Investigation of Flow Structure Transition in Lower Plenum of ABWR

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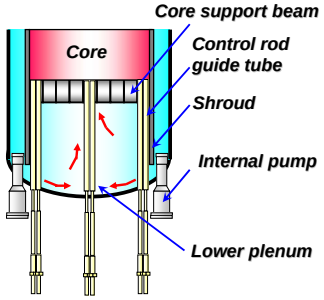
Background



Schematic diagram of lower plenum of ABWR

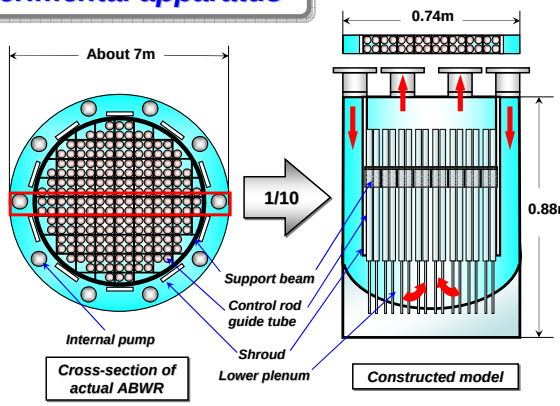
To reduce of the cost of nuclear power plants ⇨ Increase the power outputs

It is important to evaluate the flow behavior in the reactor in detail

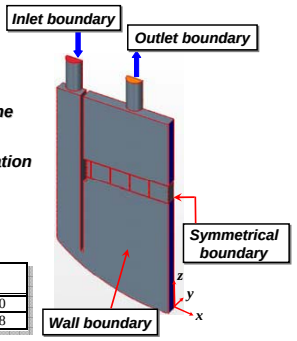
- The method of design by flow analysis using *CFD codes* is very useful.
- There are not enough data to verify the models in CFD codes to evaluate the flow structure in lower plenum.
- The analysis results by CFD code is considerably dependent on the models

It is necessary to clarify the flow structure in the lower plenum.

Experimental apparatus



CFD analytical model



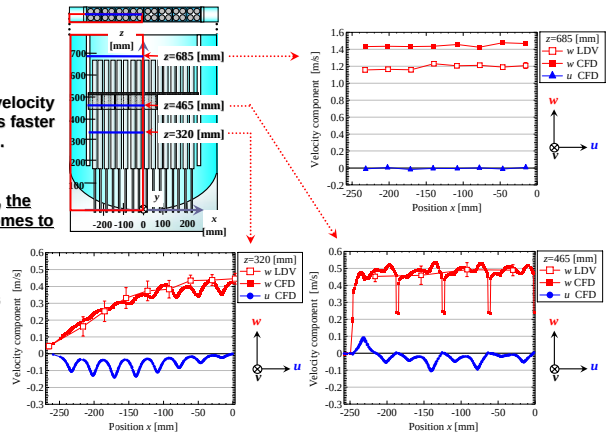
Analysis code : STAR-CCM+
Discretization procedure : Finite-volume scheme
Basic equation : Equation of continuity
Momentum conservation equation
Analytical approach : SIMPLE method
Turbulence model : Standard k-ε model
Cell number : About 2.7 million

	Water temperature [°C]	Inlet pressure [MPaG]	Flow rate [l/min]	*Re*
PIV, LDV	14.9	0.10	209	2620
CFD, LDV	10.8	0.10	225	2548

Results

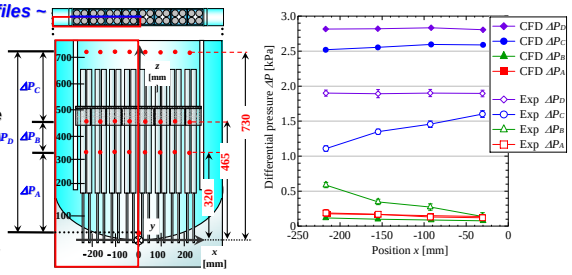
- Velocity profiles -

- In the lower plenum, the velocity at the center (x=0 [mm]) is faster than that near the shroud.
- In the core support beam, the velocity distribution becomes to be flat.
- Once the velocity profiles becomes to be flat at the core support beam, the coolant flow into the part of core inlet maintaining flat tendency.



~ Differential pressure profiles ~

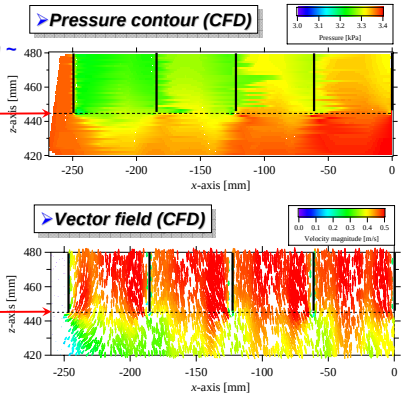
- The differential pressure of lower plenum (ΔP_A, ΔP_B) is small.
- On the other hand, the profile ΔP_C is very dominant where the side entry orifices are existing.
- The profiles of experiment and analysis are qualitatively coincident each other.



~ Flow structure at inlet of core support beam ~

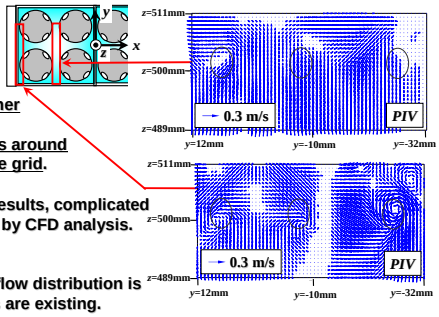
- From the analysis result of pressure contour at inlet of the core support beam, it is found that the pressure distribution is almost uniform at the region of the lower plenum.
- On the other hand, in the core support beam, the pressure at the center grid is larger than that near the shroud.
- From the velocity field, it reveals that the coolant flow distribution becomes to be uniform at the inlet of the core support beam.

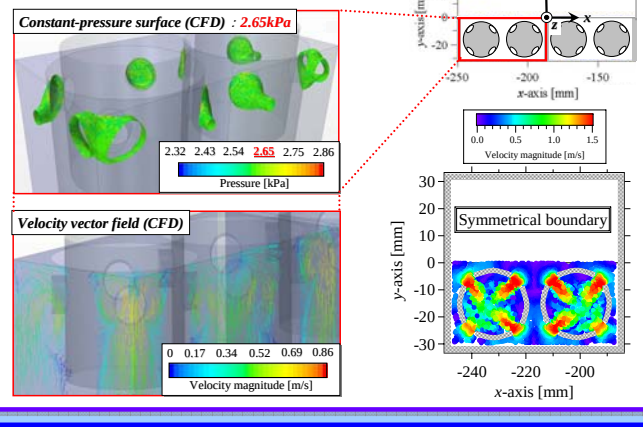
Inlet of core support beam



~ Flow structure around side entry orifices ~

- In the PIV results, it is confirmed that vortices arise around the orifices at the corner and near the beam. However, there are no vortices around the orifices at the center of the grid.
- Along with the experimental results, complicated flow structures are described by CFD analysis.
- At the corner orifice, coolant flow distribution is the lowest where two vortices are existing. It is thought that such flow structure fulfill a function for the coolant flow distribution to the core.





Conclusion

- In the lower plenum, the velocity at the center section is faster than that near the shroud. The velocity profiles show the tendency to be flat in the core support beam and core inlet region. These experimental and analytical profiles are coincident each other.
- About the differential pressure profiles, the profile of the region including the side entry orifices is dominant against the profiles of upstream. And the profiles of experiment and analysis are qualitatively coincident each other.
- Along with the experimental results, the complicated flow structures like vortices are described by CFD analysis. In addition, it is found that the coolant flow distributions are different depending on the location of the orifices. Thus, it is thought that such flow fulfill a function for the coolant flow distribution to the core.