Evaluation of Long Term Core Cooling Associated with Sump Debris Effects

Chemical Precipitation in the Core

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PWROG
PWR Owners Group

Chemical Effects in the Core

Primary concern is for precipitation of dissolved material in the core:

- Precipitation may occur by the boiling concentration process
- Precipitation may occur due to temperature induced solubility changes

PWROG Investigation of Core Precipitation

Evaluate potential for precipitate formation to affect the performance of the ECCS:

- Evaluate chemical precipitates likely to form in core based on expected core conditions post-LOCA
- Determine precipitate properties required to evaluate plant-specific precipitation and its impact on fuel heat transfer
- Develop a methodology for plant specific prediction of precipitation in the core

Preliminary Analysis of Boiling Concentration Process

- Boiling concentration process:
  - In cold leg break scenarios, coolant inflow is nearly equal to the core steaming rate
  - Concentration of the chemical constituents may occur due to boiling
- Of most concern early in accident (highest steaming) when build up of dissolved ions is low

Preliminary Analysis of Boiling Concentration Process

- Plants with high dissolved ion concentrations will be most susceptible
  - Plants with high calcium dissolution entering the core as opposed to precipitating in the sump
- Cal Sil and other fibrous insulation contribute to calcium dissolution
  - Cal Sil dissolves at lower temperatures, so greater amount when have less steaming
  - Other insulations contribute less calcium but are more susceptible to dissolution at early high temperatures

The Temperature Driven Precipitation Process

- Applies to chemical species that become less soluble at higher temperatures
- Chemical species with the highest differential solubility will be deposited on the core most rapidly
- Solubilities of debris components at different temperatures have been predicted using thermodynamics

Temperature Driven Precipitation Process

- Preliminary Results

- Low risk for temperature driven precipitation on core
  - Plants with calcium precipitation occurring in the sump
  - Plants with low calcium dissolution
- Expected types of precipitation for these plants present low risk
  - For TSP plants, calcium phosphates form in sump and are insoluble at all temperatures
  - Aluminum compounds have low solubilities at typical sump conditions and increasing solubility with temperature

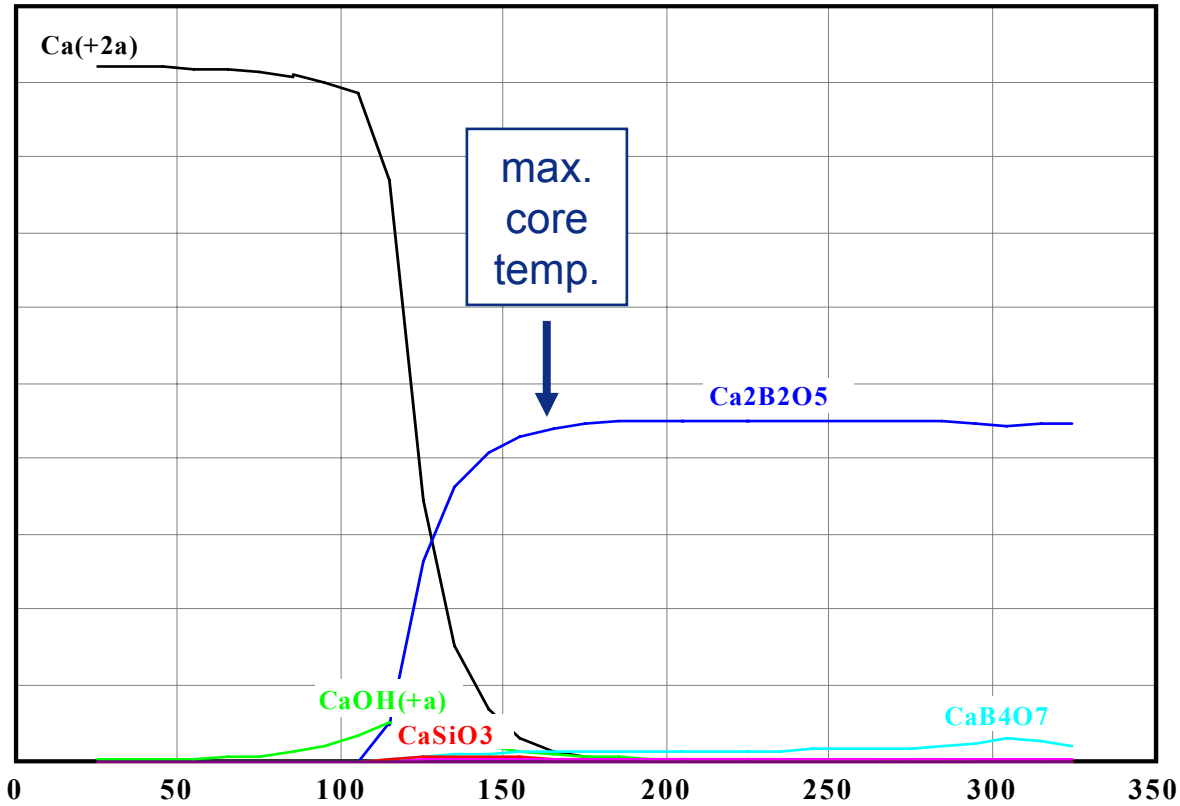
Temperature Driven Precipitation Process

- Preliminary Results

- Potential for temperature driven precipitation on core
  - Plants with significant amounts of calcium-containing insulation
  - Potential for calcium precipitation on the core due to retrograde solubility of calcium compounds

Temperature Driven Precipitation Process

- Calcium Borate Predicted to Form at 160ºC and pH 9.4



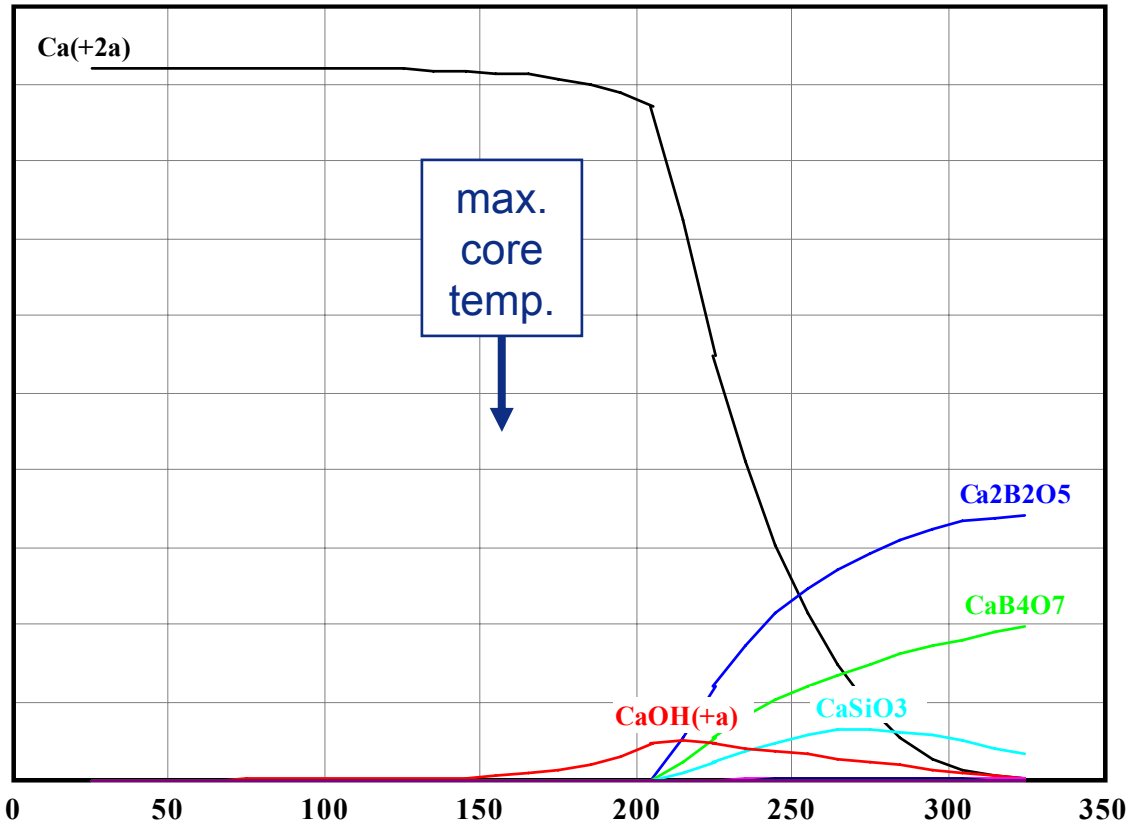
High calcium silicate loading with no boiling concentration in core

Temperature Driven Calcium Precipitation
-Competing effects

- Competing effect of pH on expected calcium precipitation
  - Calcium silicates and borates become more soluble in core at lower pH values
  - Greater dissolution of Cal Sil predicted in sump solution at lower pH values

Temperature Driven Calcium Precipitation

-None predicted at pH 7 and fuel temperature of 160ºC



High calcium silicate loading with no boiling concentration

Temperature Driven Calcium Precipitation

-Competing effects

- Presence of dissolved aluminum may impact calcium precipitation
  - When dissolved Al is present, reactions occur to form calcium aluminum silicates in the sump
  - These reactions will compete with deposition of calcium borates on the core
- More detailed modeling will be required to determine deposit quantities and their pH dependence

Temperature Driven Calcium Precipitation -Results

- Calcium borate predicted to form at pH of 9.4 and core temperature at time of recirculation
- No calcium precipitation predicted in case with pH of 7.0 and recirculation core temperature
- Conclusions: Dissolved calcium is concern for in-core precipitation
- Plant specific evaluation required to evaluate impact of Ca precipitation on core cooling
  - Plant specific calcium concentration vs. time (based on conditions in sump)
  - Temperature and pH in core vs. time

Summary

- There is a potential for precipitation of dissolved insulation components on the fuel after a LOCA
- The most risk of core precipitation is expected to be in plants with high levels of dissolved calcium entering the core at elevated temperatures and pH
- Aluminum deposition on core by precipitation will be limited by the low solubility of Al compounds and "normal" solubility behavior
  - Aluminum precipitates become more soluble at core temperatures

Path Forward

- Build a model that includes simulation of the boiling concentration process in the core
- Include debris dissolution rates in the model
- Predict precipitation expected to occur in the core based on plant specific conditions
- Use quantitative core deposit estimates from model to evaluate the impact of precipitation on fuel heat transfer