SC/16

Workshop on Risk Related to Spent Fuel Pool Accidents at Decommissioning Plants

Thermal Hydraulic Discussion Session

UNITED STATES NUCLEAR REGULATORY COMMISSION

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Discussion Session on Thermal-Hydraulics

- Discussion Focus
  - Deterministic calculation
  - Foundation for risk informing the process
- Goals
  - Understand current analysis
  - Identify important parameters
  - Explore other options
- Communicate Clearly
  - Dialogue = Shared Meaning
  - Reach Alignment
  - Establish a Sound Technical Basis for Decision-Making

Thermal Hydraulic Analysis Scenario

- Analyzes temperature of spent fuel when exposed and cooled by only air.
- Calculates "Critical Decay Time" - minimum length of time elapsed since reactor shutdown for the most recently discharged fuel such that decay heat is not sufficient to heat fuel to a limiting temperature below zirconium-air runaway oxidation.
- Once water is lost below the level that it can adequately cool the spent fuel, the fuel will begin to increase in temperature.

Thermal Hydraulic Analysis Scenario

- Early in the sequence, the increase in temperature is due to the decay heat of the spent fuel.

- Oxidation reaction of air and zirconium is exothermic (produces energy). As the temperature increases, the temperature increase becomes more rapid (runs aways) and is dominated by the heat from the oxidation reaction.

- The higher temperatures can be sufficient to release fission products from the fuel. A fire could provide an energy source sufficient to transport the fission products offsite.

Existing Thermal Hydraulic Analyses

- The TWG review existing studies for applicability to decommissioned plants.

- In 1980's, in support of Generic Safety Issue (GSI) 82, National Laboratories (NLs) studied the probability, phenomena, and consequences of self-sustained zirconium oxidation (zirconium fire) in air for operating reactors.

- In 1997, Brookhaven National Laboratory issued a study of generic decommissioning plants including the potential for zirconium fire.

Existing Thermal Hydraulic Analyses

- TWG concluded that the critical decay times calculated in existing studies were not accurate to support regulatory decisions or provided sufficient detail for license amendments.

- GSI 82 studies used SFUEL and SFUEL 1W computer codes

  - lower burnups than used today
  - less dense storage racking than used today
  - codes could not model actual fuel configurations

Existing Thermal Hydraulic Analyses

- 1997 BNL study used the SHARP computer code
  - lower burnup for BWR than used today
  - code unconservatively neglected flow losses through grid spacer in assemblies
  - code unstable for some input
  - code not verified or validated
  - code could not model actual fuel configurations

Existing Thermal Hydraulic Analyses

- Staff believes that the actual critical decay times for current practices are longer than existing generic calculations
  - Longest existing calculated critical decay time is 700 days

- General conclusion from reports are valid
  - The conditions which could lead to oxidation of the clad are highly dependent on storage configuration and decay power

- For a generic solution, calculations for today's operating and storage practices are needed

Generic Decay Time Estimates

- Primary References
  - NUREG/CR-0649 Spent Fuel Heatup Following Loss of Water During Storage
  - NUREG/CR-4982 Severe Accidents in Spent Fuel Pools in Support of GSI 82

- TWG assumed a bounding configuration
  - Full Pool
  - High Burnup
  - High Density Racks

- Used previously determined generic criteria
  - 6 KW/MTU Critical Decay Power

Generic Decay Time Estimates

- Factored in phenomena missing from previous analyses based on observations from cfd calculations that can extend the critical decay time
  - 3D Flow and Mixing
  - Grid Spacer Flow Resistance

- All of the above information was considered to provide a rough estimate of 3-5 years critical decay time. More detailed calculations are needed to reduce uncertainty.

Important Parameters and Phenomena in Spent Fuel Pool Heatup Calculations

- Rack geometry
- Fuel loading pattern
- Building ventilation assumptions
- Decay heat load
- Fuel and rack flow resistance
- Convection, radiation, and conduction heat transfer
- Zirconium oxidation in air
- 3D flow Mixing
- Clad Ballooning and severe accident phenomena

Adiabatic Heatup Calculations

- Used to estimate time available to evacuate
- Gives a lower bound on the available time for any accident. No knowledge of geometry or other parameters is needed.
- Available time is underestimated by approximately a factor of 2 for the intact fuel geometry

Dominant Uncertainties in Critical Decay Time Estimate

- Fuel rack geometry
- Fuel loading pattern
- Building ventilation
- Flow resistance and mixing
- Oxidation rate models

Bundle Flow Resistance

- Orifice loss coefficient

  $k=(A^2 - A_o^2)/(A_o^2 C_d^2)$

- Rod bundle friction

  $f \sim 100/Re$

- Grid spacer and support plate loss coefficients

  $k \sim 2.25$

Zirconium-Air Oxidation

- Energy release is 262 kcal/mole-Zr
- Parabolic rate equation reaction rate
- Oxidation energy release is much higher than decay heat during "zirconium fire"

Future Heatup Analyses

- TWG requests suggestions on:

- Alternate or values for parameters in generic heatup analyses:
  - Initial spent fuel pool conditions
  - Items on "Important Parameters and Phenomena in Spent Fuel Pool Heatup Calculations" slide

- Alternative calculation or analysis to adiabatic heatup calculation

- Alternative methods to the present calculations that will demonstrate no offsite consequences or sufficient time for offsite protective measures