Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

The Flow Phenomena in the Upper Plenum of Kori unit 1

J. H. Park, and D. G. Lee
KONES, #6F, Hapdong-bldg., 210-2 Yangjae-dong, Seocho-gu, Seoul, Korea, park2005@kones21.com

1. Introduction

In this paper the dynamical fluid behavior of safety injection water in upper plenum (UP) of Kori unit 1 is investigated in case of the break-down of hot leg. Normally strong mixing of the up-flowing vapor from core and the injection water from EEC injection nozzle on the side of the UP happens. Because of great enthalpy difference between the both media, flow pattern in the UP shows very complex thermodynamic phenomena. It includes evaporation of the injected water and also re-condensation of the up-flowing vapor near the columns and tubes in the UP (See Figure 1.). It is basically two phase flow of the strong mixed water and vapor. At present there are no numerical tools, even the most developed commercial CFD codes, to handle these complex phenomena exactly. Therefore the pure immiscible water-vapor two phase flow is assumed and the jet impingement of immergence water on the wall of the columns and tubes in the UP is mainly investigated. For the evaluation the VOF and k-epsilon turbulence model of FLUENT code are used [1].

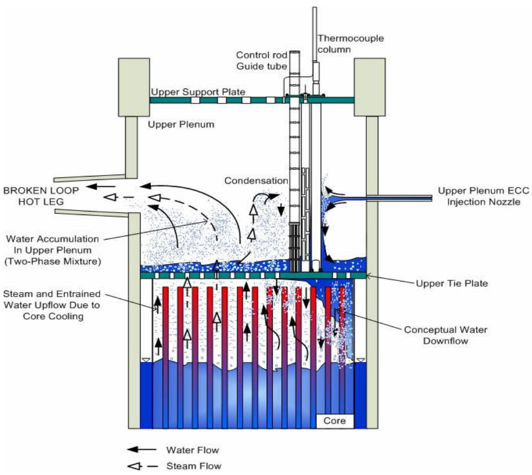

Figure 1. Schematic figure of the flow phenomena in UP

2. Computational Domain and Grid Cells

The computational domain is selected between the top of upper core plate (UCP) and the bottom of upper support plate. In this region many supportive structures, i.e. cylindrical support columns, rectangular guide tubes, free standing mixers and open holes, are installed. Among them we consider only 32 support columns and 33 guide tubes which play important roles for the flow development. About 2 million mixed tetrahedral and hexahedral grid cells are implemented and the fine boundary layer cells on the walls of columns and tubes are also taken account of (See Figure 2.).

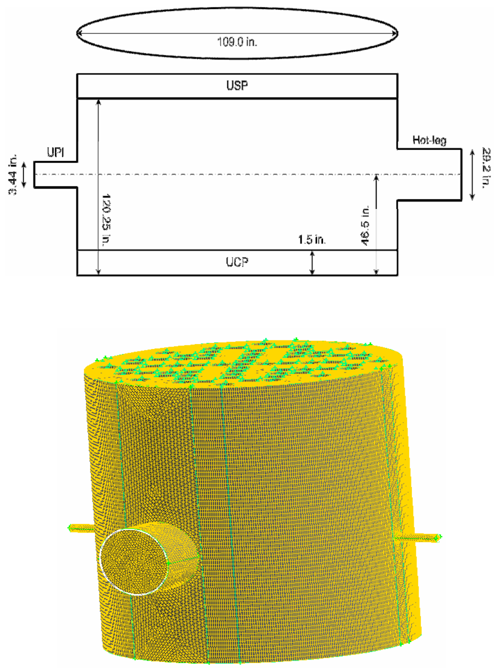

Figure 2. Computational domain and grid cells

3. Analysis Methods

3.1 Boundary conditions and Fluid properties

UP is initially quiescent and completely filled up with the vapor with the pressure of 2.5bar and the saturated temperature of 401K. The velocity of the up-flowing vapor on the bottom of UP amounts 4.5526m/sec. The safety water is injected from EEC injection nozzle with the velocity of 15m/sec under the normal temperature of 300K. For the evaluation we apply the fluid properties corresponding to the above assumed pressures and temperatures. (See Table 1.)

Table 1. Material properties of water and vapor

Parameter	Value	Unit	Remarks
Water density	999.6115	Kg/m^3	1.0bar, 300K
Water viscosity	$8.5154x10^{-4}$	Pa· sec	1.0bar, 300K
Vapor density	1.3919	Kg/m^3	2.5bar, 401K
Vapor viscosity	$1.3228x10^{-5}$	Pa· sec	2.5bar, 401K

3.2 Models

The Mach- and Reynolds number of the vapor in front of the ECC injection nozzle amount 0.031 and $1.534x10^6$ respectively. Therefore the flow field can be reasonably assumed as incompressible and turbulent. The simple k-epsilon model is chosen for a turbulence model and the default values given in FLUENT code are used for all of the semi-empirical model constants [1]. Between two phases and also between both fluids and walls any surface tension models are not considered.

4. Results

The flow behavior is evaluated up to 1.45sec. Following figures show the injected water distribution using the iso-surface of the vapor volume fraction 0, 0.1, 0.3, and 0.5 at each time step.

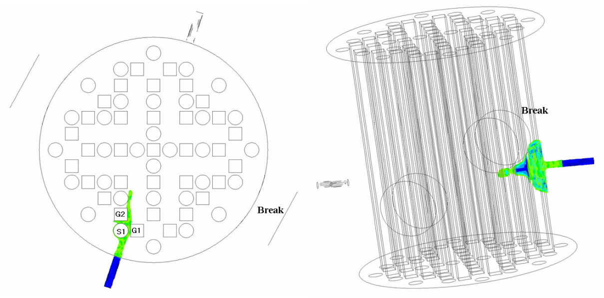

Figure 3. At time t = 0.1 sec

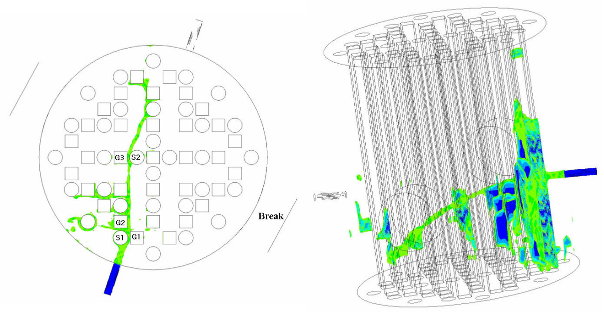

Figure 4. At time t = 0.5 sec

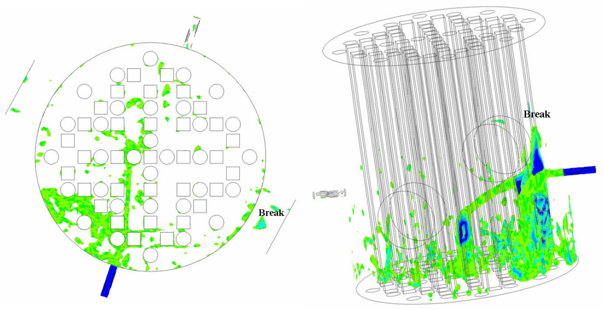

Figure 5. At time t = 1.4 sec

At the initial phase (Figure 3) the injected water jet bumps against the nearest guide tube G1 and the flow direction is changed to the left side from the original injection direction, i.e. to opposite side of the broken hot leg. At later time (Figure 4) the long stretched front of the water jet still survives through the narrow passage between support column S2 and guide tube G3 in the middle of the UP. But the most water moves slowly down along the wall of the columns and tubes. At the late phase (Figure 5) the surface of water accumulated at the bottom of the UP becomes more fluctuated due to the influence of the up-flowing vapor. At the same time the long stretched front of jet slowly disappears. Because the flow direction changes to the broken hot leg, the front scattered through the collisions on the near columns and tubes. Some of the water fraction can be swept out through the broken hot leg. But the main part of the injected water still moves down along the wall of the columns and tubes in the left quarter of the UP and accumulates at the bottom. This fact can be clearly confirmed by the following cross-sectional view of the vapor volume fraction (Figure 6). This result is also in good agreement with the former research work [2].

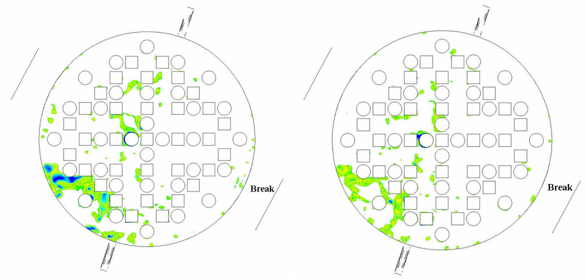

Figure 6. Vapor Volume fraction between 0-0.2m (left) and 0.2-0.4m (right)

5. Conclusion

The dynamical fluid behavior of the safety injection water in the UP of Kori unit 1 was investigated. The injected water jet bumps against the nearest guide tube and changes its direction to the left side from the original injection direction. Some of the water fraction can be swept out through the broken hot leg. However most of the injected water is trapped by the columns and tubes in the left quarter of the UP and moves down along the wall of the columns and tubes.

ACKNOWLEDGEMENTS
This work was supported by Dr. C. H. Ban of KNFC.

REFERENCES

[1] FLUENT 6-2 User's Guide.
[2] K. Takeuchi, M.E. Nissley and J. S. Spaargaren, Modeling of upper plenum injection for the best estimate LOCA analysis, NURETH-9, 1999.