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Fuel Particle Transport

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Meeting Objectives

Review Framatome's plan to assess fuel particle transport and settling in the reactor related to FFRD

Provide an opportunity for NRC feedback

Agenda

Introduction	Morris Byram
Function of the study	Scott Franz
Application of GOTHIC	Scott Franz
Qualification of GOTHIC	Jeff Lane
Planned Models	Scott Franz
Summary	Morris Byram
Next Steps	Morris Byram

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Introduction

Morris Byram

Introduction

Evaluation of Fuel Fragmentation, Relocation and Dispersal (FFRD) is part of the increased burnup topical report

An evaluation of potential fuel particle transport and settling is part of the FFRD evaluation

Framatome is planning on using GOTHIC to simulate fuel particle transport and settling following dispersal from a fuel rupture during a LOCA event

GOTHIC's qualifications for evaluating fuel particle transport behavior have been assessed and will be discussed today

Results from the studies will be used to provide conservative conclusions to support downstream evaluations of fuel particle transport and settling following dispersal

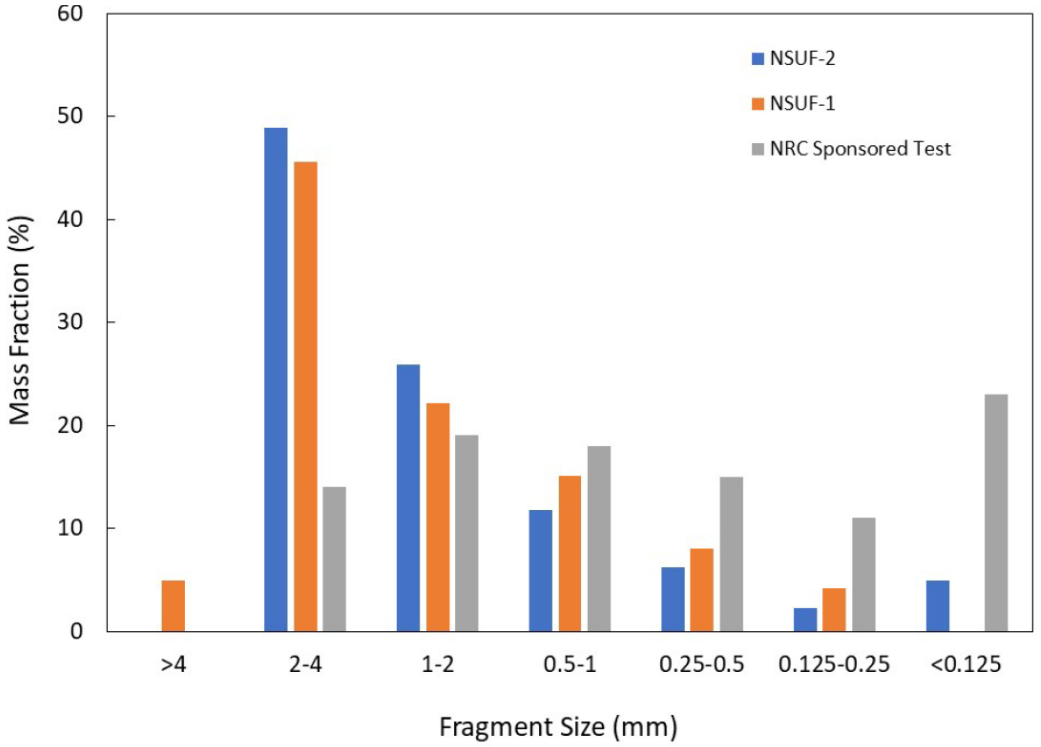
Function of the study

Scott Franz

Function of the study (cont.)

Small particles ejected from high burnup fuel may disperse into the reactor system during a burst event

As can be seen by the figure, a large range of particle sizes can occur for high burnup fuel



Function of the study (cont.)

Particles with the sizes described in the previous slide have the potential to flow and settle in several places in the reactor

Application of GOTHIC

Scott Franz

Application of GOTHIC (cont.)

GOTHIC is a full 3D Thermal Hydraulic solver

- Liquid, vapor, and droplet fields are modeled with energy, mass, and momentum solutions in full 3D treatments (nine equation code)
- Multiple droplet fields can be accounted for independently in a single model where agglomeration and breakup are also modeled
- GOTHIC includes models based on aerosol mechanics for drop deposition, entrainment, agglomeration, breakup and for the heat, mass and momentum exchange with the vapor phase
- GOTHIC has its roots from the COBRA family of codes and has been expanded to include containment assessments. As a result, GOTHIC has the capability to analyze problems across several scales

Application of GOTHIC

GOTHIC includes abilities to model solid particles

For particles in the continuous liquid field, GOTHIC models the convective transport, settling, bed load (motion of the settled material), resuspension of settled particles, and diffusion of suspended particles

GOTHIC accounts for

- Drag, buoyancy, and particle stored energy
- Particle surface heating or cooling based on the fluid the particles are in contact with

Coefficients are available to model different particle shapes which can impact drag

Multiple particle groups can be simulated and tracked separately in a single model

GOTHIC models particles in the continuous liquid and droplet fields

Qualification of GOTHIC

Jeff Lane

GOTHIC treatment for particle transport

GOTHIC models solid particles in the continuous liquid and droplet fields

The particles occupy volume in the carrier field. In the continuous liquid the suspended and settled volume fractions are separately tracked

The momentum of the particles is included in the continuous liquid and droplet field momentum balances. Except for settling in the continuous liquid field, the particles move at the same velocity as the carrier field

The density and specific heat of the particles are assumed constant (independent of temperature and time)

The presence of the particles does not affect the viscosity, thermal conductivity or surface tension of the carrier field

GOTHIC treatment for particle transport

The particles do not dissolve or precipitate out

The particles are non-interacting and non-cohesive

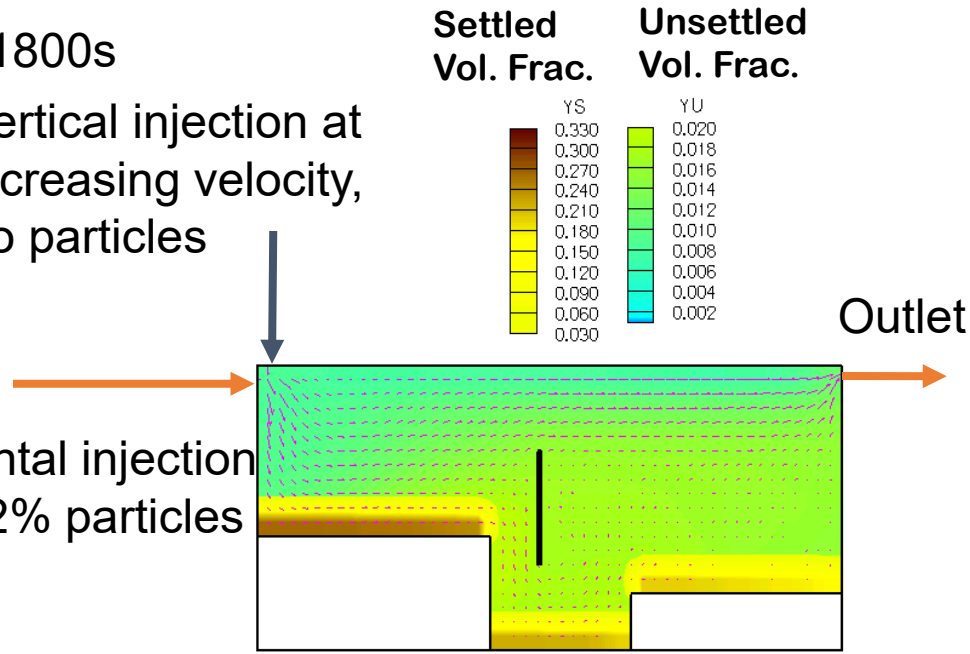
Settling is due to buoyancy forces only

Particles in a droplet field are assumed to be encased by liquid. The particles are not exposed to the vapor space until the droplet field has almost fully dried out

Particles are transferred between the continuous liquid and droplet fields as part of the entrainment, deposition and agglomeration processes

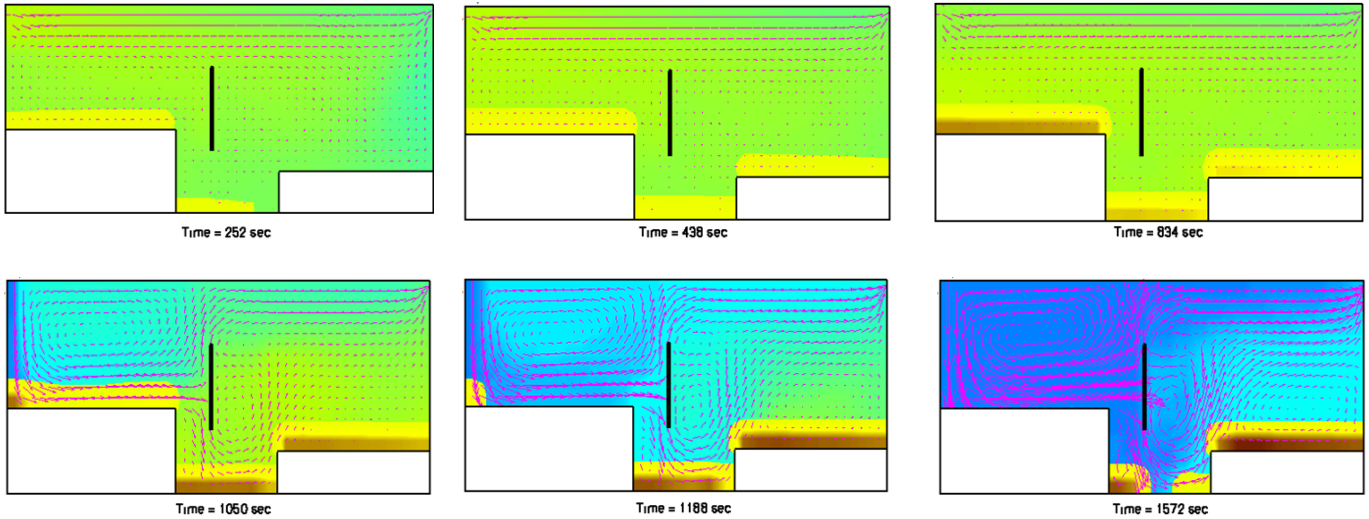
Example

- 800-1800s
  - Vertical injection at increasing velocity, no particles
- 0-1000s
  - Horizontal injection 2 ft/s, 2% particles



Example

Snapshots in time



GOTHIC Qualification

Validation of particle transport is partially reliant on the droplet transport tests that have been performed for GOTHIC

Verification of individual phenomena (e.g., settling, deposition, entrainment, etc.) by comparison to analytic solutions and separate effects tests

Applicable benchmarks to integrated effects tests include

- IRSN CARAIDAS SARNET-2
- Water Aerosol Leakage Experiments (WALE)
- Carolina-Virginia Tube Reactor (CVTR) Tests with Sprays
- Nuclear Power Engineering Corporation (NUPEC) Tests with Sprays
- Battelle-Frankfurt Model Containment (BFMC) Tests
- Marviken Full Scale Containment Tests
- HDR Full Scale Containment Tests

GOTHIC Qualification (cont.)

Zachry has performed several verification assessments of the particle modeling capabilities as part of the software development and implementation process. These assessments are not explicitly included in the GOTHIC qualification report but are documented as part of the software QA program.

The verification covers both the continuous and drop field qualifications

For the continuous liquid field this includes convective transport, diffusion, buoyancy/settling, thermal response, bed load and resuspension

For the drop fields this includes convective transport, entrainment, deposition, thermal response, particle dryout and carrying velocity

GOTHIC Qualification (cont.)

This is an example of one verification assessment that has been performed. It shows the required fluid velocity to suspend particles of various sizes in different environments is captured by GOTHIC.

Applicability

Planned Models

Scott Franz

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Planned Models

Planned Models (cont.)

Summary

Framatome will be using GOTHIC to investigate general fuel particle transport and settling during a LOCA event

Next Steps

Morris Byram

Next Steps

Future status meetings	TBD
Increased burnup topical report submittal	[ ]

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