Numerical Analysis of Break Flow According to Ambient Control Volume Size

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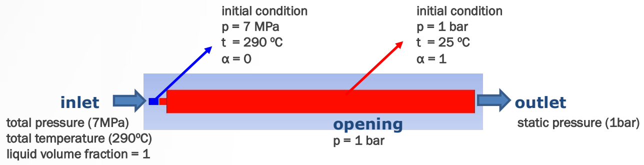
Motivation

Steam generator feed water line break accident is regarded as one of the important limiting events in PWR safety analysis. For numerical analysis of this event, appropriate modeling of feed water line break is important because it directly affects the amount of heat removal in primary system by the feedwater line break. To properly simulate the physical phenomena including flashing flow, it is important to define the appropriate modeling parameters such as numerical schemes, definition of modeling domain, initial conditions and so forth. Among them, the dependency on the control volume size of ambient size will be assessed in this study with CFX version 19.2.

If the diameter of ambient control volume is too small, the flashing flow to the free volume might be inaccurately modeled because the flow will be limited by the ambient control volume boundary. On the other hand, if the diameter of ambient control volume is too large, the flashing flow might be exactly modeled but the large computational resources are required. Thus, the appropriate ambient control volume size should be determined in terms of accuracy and computational time. For this, four cases with different ambient control volume sizes are simulated under the identical flashing flow conditions in this work.

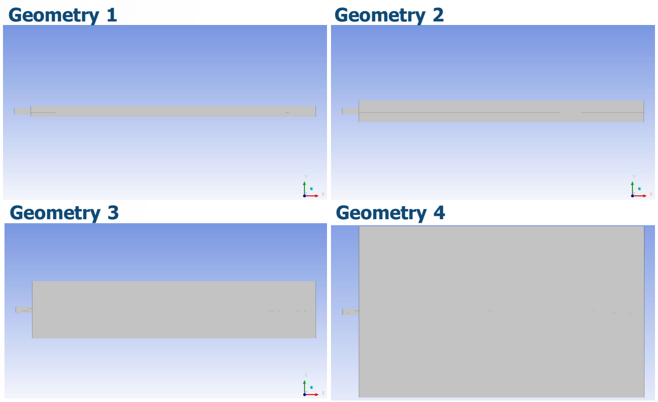
Assumption for Accident Analysis

✓ Ambient control volume is modeled in the form of a cylinder, and the break is considered as circle shape at the center of one circular plane of the cylinder volume. Break size is assumed to be 2 inches

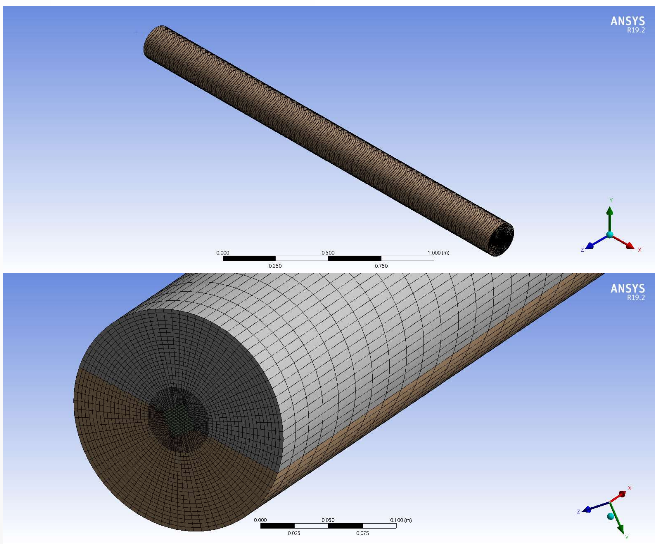


✓ Geometries of four different ambient control volumes

	Ambient Volume Diameter (m)	Ratio to Break Diameter (-)
Geometry 1	0.087	1.7
Geometry 2	0.173	3.4
Geometry 3	0.462	9
Geometry 4	1.385	27



✓ Mesh type: hex elements

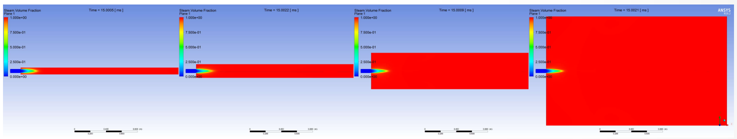


Modeling Methods

Analysis Type
transient
adaptive time step (Courant number < 1)
Fluid Models
inhomogeneous mass, momentum, energy eq (2 continuity, 6 momentum, 2 energy, 1 volume conservation equations)
SST turbulence model
Multi-phase Flow
dispersed system
IAPWS library material properties
dispersed phase mean diameter = 1 mm
Interphase Models
particle model
Shiller-Naumann drag force model
thermal phase change model
Ranz-Marshall heat transfer model

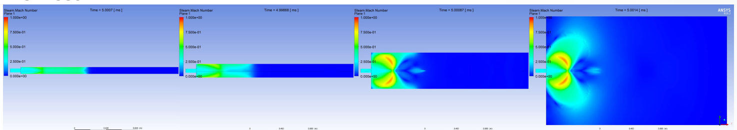
Results

- **Void fraction**

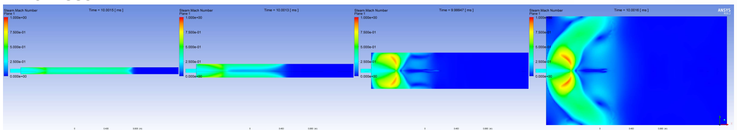


- **Steam Mach number**

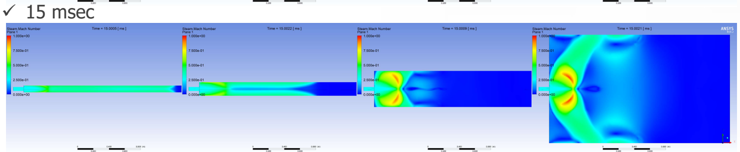
✓ 5 msec



✓ 10 msec

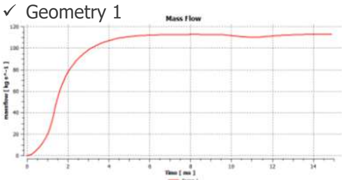


✓ 15 msec

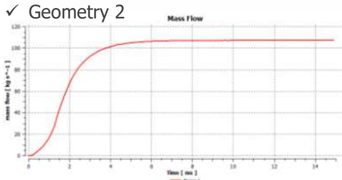


- **Mass Flow at break**

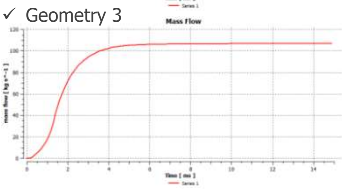
✓ Geometry 1



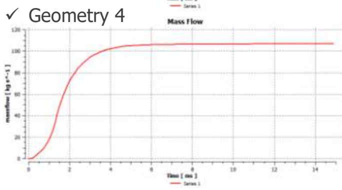
✓ Geometry 2



✓ Geometry 3



✓ Geometry 4



In void fraction graphs, it can be seen that all four geometries predict the water jet well. However, it can be checked from steam Mach number graphs that the phase change occurs around the water jet and the occurrence of the maximum Mach number in the vicinity of the phase change is observable only in geometries 3 and 4. In geometries 3 and 4, the maximum Mach number was about 0.97, but in geometries 1 and 2, only about 0.75 was observed. On the other hand, in the mass flow graphs, it can be seen that geometries 2, 3, and 4 predicted almost the same mass flow trends, whereas geometry 1 had an unstable values between about 10-12 msec.

Conclusion

Prior to the steam generator feedwater break accident analysis, the analysis according to the control volume size is performed using CFX 19.2 to simulate the free volume. Ambient control volume size is sufficient from a diameter of about 9 times the break diameter.