Presentation Poster: Boron Tracking and Precipitation Model in CTF

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Kim et al.’s solubility correlation is derived in a temperature range (including the effects of buffer agents (tri-sodium phosphate (TPT)), which generate particulate oxide corrosion products and increase the risk of precipitation by chemical reactions with other dissolved materials.

Flow Field Calculation
Calculation of Boron Flux Rate at All Junctions
Calculation of Boron Mass and Cont. in Each Node
Model Implementation Algorithm
Stability and Robustness
High Accuracy and Low Numerical Diffusion
Boron Precipitation Model

Model Assumptions:
- Sufficiently dilute solute
- Negligible liquid property change by the presence of the solute
- No energy transfer by the solute
- Negligible inertia of the solute

ADDITIONAL FIELD EQUATION FOR THE SOLUTE CONSERVATION IS INCLUDED

Boron Tracking Model

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VERIFICATION: ANALYTICAL TEST — MODIFIED GODUNOV VS. UPWIND SCHEME –

In order to measure how well the numerical schemes can predict the exact solution of an analytical equation, the pulse function is used.

The transient was started at the 30°C single-phase 1000 gpm borated water entering at a speed of 5 m/s, was inserted from the bottom section of 20 m unheated vertical pipe with 50 mm hydraulic diameter. The outlet pressure is set as 1 atm. The pulse function was applied at 10 s with a pulse width is also very short with at full width, half maximum of approximately 0.025 seconds. It is found that the power spike was more intense with a peak power factor of 859.014 at time 1.31 seconds. The pulse width is also very short with at full width, half maximum of approximately 0.025 seconds. Larger spike is due to the condensate slug being able to enter further into the core before significant Doppler feedback was able to bring the power level back down again.

The start of a reactor coolant pump would drive the mass of borated water through the cold leg and reactor vessel and into the core at a much higher velocity. The resulting insertion of positive reactivity would be much more rapid and the power level of the core would be able to increase further before prompt feedback reduces the power level again.

Besides reducing the numerical error in each time step, the modified Godunov model gives new information about the physical effect of the turbulence in flow field. Thus, the modified Godunov scheme provides more realistic results compared to the first and the second order accurate models. It is shown the boron concentration evolution for different pulse sizes for both schemes, as well as, a sensitivity analysis over the mesh size and timestep size.

Boron Tracking and Precipitation Model in CTF
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VERIFICATION: BORON DILUTION TRANSIENT SCENARIO
GSI 185 Accident: Control of Recriticality following Small-Break LOCAs in PWRs

Assumptions and Scenario Formulation
In the final phase of this study, the verified CTF code is employed in the simulation of a series of boron dilution transients using the Purdue MOX core model. Heterogeneous boron dilution transient scenarios are simulated in order to fully exercise and demonstrate the boron tracking capability of CTF.

The condensate slug entrance radial location is first varied assuming that a SBLOCA occurred while the reactor was at full power operation. The most limiting radial entrance location is determined from these results and most sensitive case is considered when actuation of a main reactor coolant pump drives a single condensate slug into the core at the most limiting entrance location at a high velocity.

The current scenario is largely based on an accident sequence postulated in NRC Generic Safety Issue – 815, “Control of Recriticality Following Small-Break LOCAs in PWRs.” While the reactor is at full power operation, the primary loop boron concentration is approximately 1680 ppm to control rods withdrawn.

In order to build a post-SBLOCA boron dilution transient simulation scenario, a number of assumptions and simplifications must be made.

To determine the most limiting entrance location of the condensate slug, eight cases are simulated in which the entrance locations are varied from the core periphery to the core center region. Based on the assumed path of the condensate travel depicted, the condensate slugs are centered on the fuel assemblies.

The condensate slug is assumed to have a circular cross section of the same inner diameter as the cold leg pipe. The resultant boron concentration is discretized in the same manner as the CTF sub-channel discretization using an area-weighted boron distribution to calculate the regional boron concentrations.

A more severe boron dilution transient would occur if forced circulation were started by actuation of a RCP.

The excess is precipitated and the precipitated density is maximum.

Model

Results and Analysis
The start of a reactor coolant pump would drive the mass of borated water through the cold leg and reactor vessel and into the core at a much higher velocity. The resulting insertion of positive reactivity would be much more rapid and the power level of the core would be able to increase further before prompt feedback reduces the power level again.

It is found that the power spike was more intense with a peak power factor of 859.014 at time 1.31 seconds. The pulse width is also very short with at full width, half maximum of approximately 0.025 seconds. Larger spike is due to the condensate slug being able to enter further into the core before significant Doppler feedback was able to bring the power level back down again.

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As predicted, at the time of peak core power, the condensate slug has entered further into the core than in the natural circulation case which contributed to the more rapid and higher power increase.

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