Idaho National Engineering and Environmental Laboratory

Assessment of a Molecular Diffusion Model in RELAP5-3D

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Outline

- Introduction
- RELAP5 diffusion model
- Japanese inverted U-tube experiment
- Assessment results
- Conclusions
- Future work

Introduction

- *The core flow may stagnate following a LOCA in the VHTGR due to non-uniform concentrations of helium and air*
- *Molecular diffusion will act to make the concentrations of helium and air uniform and establish natural circulation*
- *Natural circulation leads to air ingress into the core that results in graphite oxidation, which increases peak cladding temperature and is thus of concern*

RELAP5-3D is being improved to support analysis of VHTGRs

- Models have been previously added to the code
  - CO, CO_2, and O_2 noncondensible gases
  - Graphite oxidation models for air ingress
- A molecular diffusion model has been added to an experimental version of the code
  - The model has not yet been incorporated into the mainline version of the code

A molecular diffusion model has been added to the code: (1/2)

- *The molecular diffusion model is based on Fick's second law for spatially uniform pressure and temperature*
- *Binary diffusion coefficients are obtained from the correlation of Fuller et al.**
- *The model currently assumes binary diffusion and a simply connected nodalization*

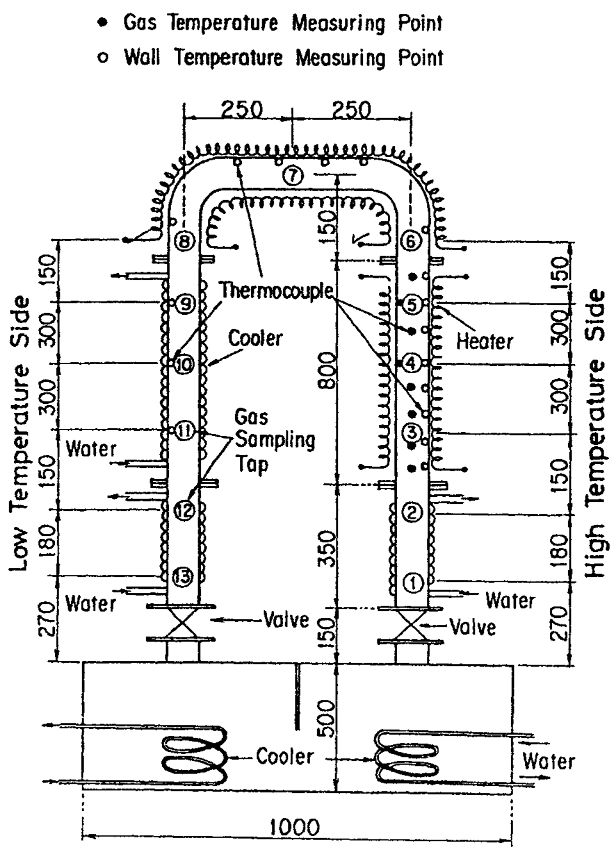
**R. C. Reid et al., "The Properties of Gases and Liquids," Fourth Edition McGraw-Hill Book Company, 1987.*

A molecular diffusion model has been added to the code: (1/2)

- *Assessments have been completed using data from a Japanese inverted U-tube experiment,** which is the subject of this presentation*

*** M. Hishida and T. Takeda, "Study on air ingress during an early stage of a primary-pipe rupture accident of a high-temperature gas-cooled reactor", Nuclear Engineering and Design 126 (1991) 175-187.*

Inverted U-tube apparatus*

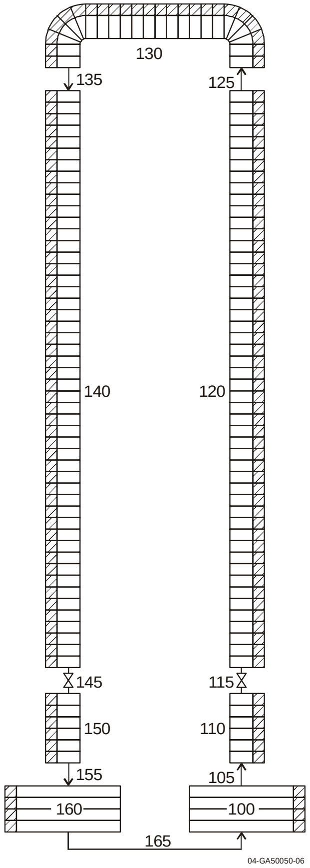


- Contains U-tube, ball valves, and tank
- U-tube initially contains He, tank contains N_2
- Temperature controlled by heaters and water jacket

Two tests were conducted

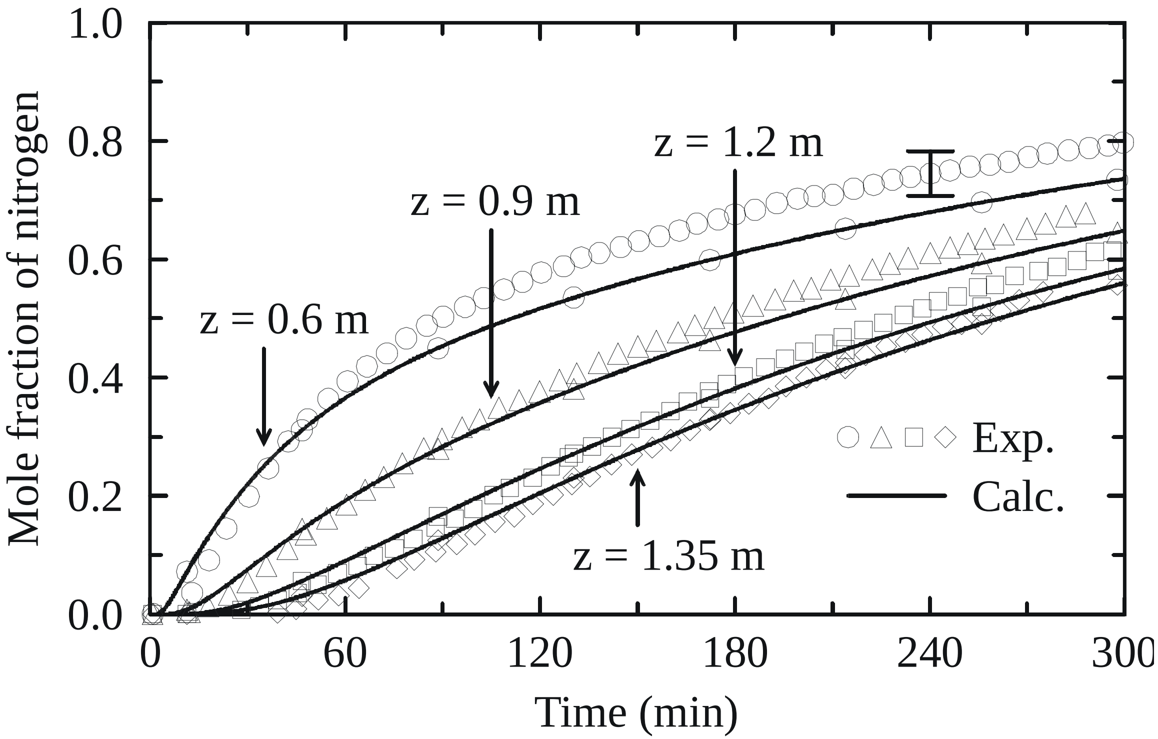
- *Mole fraction of nitrogen was measured as a function of time*
- *Tests were initiated by opening the ball valves*
- *An isothermal test at room temperature*
  - *Molecular diffusion was the dominant effect*
- *A non-isothermal test with temperatures varying between 19 and 256°C in the "hot" vertical leg and between 18 and 124°C in the "cold" vertical leg*
  - *Molecular diffusion and convection were both important*

A RELAP5 model of the inverted U-tube was constructed



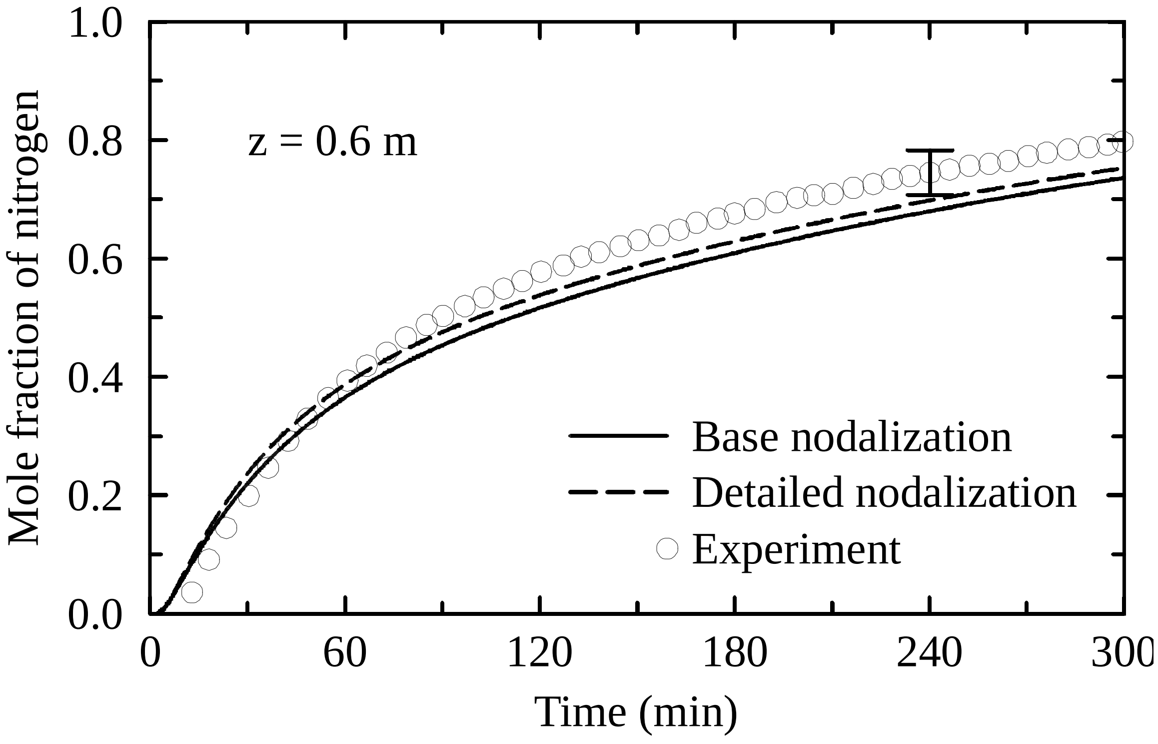
- Model much more detailed than typical reactor models (144 control volumes, most 2.45 cm long)
- Heat structure outer surface temperature set at measured value
- Tank divided into two halves

RELAP5 results were in reasonable agreement for the isothermal test



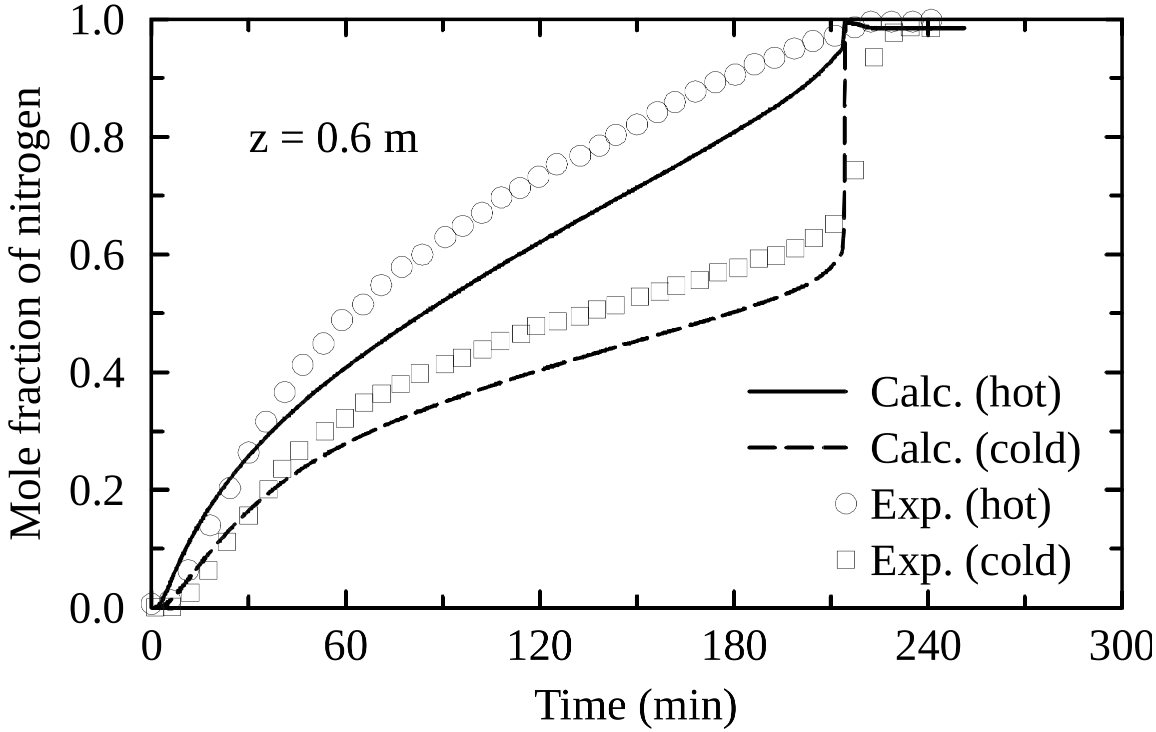
- N_2 mole fraction increased symmetrically in both legs
- Calculation slightly outside uncertainty band at lowest elevation, better at upper elevations

Results slightly better with increased nodalization



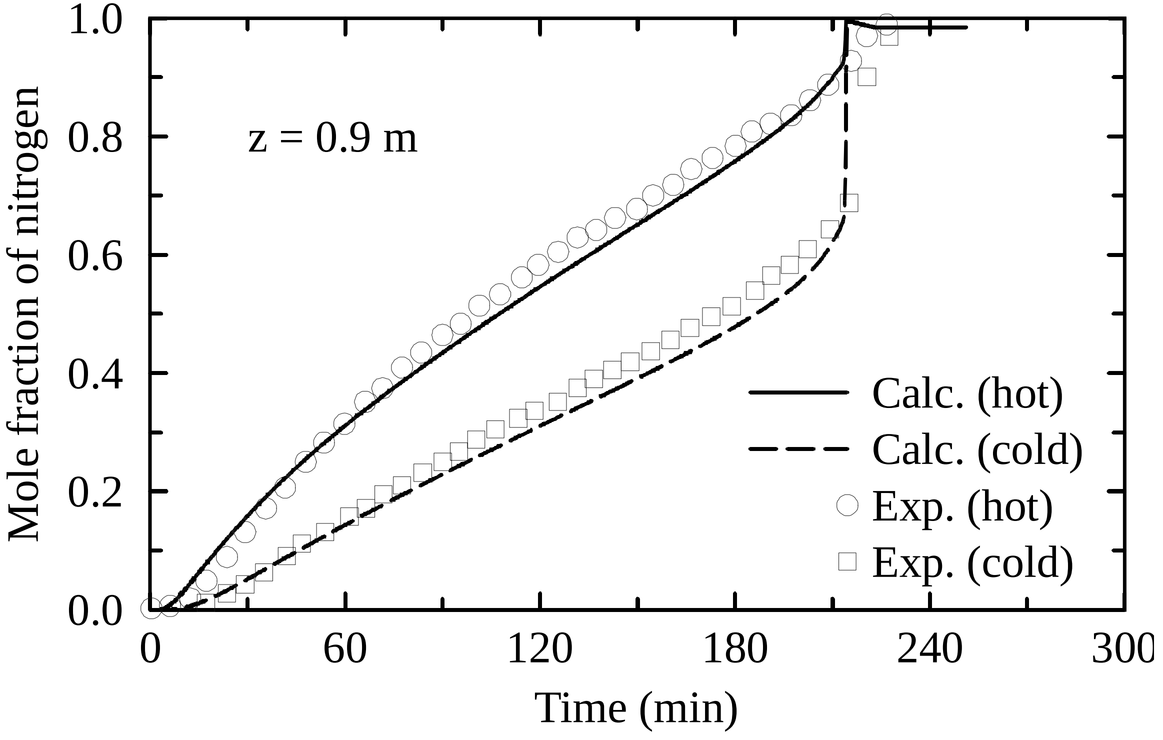
- The number of control volumes was doubled with the detailed nodalization

Similar results were obtained for the heated experiment



- Mole fraction increased more rapidly in hot leg because of higher diffusion coefficient and buoyancy effects
- Rapid increase near 220 min was caused by onset of natural circulation
- Timing of onset well predicted

Better comparisons were obtained at higher elevations



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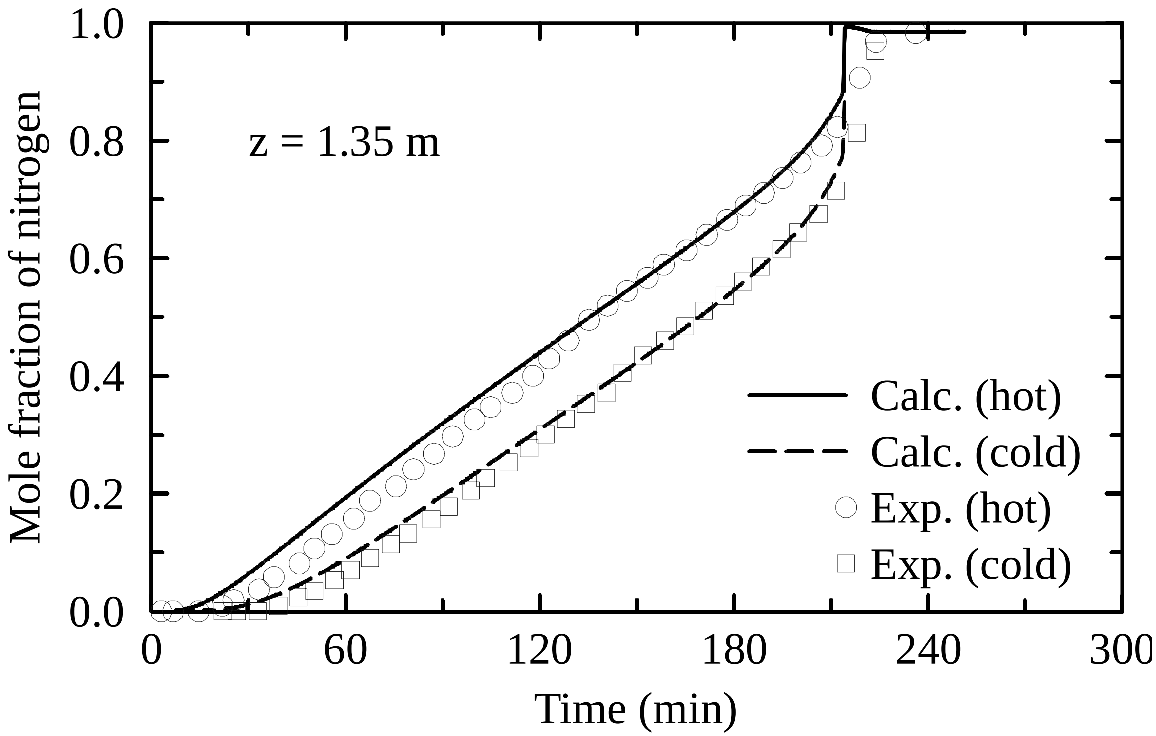

Conclusions

- *The RELAP5 results were in reasonable agreement with the data from the Japanese inverted U-tube experiment*
  - *Important trends were replicated*
  - *Timing of the onset of natural circulation was predicted well*
- *Results not expected to be as accurate using typical reactor nodalizations, but should show trends*

Future work

- *Comparisons with additional diffusion experiments*
  - *Preliminary results in poor agreement with the Japanese HTTR scaled experiment*
  - *Preliminary results obtained for the NACOK facility are qualitatively similar to those predicted by German researchers*
  - *Additional work required*
- *Generalization of the diffusion model to allow:*
  - *Five species*
  - *Complex nodalizations (with branching) that are representative of reactor models*
- *Comparisons with NACOK pressure drop experiments*