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# CFD Analysis of the Safety Injection Tank and Fluidic Device

Jai Oan Cho, Yacine Addad, Yohanes Setiawan Nietiadi, Jeong Ik Lee*

KAIST NQE
M.S. student

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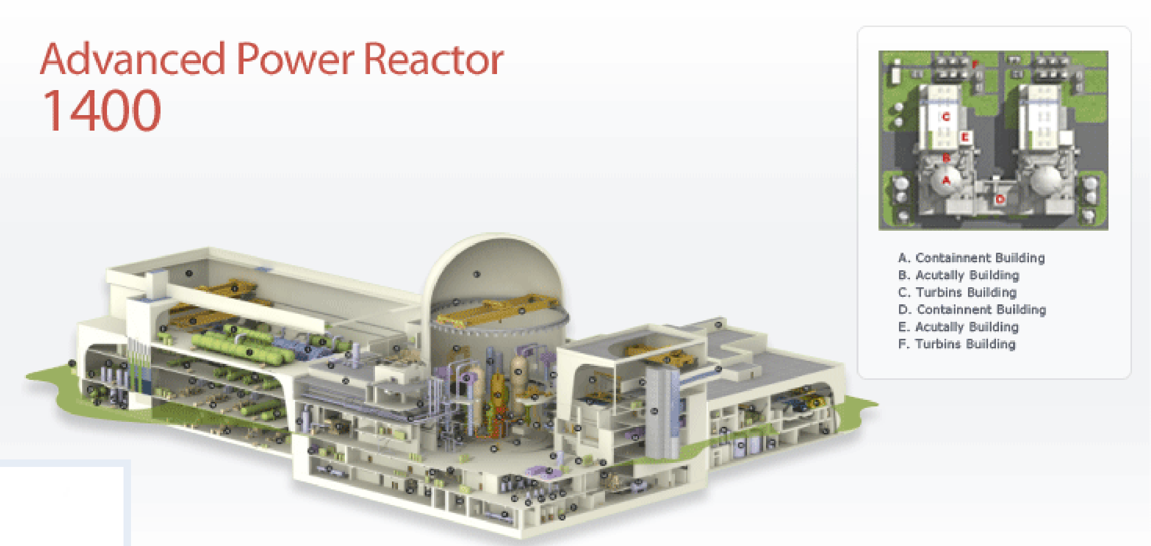
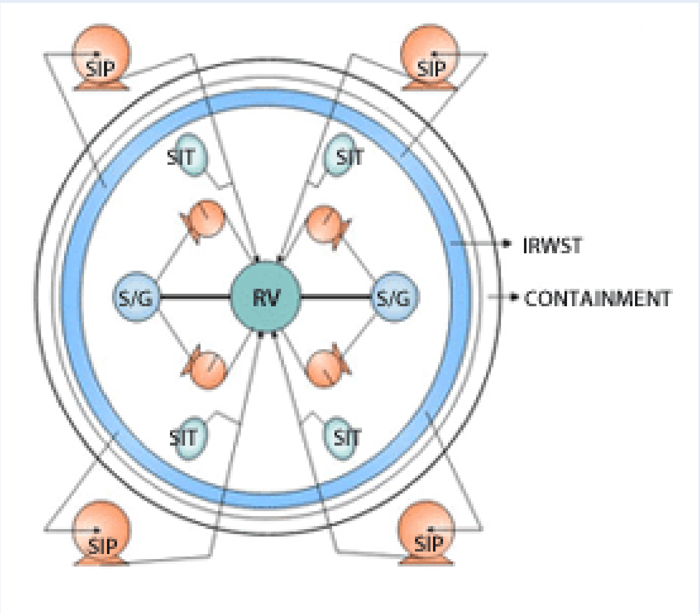
# Introduction

The APR 1400 is a large pressurized water reactor (PWR). Just like many other water reactors, it has an **emergency core cooling system (ECCS)**.

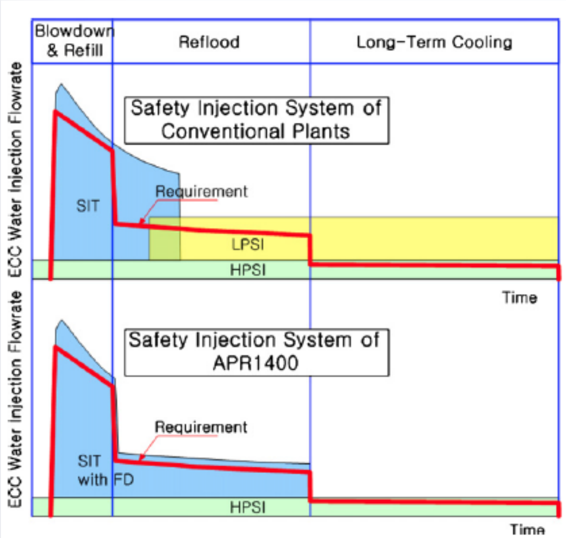


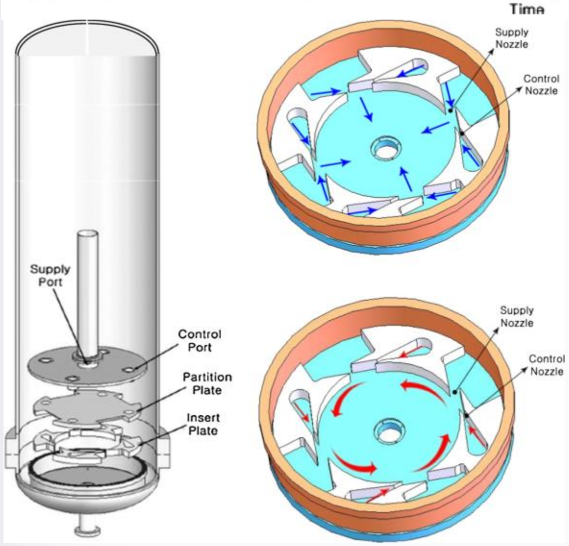




Safety Injection System

- One of the most important components in the ECCS is the **safety injection tank (SIT)**.
- The SIT is designed to provide ECC water in LOCA scenarios.
- The tank is pressurized to a certain level and once the system pressure drops below that level, the check valve opens and water flows into the core.

# Safety Injection Tank



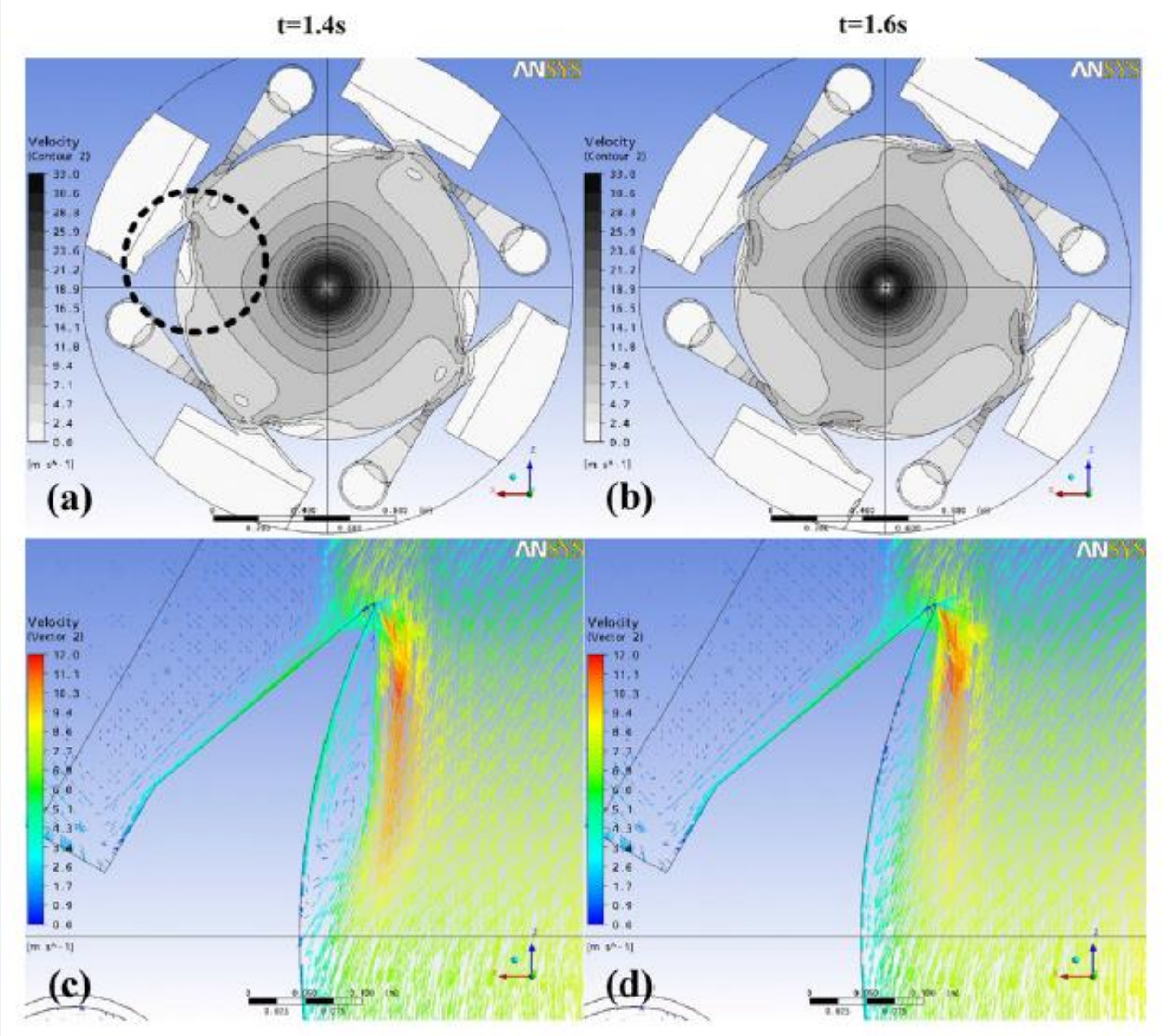




- Inside the SIT, a **fluidic device** is installed, which passively controls the mass flow of the safety injection and eliminates the need for low pressure safety injection pumps.

- As more passive safety mechanisms are being pursued, it has become more important to understand flow structure and the loss mechanism within the fluidic device.

- Current computational fluid dynamics (CFD) calculations have had limited success in predicting the fluid flow accurately. **This study proposes to find a more exact result using CFD and more realistic modeling.**

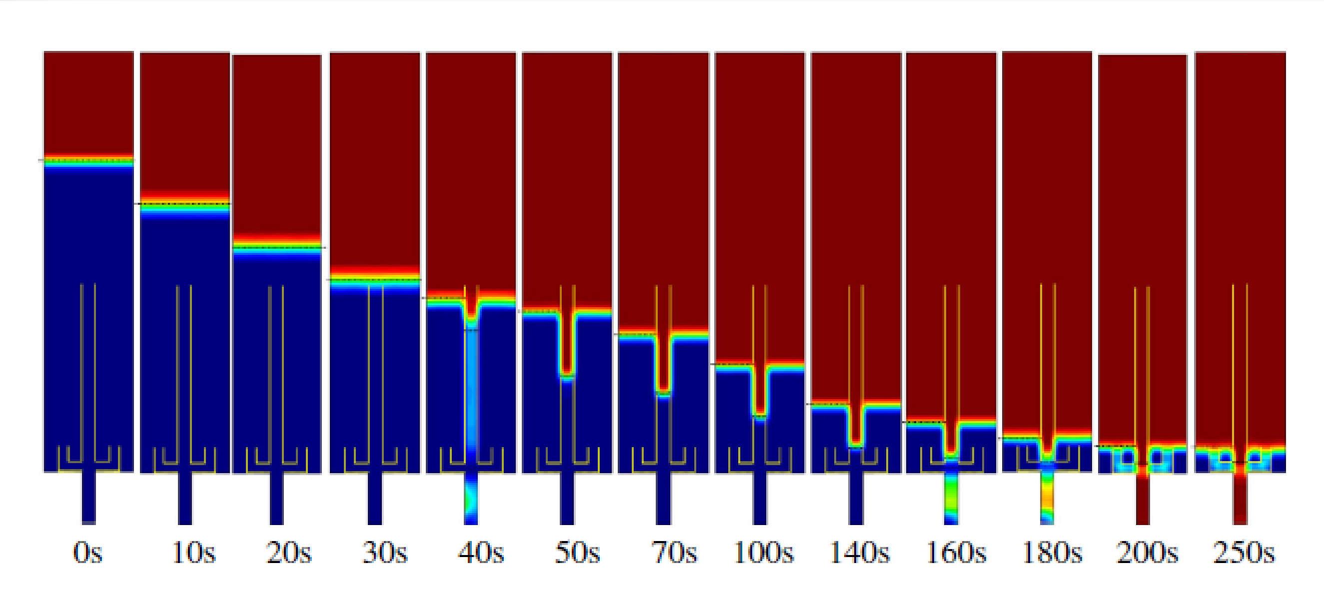
# Literature Review

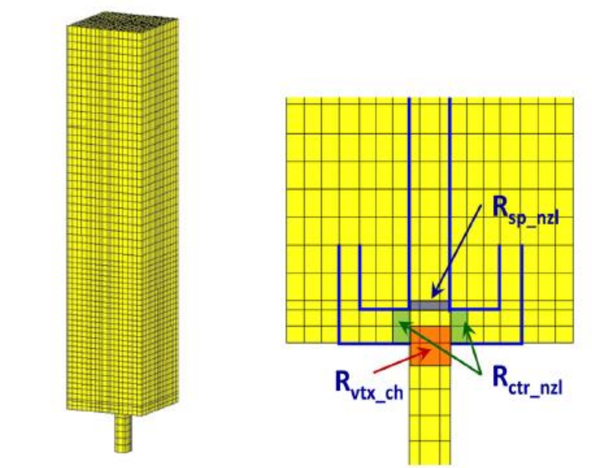



Benchmark and parametric study of a passive flow controller (fluidic device) for the development of optimal designs using a CFD code
- *Korea Hydro & Nuclear Power Company*

- No nitrogen
- Free surface effect neglected

# Literature Review



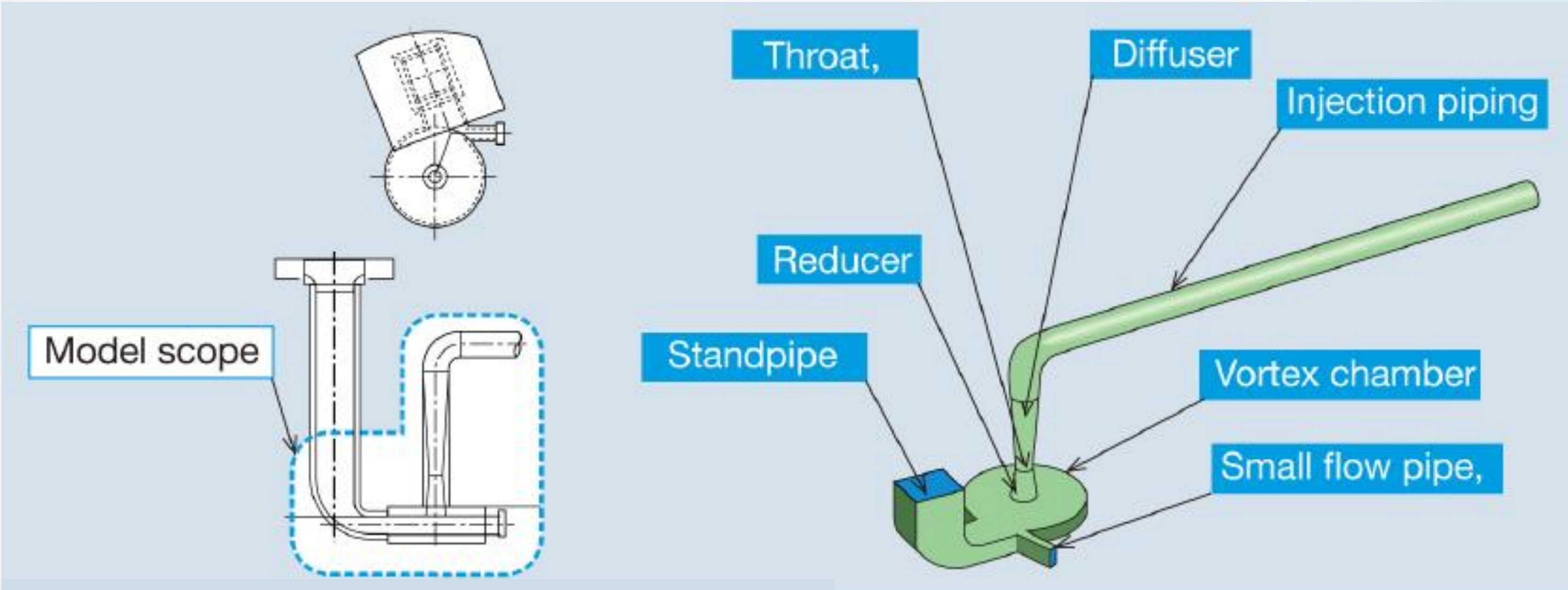

(a) Hexagonal grids for SIT

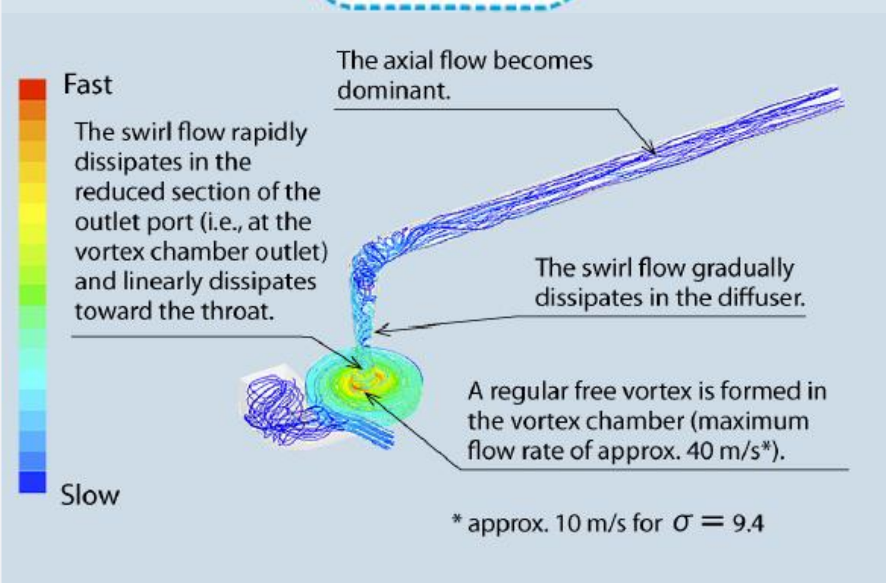
(b) Flow resistance model

A multi-scale analysis of the transient behavior of an advanced safety injection tank - *Korea Atomic Energy Research Institute*

- Geometry simplified
- K-factor given artificially

# Literature Review




CFD on Small Flow Injection of Advanced Accumulator in APWR
- *Mitsubishi Heavy Industries*

- FD only
- Steady-state



NPNP

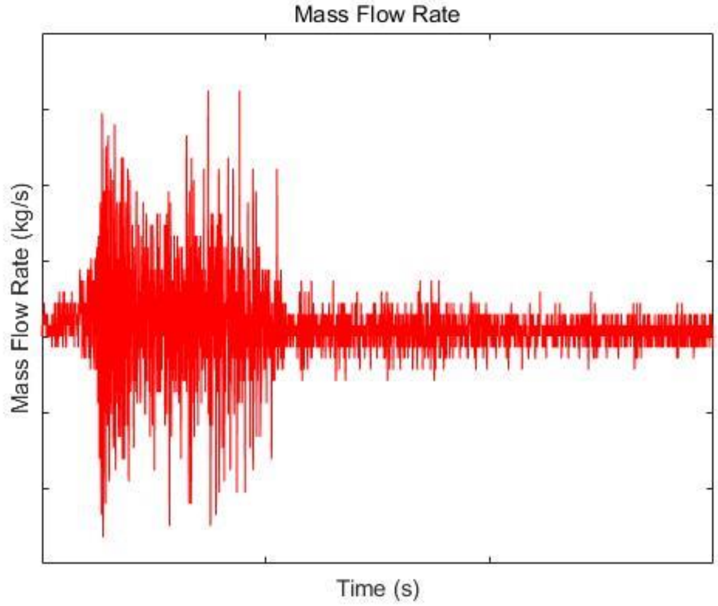
# Research Uniqueness

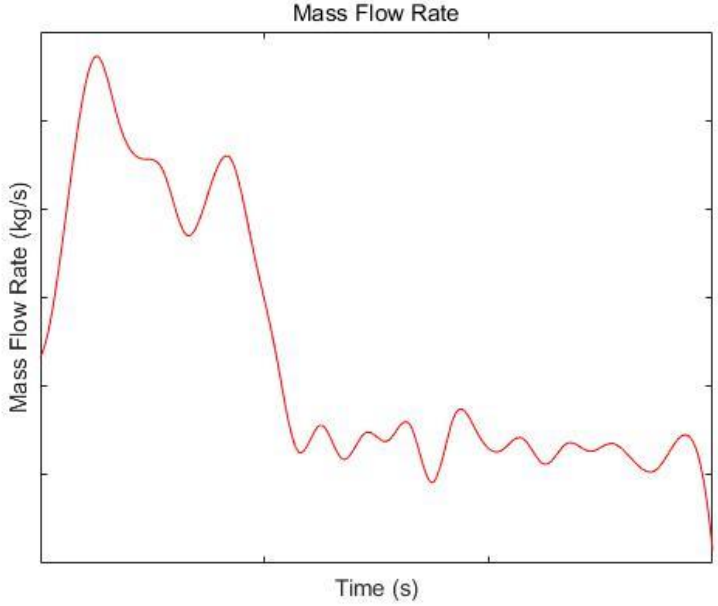
| | Nitrogen | Precalculated K factor | Full Geometry | Transient |
|---|---|---|---|---|
| KHNP | X | X | X | X |
| KAERI | O | O | Δ | O |
| MITSUBISHI | X | X | X | X |
| KAIST | O | X | O | O |

**Proposed Work**

- With Nitrogen
- Without Precalculated K-factor
- Full Geometry
- Transient

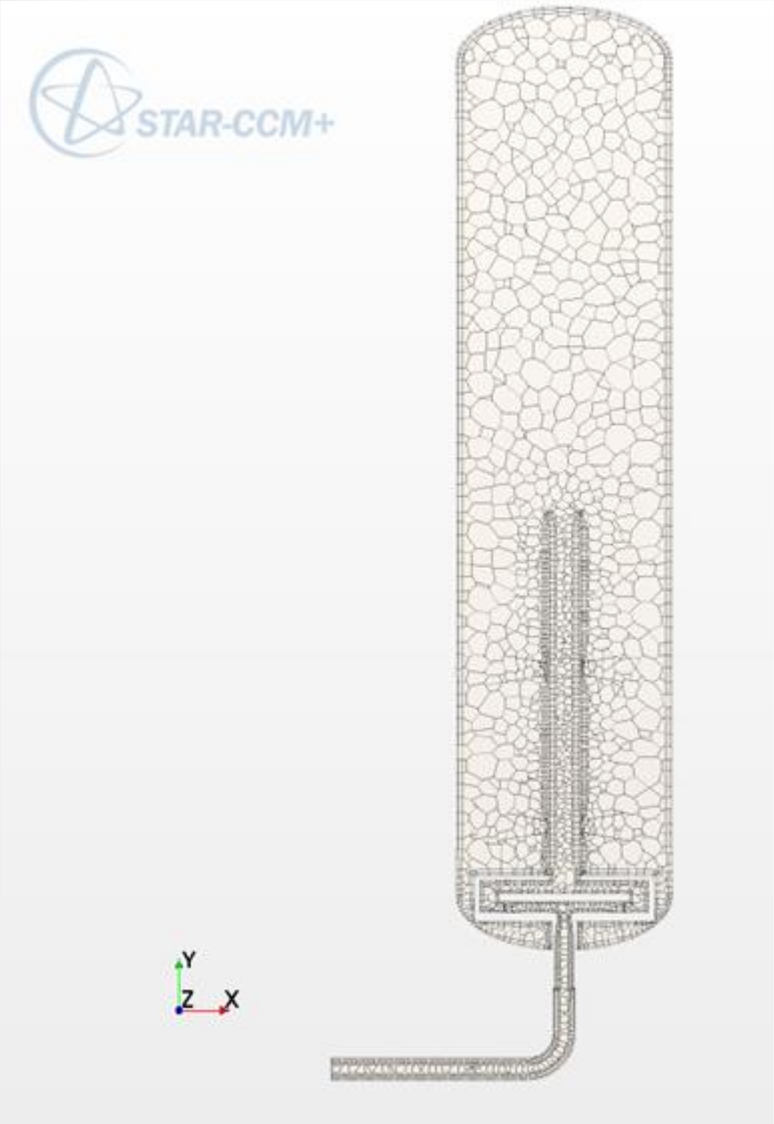
# Preliminary Results



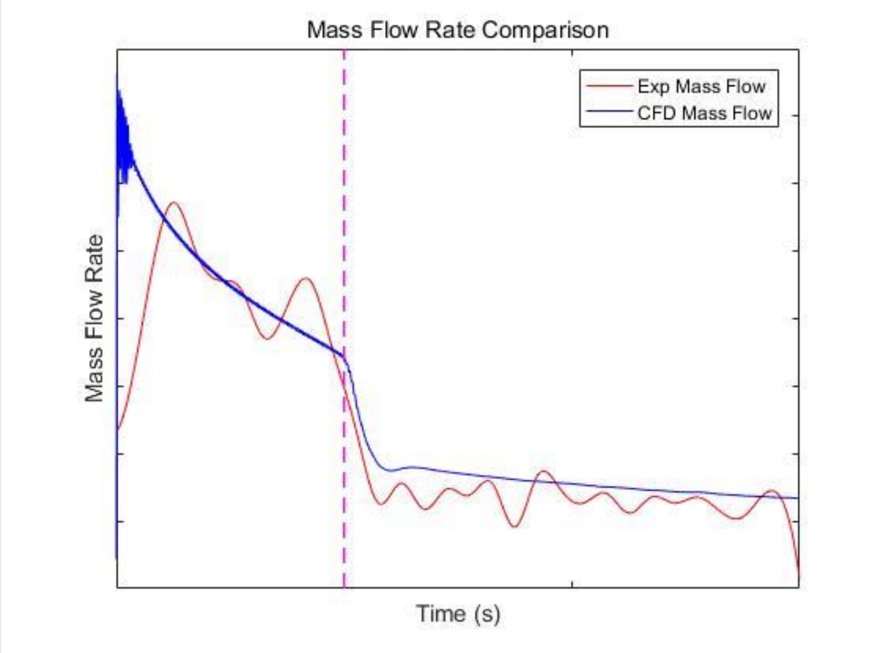

- Mass Flow Rate was retrieved by differentiating the water level.
- However fluctuation in water level was too violent.
- To get a meaningful result, the water level was averaged over 5 secs.

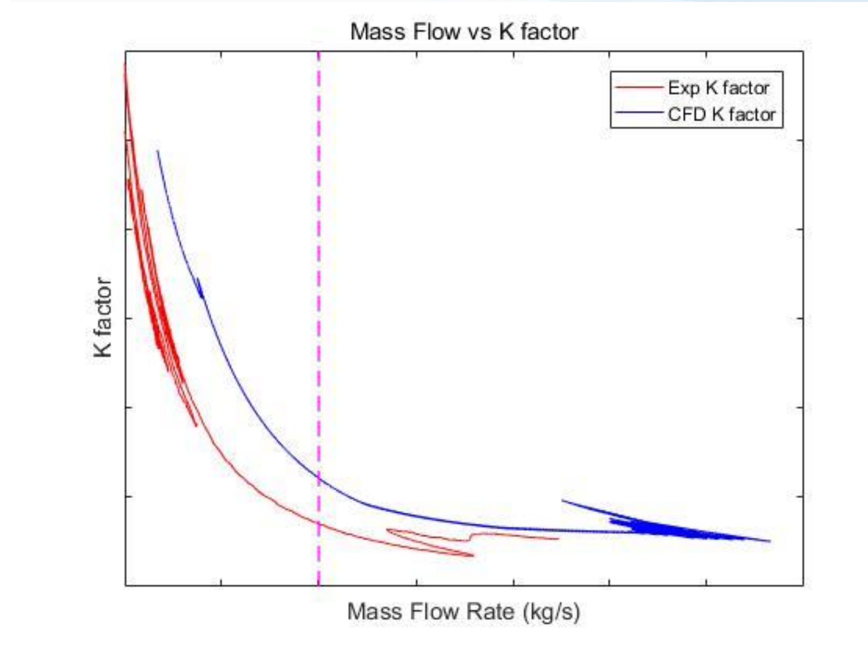
# Preliminary Calculation Conditions




- The **K-epsilon model** was used for the computation.
- **Polyhedral meshes** were used.
- Due to the violent vortex, finer meshes were used in the fluidic device.
- The tank was given a **constant thermal resistance** and **constant ambient temperature** with **convective boundary condition** on the tank wall.
- Lastly, a **pressure boundary of 1 bar** was given at the end of the discharge pipe.

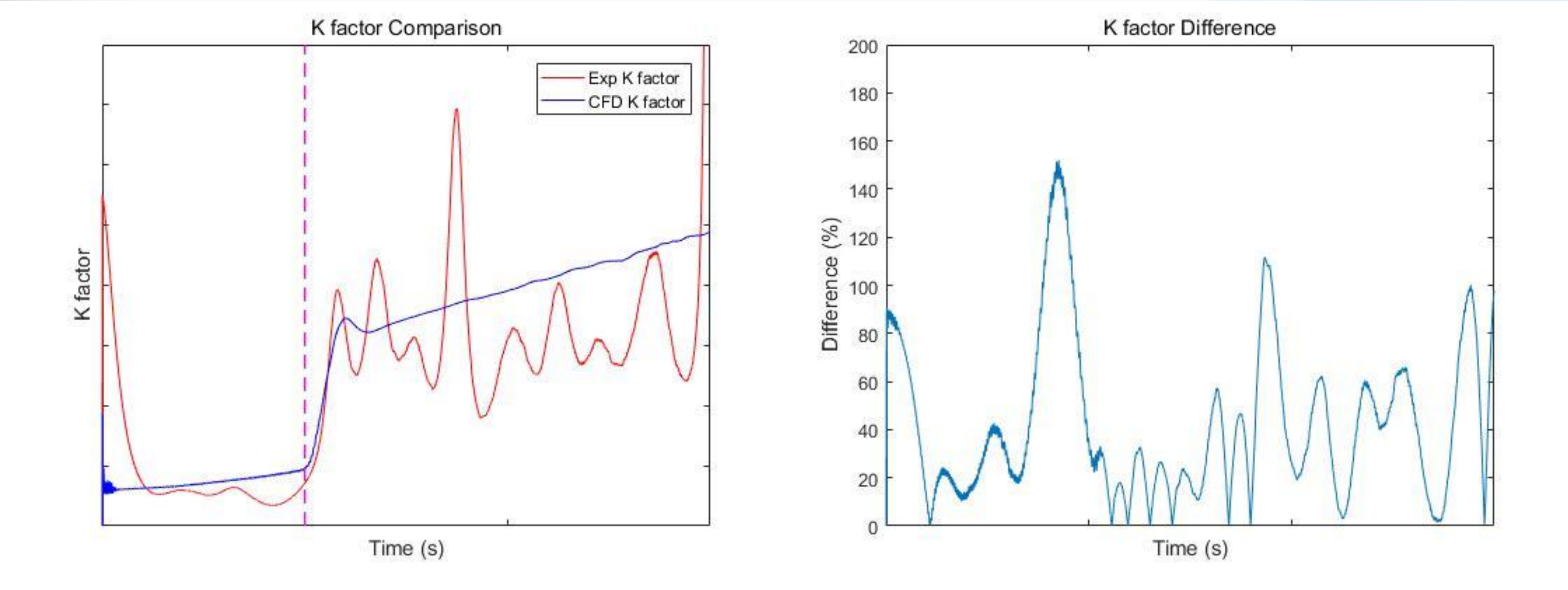
# Preliminary Results



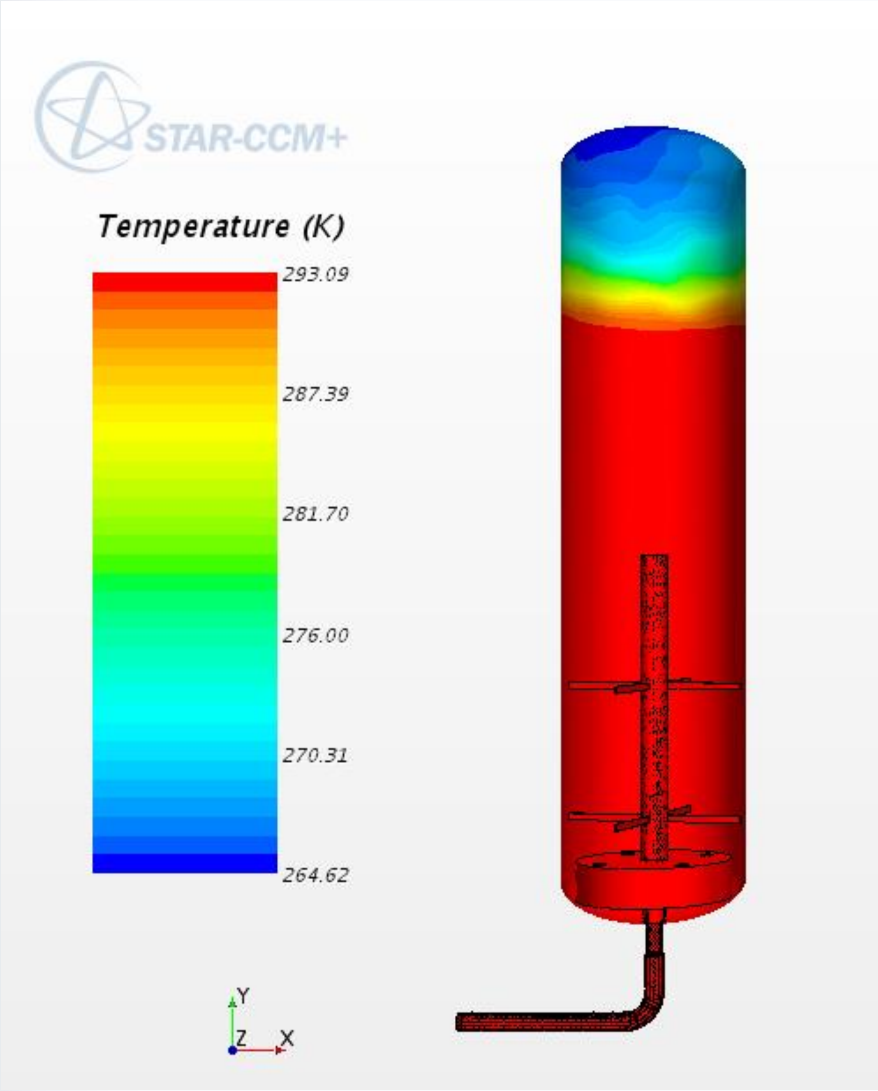

- ❖ The CFD mass flow rate matches quite well with the experimental result.
- ❖ The total k factor(form loss factor) was calculated in the discharge pipe using the equation below.
- ❖ $K = \frac{2*Pressure*Density*Area^2}{MassFlowRate^2}$

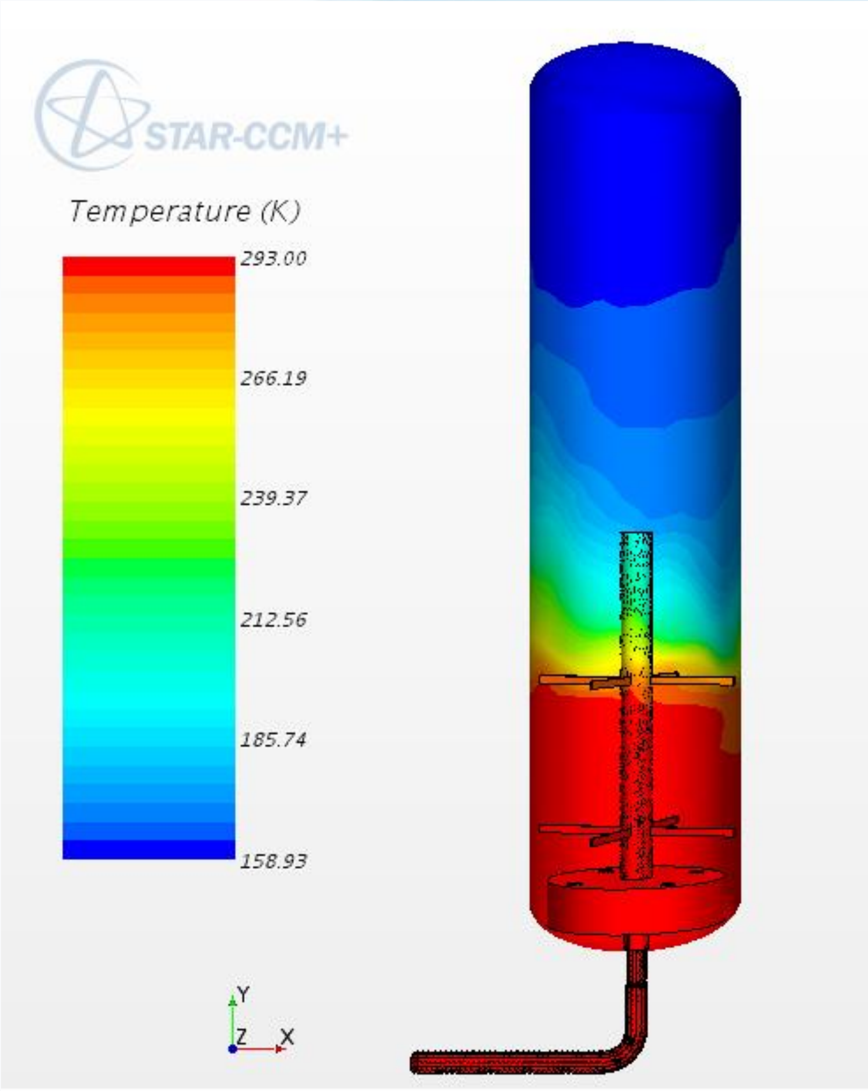
# Preliminary Results




❖ K factor plotted over time along with difference.

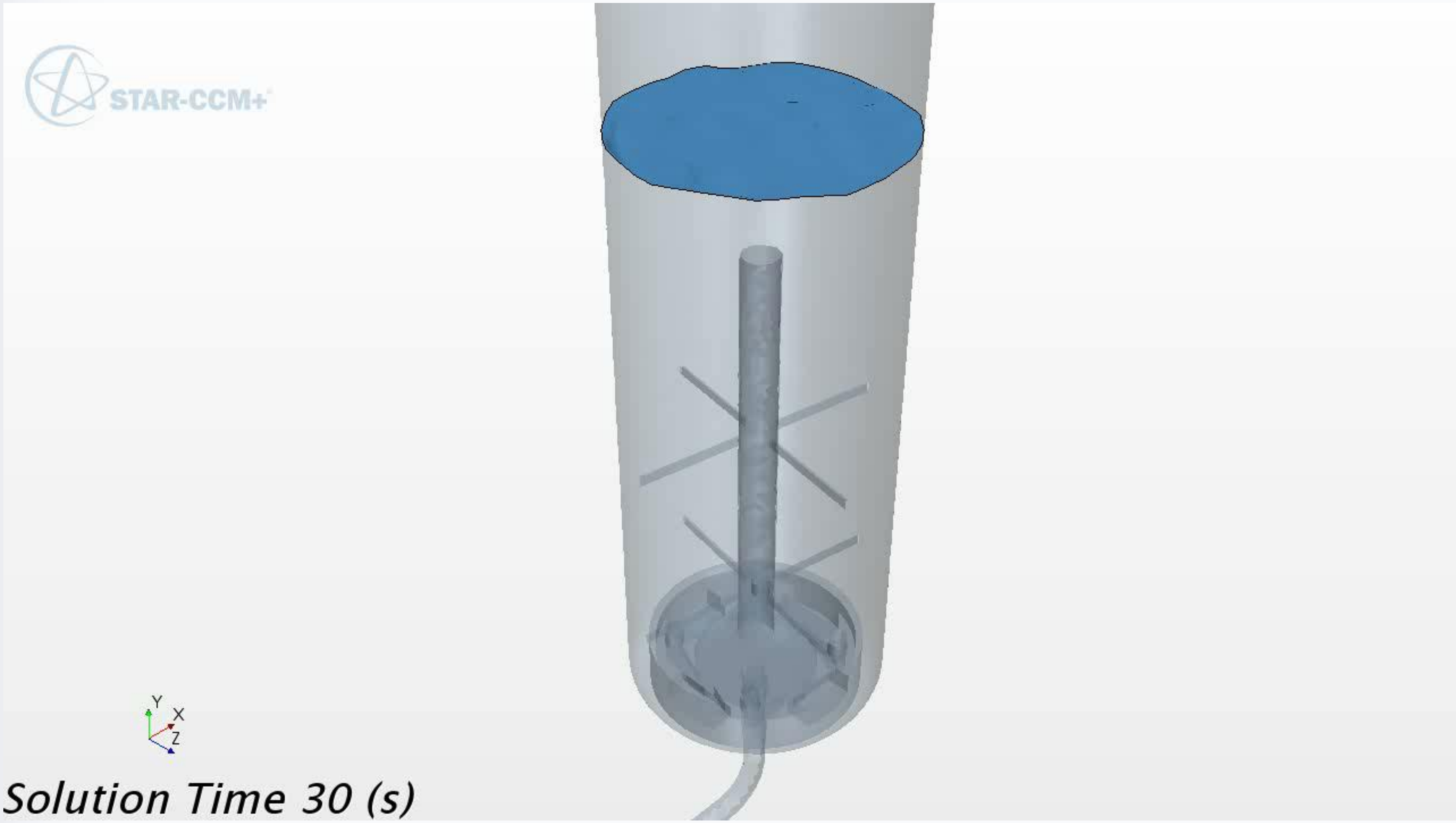
# Temperature Distribution



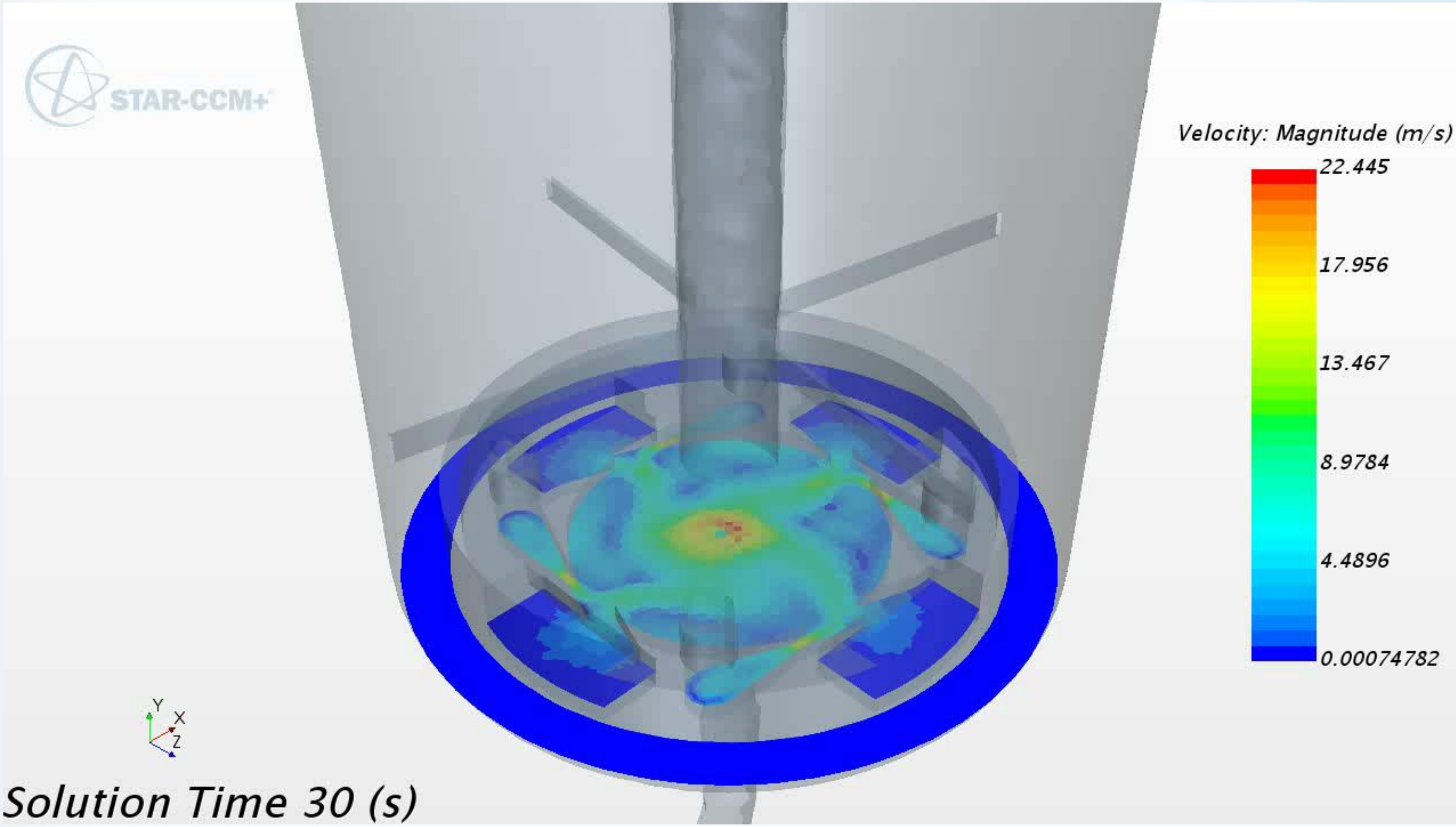

- High Flow Mode
- Low Flow Mode

# Animation




Liquid Volume Fraction 0.8 Isosurface

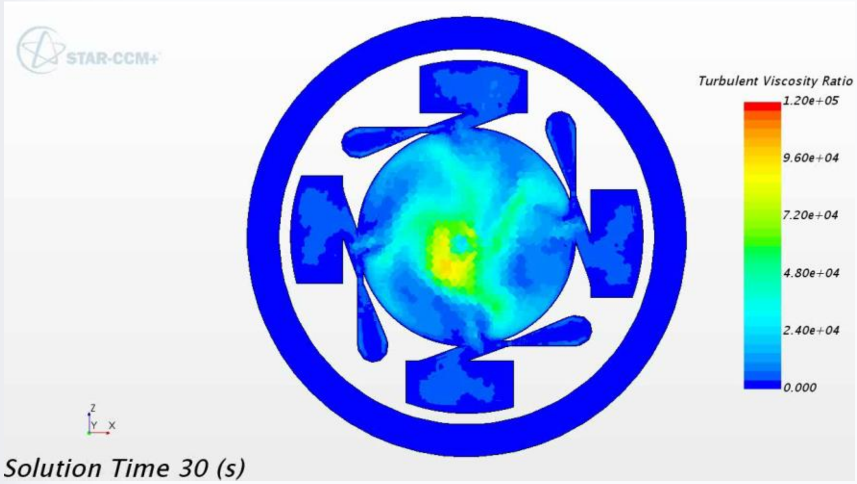
# Animation



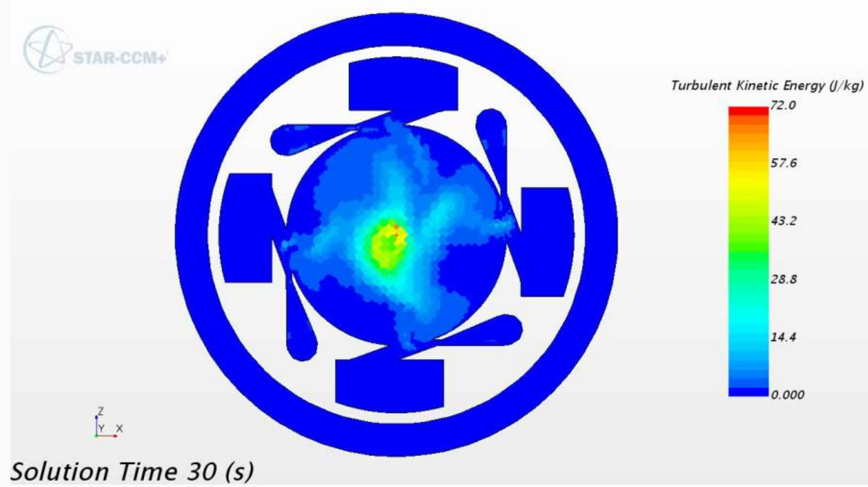

Velocity in Fluidic Device

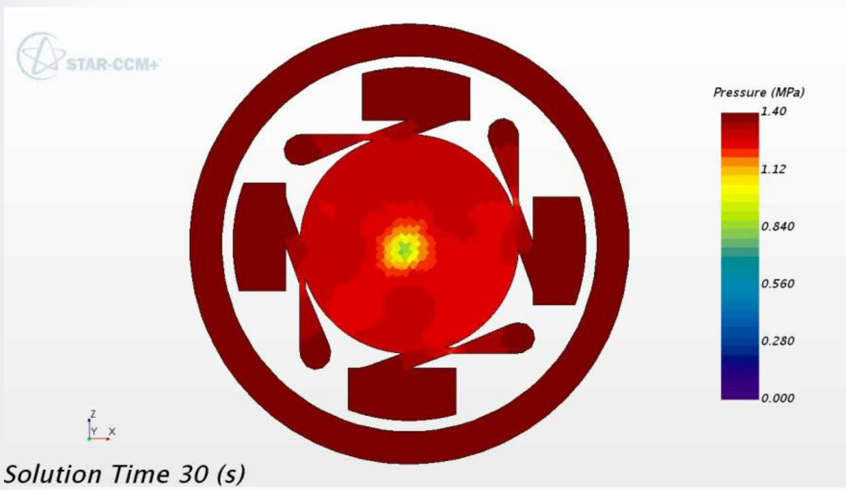
# Animation

Turbulent Viscosity Ratio

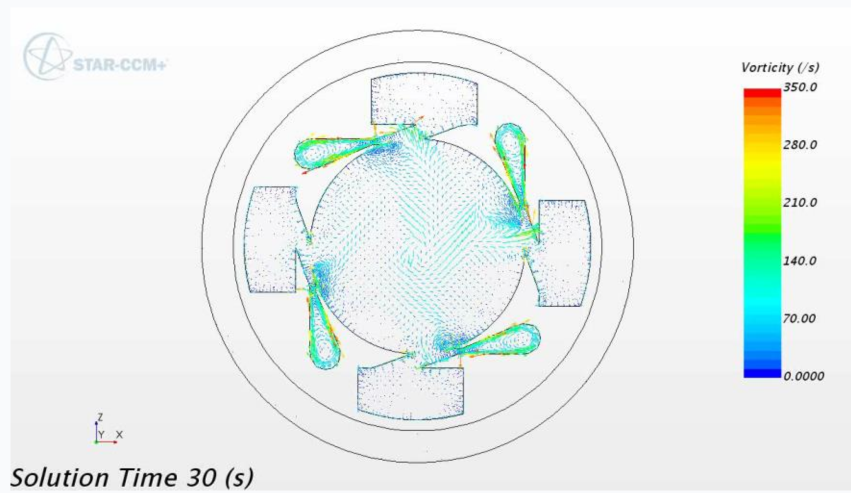



Turbulent Kinetic Energy



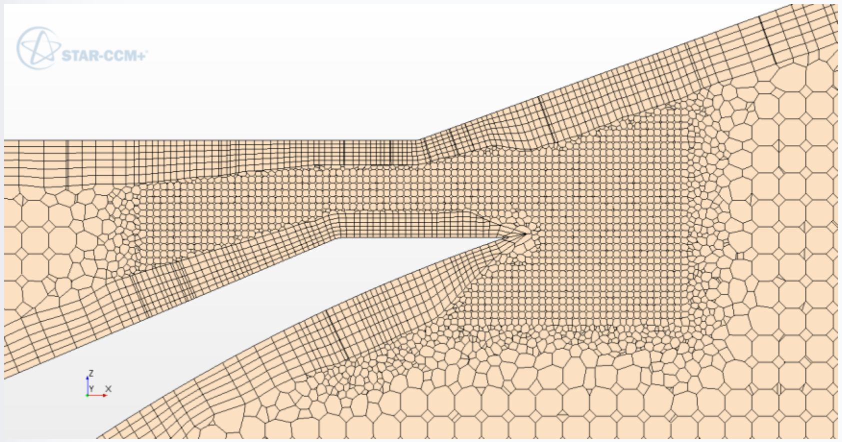



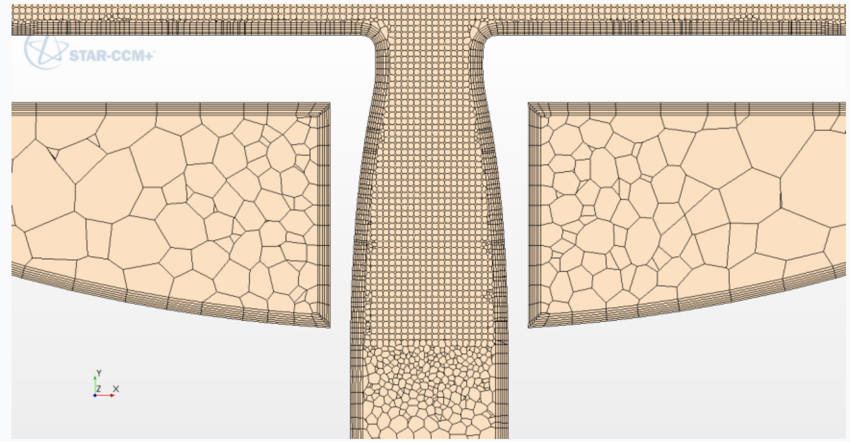

Pressure




Vorticity

# Comprehensive Analysis




## Updated Mesh

# of cells: 4 million
Tank Base size: 10cm
FD Base size: 0.25~1cm
Prism Layer: 6
Stretching Factor: 1.08
Growth Factor: 0.1

**IBM High Performance Computer II HIG**

. 11.520 Giga flops for computing.
. 25 Compute node
. 1 Master node
. 1 Login node
. IBM system x3775 M3
. CPU AMD Opteron 6174 12C *4, 256 GB RAM per node
. Infiniband by Qlogic
. 24TB Storage

**Applications**

| | |
|---|---|
| - Fluent | - RELAP5 |
| - CFX | - SCDAP |
| - Star-CD | - SNAP |
| - Star-CCM | - TRACE |
| - CONTAIN | - TRAC-P |
| - MELCOR | - WIMS |

# Summary & Future Works

- The SIT of APR1400 was analyzed using CFD.
- Calculation using CFD was performed to compare with experiment.
- Overall, the curve trend of CFD result followed the experimental result well.
- Mesh sensitivity analysis will be performed once comprehensive analysis is done.
- Initial Conditions for actual plant conditions (40 bar) will be tested. Results will be given as boundary conditions for testing on 1D system codes.
- Nitrogen entrainment will be analyzed.
- Fluidic Device will be optimized.

# THANK YOU