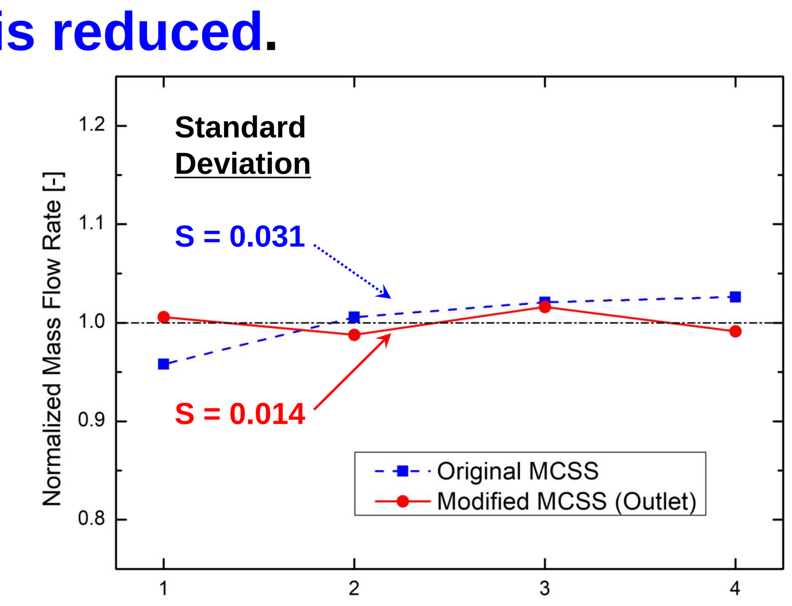


Fig. Mass flow rates over the MCSS flow compartments

Future Works:

1) Improving **the mesh quality**
2) Applying the modified MCSS design with adjusting the design details by using **CFD and structural analyses**

한국원자력연구원 KAERI Korea Atomic Energy Research Institute

KNS Spring Meeting, Jeju, May 7-8, 2026