

## Validation of Design of Specific Reactor Systems

Experimental and theoretical studies have been performed to verify and validate system designs pertaining to Advanced Heavy water Reactor (AHWR) and other research and power reactors. Following are systems on which studies have been performed

1. Moderator Flow distribution inside calandria of AHWR
2. Liquid poison injection and its distribution in moderator
3. Passive containment cooling system
4. Passive containment isolation system

Various experimental and theoretical studies have been performed to investigate specific phenomenon. Data have been collected for single and two phase pressure drop, heat transfer, velocity and concentration profiles, etc. Following are some of the phenomena studies performed

1. Investigation on pressurized thermal shock in reactor pressure vessel
2. Investigation of borated water slug mixing in reactor pressure vessel
3. Condensation in presence of non-condensable gases
4. Formation of cold trap in natural circulation system
5. Two phase flow and pressure drop studies
6. Flow and pressure drop in sudden expansion and through elbows
7. Counter current Flow studies

Following table gives the details of studies performed.

System/phenomenon	Experimental investigation	Theoretical/CFD studies
Moderator Flow distribution in side calandria of AHWR	Experimental facility established to investigate moderator flow distribution inside calandria. The measurement of local velocity has been carried out.	Three-dimensional CFD studies have been performed with and without heat generation. Studies have also been carried out with uniform and non-uniform (spatial) heat generation in the moderator. The flow and temperature distribution have been established inside the AHWR calandria. The results are

		compared with experimental data.
Liquid poison injection and its distribution in moderator	Experimental facility was established to investigate liquid poison injection and its distribution inside calandria. The measurement of local velocity has been carried out.	A computer code was developed to study the poison injection through the nozzles of sparger tube. 3D CFD studies have also been carried out. Comparison of CFD results with experimental data have been carried out.
Studies on liquid poison injection through single nozzle/multiple nozzles of sparger tube	Experimental studies have been carried out for single jet propagation with time. Experimental studies have also been carried out for multiple jet propagation with time.	3D CFD studies have been performed for single jet and multi-jet and jet propagation have been studied
Passive containment cooling system	Experimental set up has been established to study the system behavior.	A computer code is developed to study the system behavior and results are compared with experimental data collected.
Passive containment isolation system	Experimental set up was established to study the efficacy of system. It was established that system can isolate containment within the prescribed limit	The computer code was developed. The results obtained have been compared with experimental data. 3D two-phase (VoF method) CFD studies have also been performed.
Pressurized thermal shock in reactor pressure vessel	Experimental data have been taken from IAEA	3D CFD studies have been performed and results are compared with experimental data taken from IAEA.
Borated water slug mixing in reactor pressure vessel	Experimental data have been taken from IAEA	3D CFD studies have been performed and results are compared with experimental data taken IAEA.
Condensation in presence of non-condensable gases	Experimental studies have been performed to study condensation in presence of non-condensable gas. Experiments were performed for condensation inside the tube and outside the tube. Heat transfer coefficients have been determined for both cases.	The computer codes have been developed to determine heat transfer in presence of non-condensable gas. Studies have been carried out for condensation inside the tube and outside the tube. Results are compared with experimental data collected.

Formation of cold trap in natural circulation system	Experimental studies have been carried out to study the formation of cold trap during ECCS injection	3D CFD studies have been performed and results are compared with experimental data
Two phase flow and pressure drop studies	Experimental studies have been performed to study the two phase flow through fuel bundle of AHWR. Pressure drop across the fuel rods, spacers, tie plates etc. have been established	Theoretical studies have been carried out for determining pressure drop in the fuel bundle. 3D CFD studies have also been carried out to study the two phase flow and pressure drop across the fuel bundle. Two phase flow studies have also been performed inside the heated tube.
Flow and pressure drop in piping, reactor components, sudden expansion and through elbows	Experimental studies in the piping and components like elbow, sudden contraction and sudden expansion have been performed. Particle Image Velocimetric (PIV) System has been used for local velocity as well as velocity distribution. Experiments have also been performed for reactor components like moderator inlet nozzle. Flow visualization studies have also been performed.	3D CFD studies have been carried out and results have been compared with the data collected through PIV system.
Counter current Flow studies	Experimental studies have been carried out for counter current flow of hot and cold fluid through a pipe. Studies have been performed for various inclinations of pipes. Flow visualization studies have also been performed.	3D CFD studies have been performed for counter current flow of hot and cold fluid through a pipe. Results are compared with the experimental data.

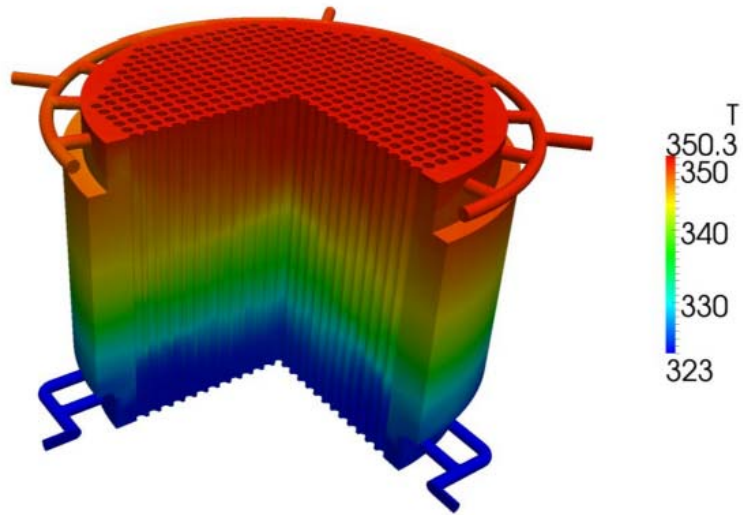


Figure 1: Moderator temperature distribution inside calandria (CFD Studies)

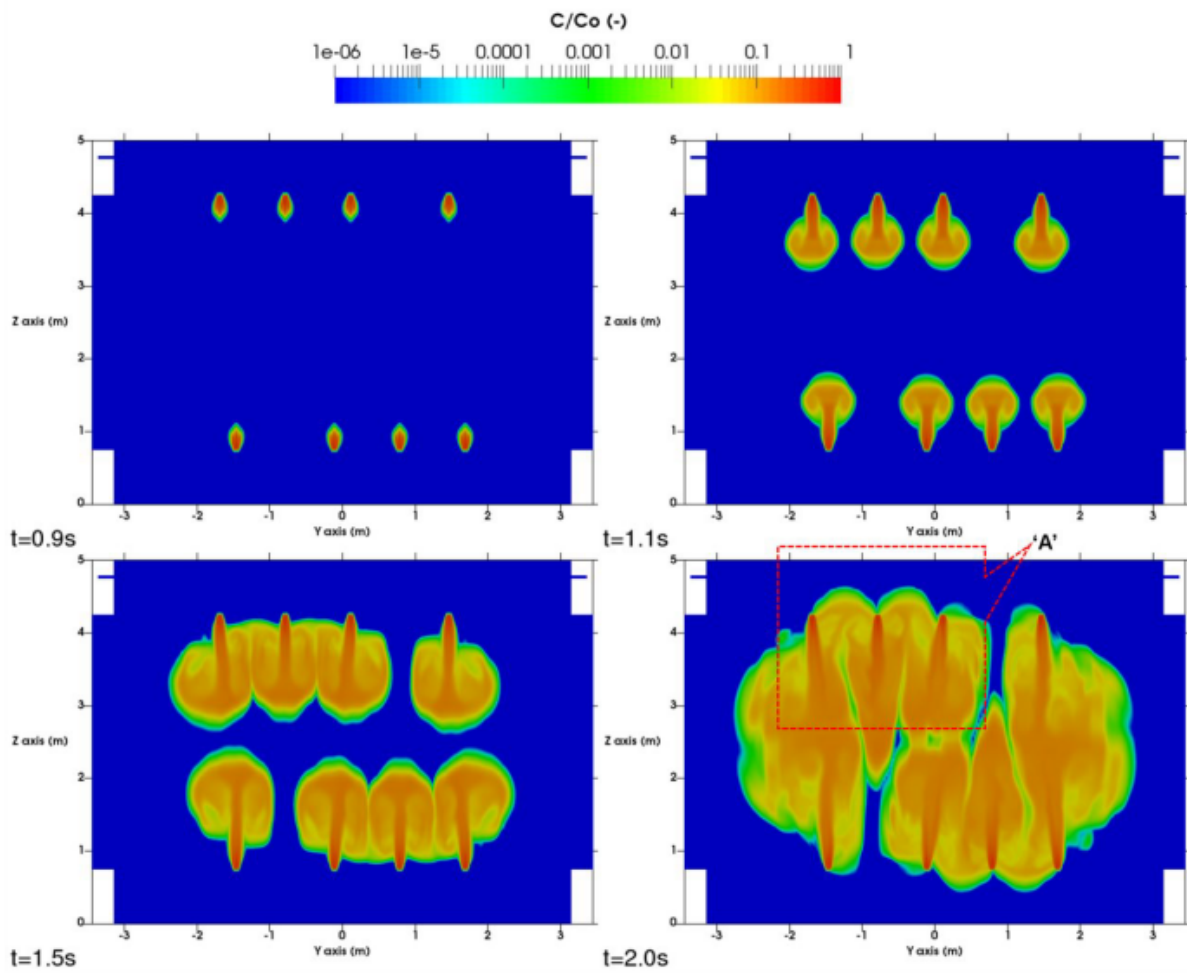


Figure 2: Poison Jet progression with time inside the calandria of AHWR (CFD Studies)

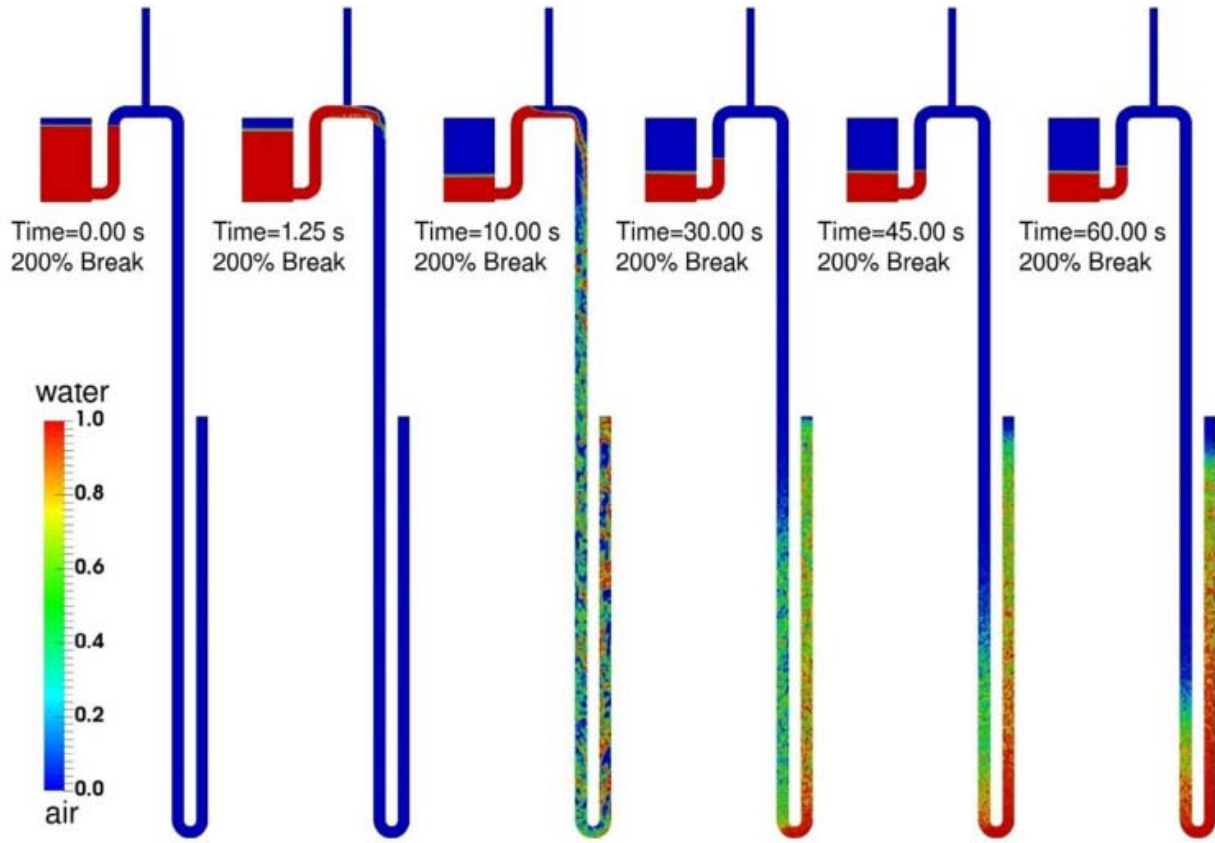


Figure 3: Water injection with time in U tube of Passive containment isolation system (CFD Studies)

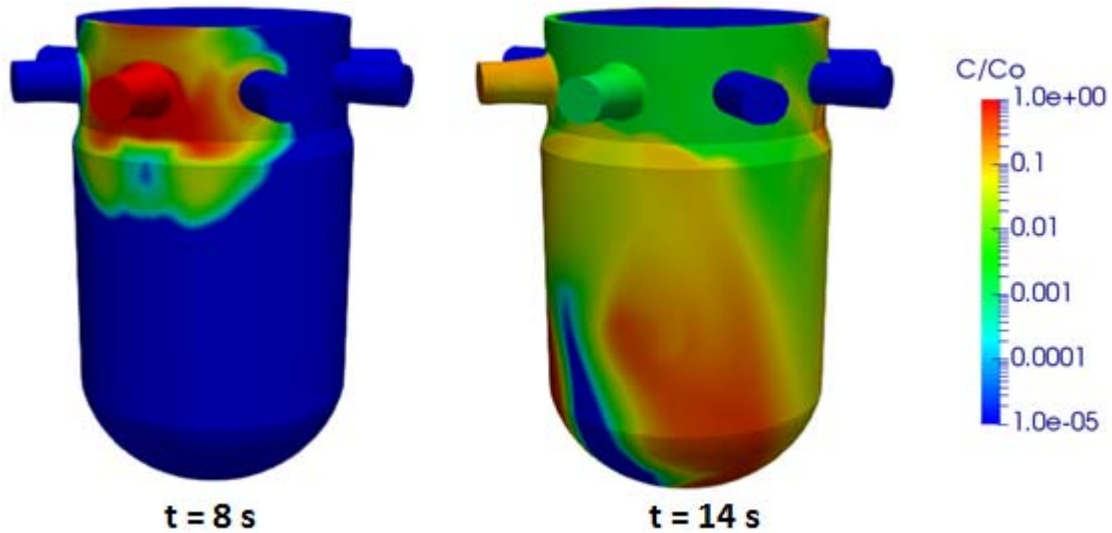


Figure 4: Mixing of borated water inside the reactor pressure vessel (CFD Studies)

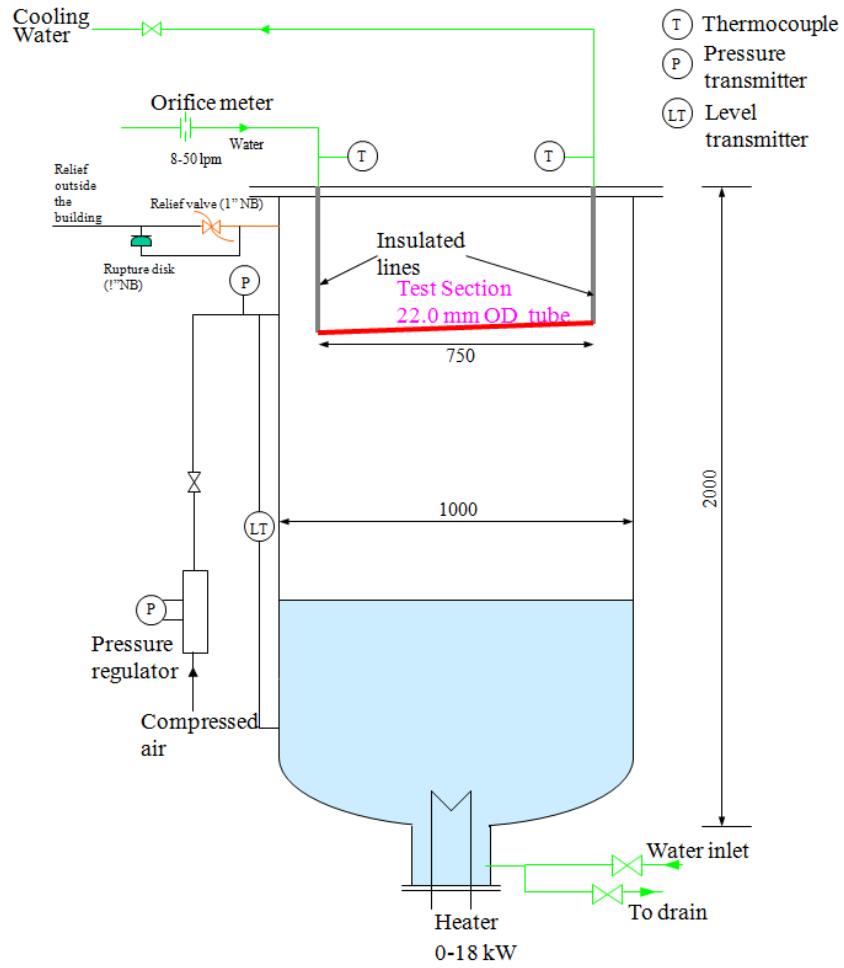
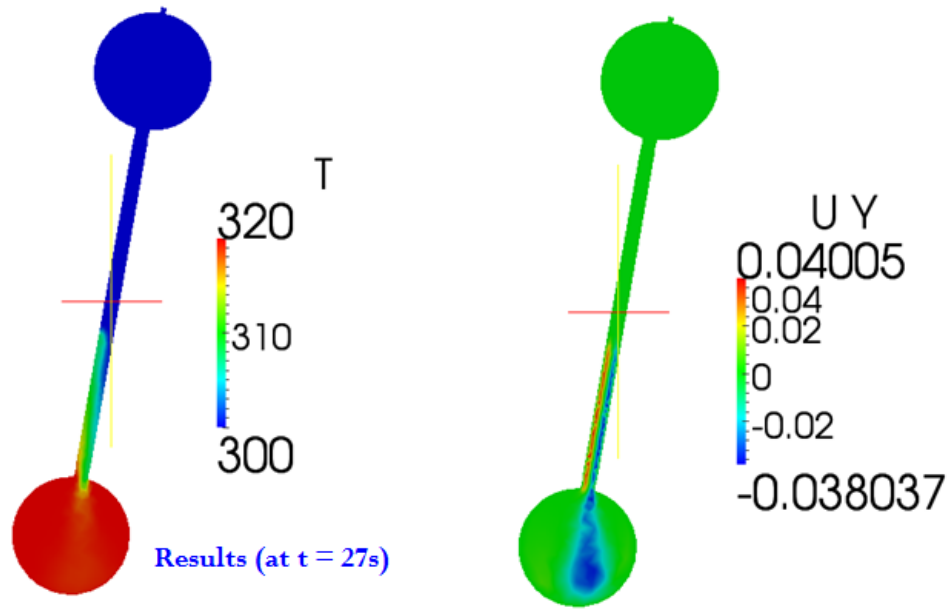


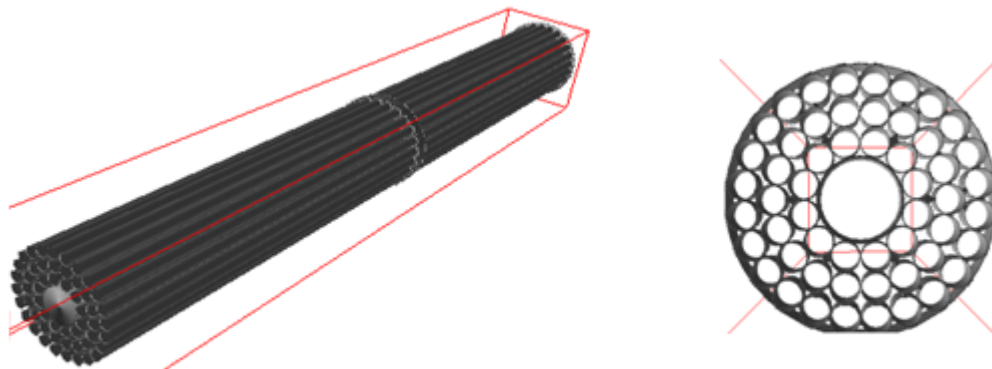
Figure 5: Experimental setup for study on condensation in presence of non-condensable gas



Temperature

Vertical component of velocity ( $U_y$ )

Figure 6: Counter-current flow of hot and cold water in the pipe (CFD studies)



(a) D-5 cluster with Single Spacer

(b) 54 Rod Spacer

Figure 7: AHWR D-5 fuel cluster

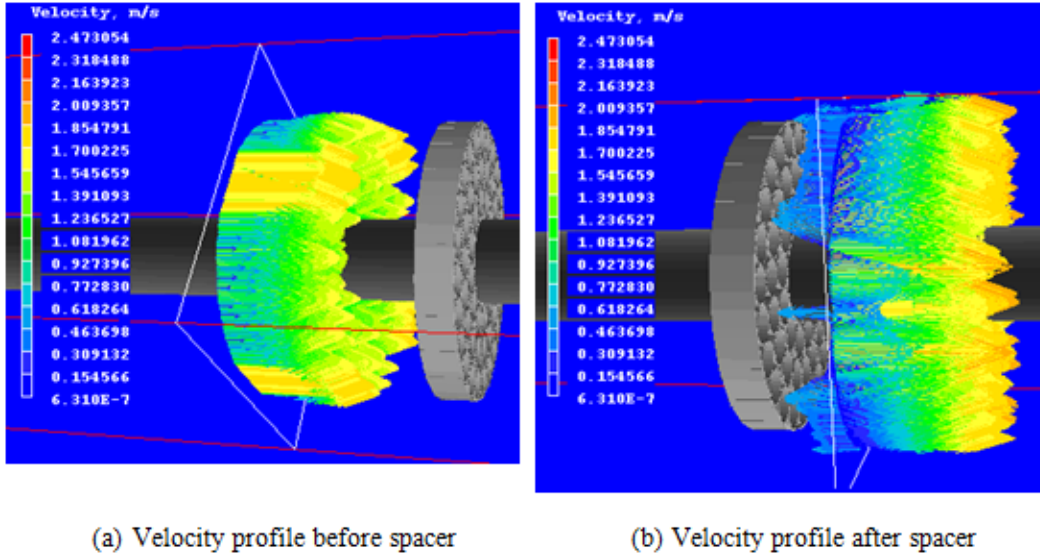


Figure 8: Two phase flow pattern across the fuel bundle of AHWR (CFD studies)

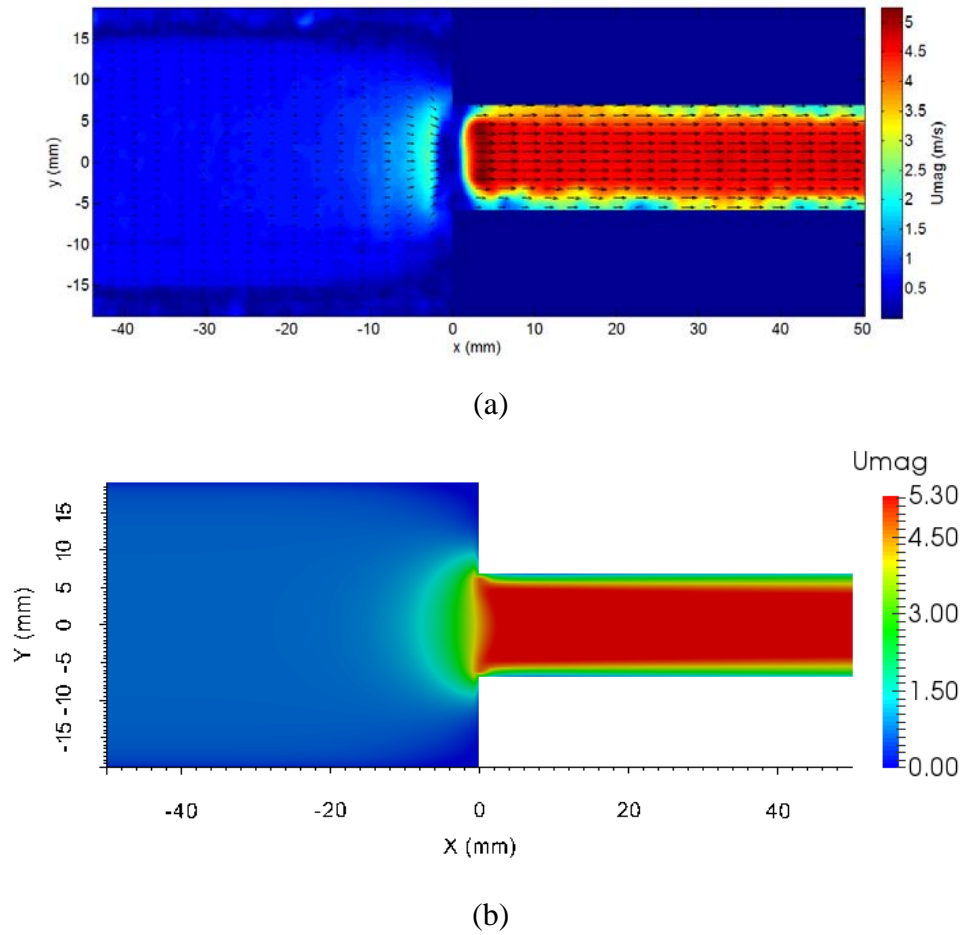


Figure 9: Comparison of average velocity contour obtained using (a) PIV system and (b) CFD analysis for 40 lpm flow in pipe flow with sudden contraction