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, Tinf or Tout 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?

– <u>previous work</u>	<u>- present work</u>
low burnup	higher burnups
partially filled pool	completely filled pool
standard racking	high density racking
plant specific assumptions	

Summary

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