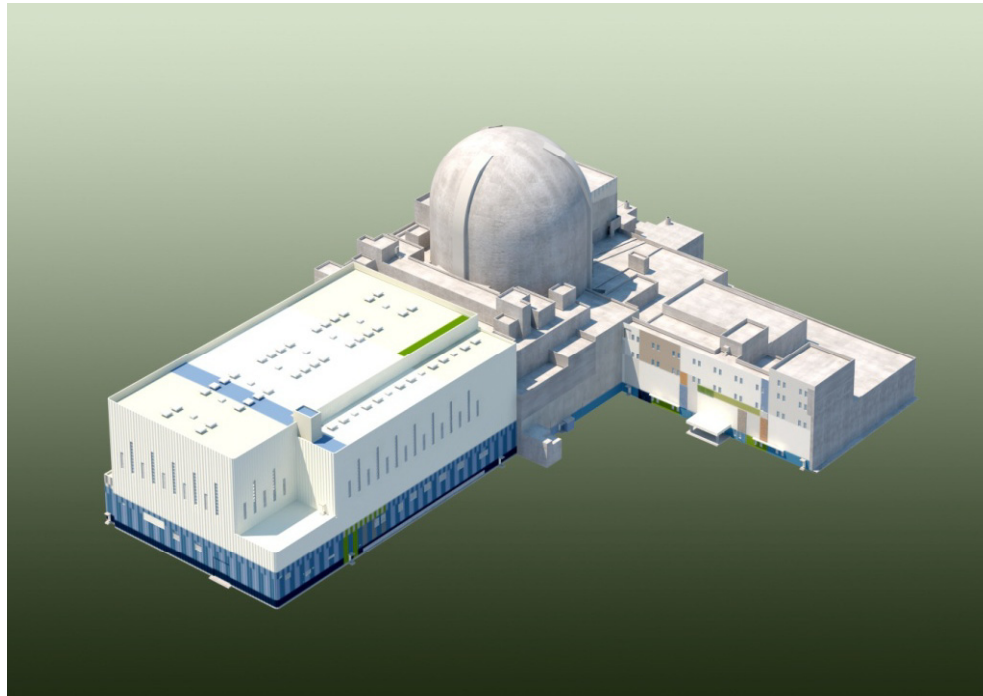


Debris In-vessel Downstream Effect Evaluation



KEPCO/KHNP

April 28, 2015

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Introduction

Introduction

- **Meeting Topic**

- ✓ **Effect of a flow channel gap change**
 - **The impact of a flow channel gap on the validity of testing that has already been conducted to address in-vessel downstream effects of the APR1400**
- ✓ **Accuracy of the flow meter**
 - **The accuracy and measurement range of the GF630 flow meter which was used in the in-vessel effect tests of the APR1400**

Introduction

- **Background**

- ✓ **NRC inspection of in-vessel downstream effect tests**

- **Date: Sep. 22 – 26, 2014**

- **Issued Inspection Report No. 99901453/2014-201**

- ✓ **Submission of documents**

- **Reply to a Notice of Violation: Dec. 10, 2014**

- **Technical Report, “In-vessel Downstream Effect Tests for the APR1400”, APR1400-K-A-NR-14001-P**

| Revision | Date | Description |
|----------|-----------|---|
| 0 | Dec. 2014 | <ul style="list-style-type: none">• Test results of the in-vessel downstream effect of the APR1400• Appendices on the effect of a flow channel gap change and the accuracy of the GF630 flow meter |

Effect of a Flow Channel Gap Change

Effect of a Flow Channel Gap Change

- Purpose of Analysis

- ✓ The manufacturing tolerance in the gaps between the test column and the bottom nozzle resulted in some discrepancies compared to the design value.
- ✓ Presents the results of a differential pressure analysis in relation to the accumulation of debris under manufacturing and design conditions.

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(a) Manufacturing Condition

(b) Design Condition

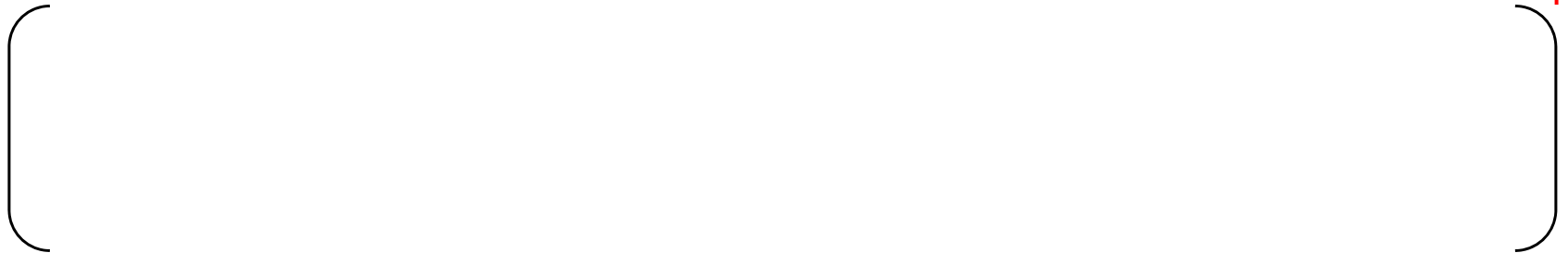
Effect of a Flow Channel Gap Change

- **Assumptions and Analysis Conditions (1/2)**

- ✓ At the inlet, fluid flows at a constant velocity: 77.6 lpm (20.5 gpm)
- ✓ The height of the gaps is maximized by modeling the bottom nozzle in the form of an hexahedron
- ✓ The measured differential pressure (DP) comes from the mock-up fuel assembly (FA) and accumulated debris

$$DP_{\text{total}} = DP_{\text{FA}} + DP_{\text{debris}}$$

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Effect of a Flow Channel Gap Change

- Assumptions and Analysis Conditions (2/2)

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Effect of a Flow Channel Gap Change

● Porous Media Model

- ✓ Based on Darcy's law and the ANSYS CFX theory

$$\frac{\Delta p}{\Delta t} = - \left(\frac{\mu}{K_{perm}} v + K_{loss} \frac{\rho}{2} v^2 \right)$$

Δp : differential pressure

μ : fluid viscosity

K_{perm} : permeability loss coefficient

v : velocity normal to the porous face

K_{loss} : quadratic loss coefficient

ρ : fluid density

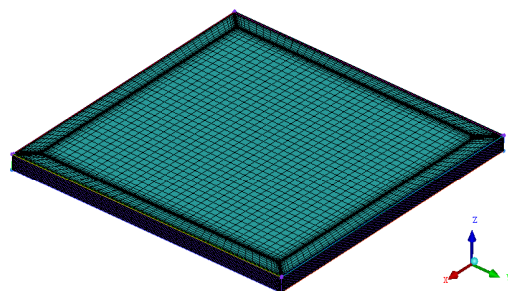
Δt : thickness of the medium

- ✓ By considering only the quadratic term, since the Reynolds number at the inlet is 6490, we can calculate K_{loss} as below.

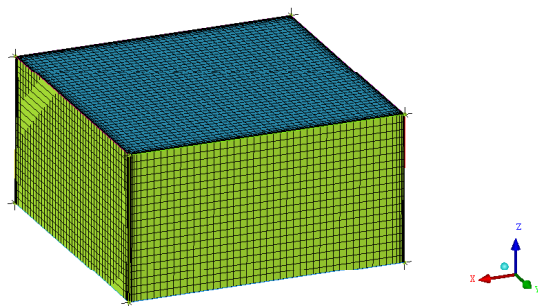
$$\frac{\Delta p}{\Delta t} = -K_{loss} \frac{\rho}{2} v^2$$

Effect of a Flow Channel Gap Change

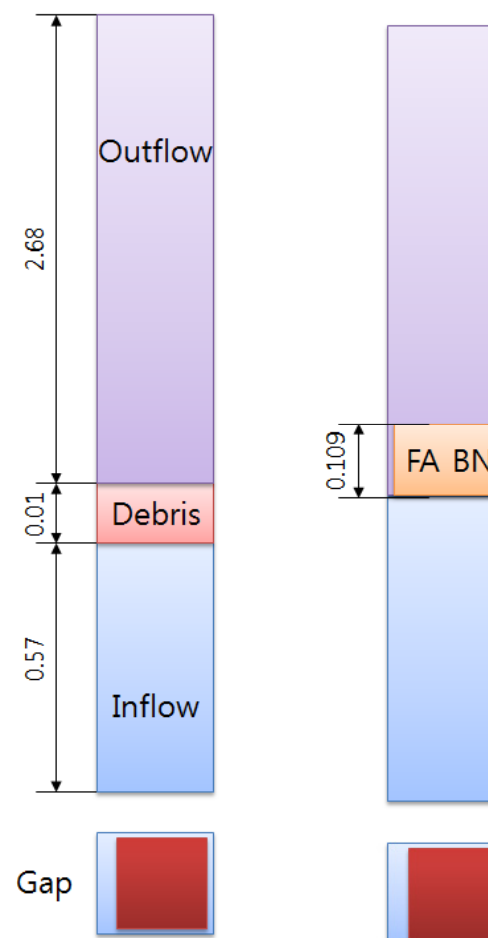
- Loss Coefficient Calculation for Debris and Bottom Nozzle(1/3)



(a) Debris bed



(b) Bottom nozzle



[Analysis Model Under the Manufacturing Condition]

Effect of a Flow Channel Gap Change

- Loss Coefficient Calculation for Debris and Bottom Nozzle (2/3) TS



Effect of a Flow Channel Gap Change

- Loss Coefficient Calculation for Debris and Bottom Nozzle (3/3)

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(a) Debris bed

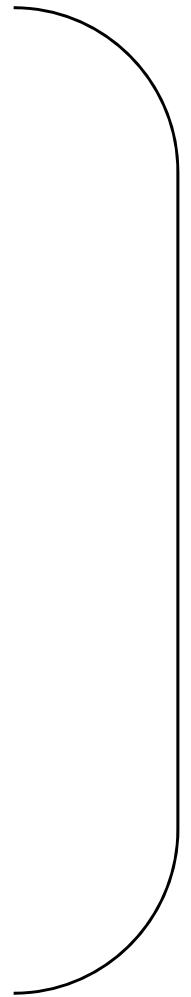
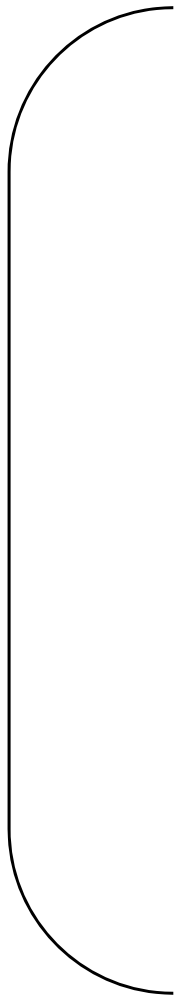
(b) Bottom nozzle

[Pressure for the Debris Bed and Bottom Nozzle Region]

Effect of a Flow Channel Gap Change

- Analysis Results Comparison of the Manufacturing Condition with the Design Condition

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Effect of a Flow Channel Gap Change

- Conclusion

- ✓ The change of flow channel gap from the as-fabricated value to the design value will cause the pressure drop to increase by less than 1%.
- ✓ Therefore, the results of test that have already been conducted are valid because there is a plenty of margin under the limiting condition of hot-leg break.

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Accuracy of the Flow Meter Used in the Tests

Accuracy of the Flow Meter

● Flow Meter Used in the Tests

- ✓ **Model: Toshiba GF630**
- ✓ **Measurement range: 7.5 ~ 250 lpm**
- ✓ **Accuracy: $\pm 0.5\%$ of rate at 50 ~ 250 lpm, ± 0.25 lpm at 7.5 ~ 50 lpm**

● Evaluation Result at the Minimum Flow Rate

| <ul style="list-style-type: none"> • Standard • flow rate(Y) • (lpm) | Measured flow rate(X) (lpm) | Deviation (X-Y) (lpm) | Requirement (lpm) | Evaluation |
|---|-----------------------------------|-----------------------------|----------------------|--------------|
| • 7.748 | 7.91 | 0.162 | 0.25 | Satisfactory |
| • 7.774 | 7.95 | 0.176 | 0.25 | Satisfactory |
| • 7.362 | 7.52 | 0.158 | 0.25 | Satisfactory |

- ✓ **After the inspection, the flow meter was recalibrated.**

Accuracy of the Flow Meter

● Results of the Evaluation

- ✓ Requirement of the flow rate to ensure control: target flow rate $\pm 5\%$
- ✓ Minimum flow rate in the tests: 9.2 lpm
- ✓ Control band at the minimum flow rate: 9.2 lpm ± 0.46 lpm
- ✓ GF630 meets the required accuracy at a flow rate less than 9.2 lpm

● Conclusion

- ✓ The GF630 flow meter met the required accuracy in the measurement range of 7.5 lpm to 250 lpm when it was recalibrated.
- ✓ The tests under the cold-leg break condition were performed with a flow meter which met the required level of accuracy.

Thank you for your attention.