

Heat Up Evaluation after Severe Spent Fuel Storage Accidents

Application of Computational Fluid Dynamics
(CFD)

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NRR's Issue

- How long does it take, post shutdown, for the fuel to cool sufficiently such that air cooling is sufficient to prevent accident progression?
 - 1 - 2 year time frame was expected
 - based on earlier plant specific studies using questionable assumptions
 - complete loss of pool water is assumed

Background

- buoyancy driven air flow is the primary means of removing heat from the fuel after a complete loss of liquid in the pool
 - at high temperatures, chemical reaction and radiation effects become important
- “largest source of uncertainty is in the natural convection flow rate”
 - (NUREG/CR-4982 pg. 57)

Background (continued)

- common codes used
 - COBRA SFS (PNNL)
 - SHARP Code (BNL)
 - SFUEL
- characteristics
 - 1 D flow components, simplified boundaries
 - some handle radiation and wall conduction
 - linkage to containment is greatly simplified

Approach

- define “near bounding” generic BWR case
- apply CFD to predict maximum steady-state fuel temperature for several post shutdown times (2 years, 4 years, etc.)
- check flow assumptions of other codes using 2D and 3D CFD results

Why Apply CFD?

- convective flows are primary means of transporting heat from fuel during accident
 - these flows may be complex
- CFD can couple building, ventilation, and fuel rack flows in one calculation
- validation of assumptions used for upper and lower boundaries of other codes
 - constant P,T
- in-house validation of COBRA and SFUEL results

CFD Limitations

- problem is too large to model geometry in detail. (1 million cells is a practical limit)
- radiation and chemistry models not applied
 - limits valid solutions to low T
- porous media assumptions used to model fuel racks and fuel
- only steady-state solutions will be practical

Preliminary Findings

- CFD not well suited to conditions specified by problem (buoyancy + porous resistance)
 - note lack of other CFD solutions in this area
- constant P and T assumptions above racks in simplified codes needs to be assessed
- pressure drop governed by viscous losses
- initial assumptions of SHARP code are not conservative
 - constant T, P, T_{inf} or T_{out} at lower plenum

Preliminary Findings (continued)

- Earlier predictions of time (1-2 years) are not going to hold up generically. (3-6 years expected)

– Why?

– previous work

low burnup

partially filled pool

standard racking

plant specific assumptions

- present work

higher burnups

completely filled pool

high density racking

Summary

- Quantitative heat up predictions from CFD have been unsatisfactory. (uncertainty in T_{max} is high)
 - stability issues
 - convergence issues
 - modeling simplifications
- Qualitative lessons learned can be applied to address modeling assumptions of simplified codes.