Experiment to Determine the Effectiveness of High Expansion Foam to Prevent A Zirconium Fire

Presentation to the NRC Staff

Tanya Eaton, Fire Protection Engineer
DSSA/SPLB
September 30, 1999

5/76

Objectives

- Background Information
- Zirconium Characteristics
- PRA and Deterministic Results
- Project Scope and Task
- Project Phases I and II
- Concerns/ Alternatives

Background

- Spent Fuel Storage in Decommissioning Plants
- Beyond design basis accidents due to licensee exemption requests
  - Staff consideration of SFP risks for reduction of certain requirements
- TWG established in April 1999
- Draft Technical Study issued in June 1999
- Fire protection reviewed existing zirconium literature
  - Reported ignition temperatures of 1100 - 1600° C
  - Recommended further research for high-expansion foam
    - Slow leakage, low water requirement, minimum manning, equipment available onsite or through local municipal fire department
  - Sand, graphite, or inert gas (argon) applied to base of fire
  - Portable monitor nozzle (500 gpm up to 100 ft)

Basic Zirconium Characteristics

- Dust & Scraps are highly pyrophoric (ignite spontaneously in air)
  - Low ignition temperatures and highly explosive
- Massive zirconium is very difficult to ignite in air.
- Massive zirconium can exhibit pyrophoric behavior
  - Heat generation >>> Heat dissipation, in limited space
  - Exothermic reaction in corrosive environment converts metal surface into extremely fine, brittle, reactive powder
  - Oxidizing impurities cause rapid corrosion and pyrophoric film
  - Hydrocholoric Acid, Sulfuric Acid, Nitric Acid (pickling)
- Mitigation
  - Pyrophoric products should not be extinguished with small water quantities, carbon dioxide, or foam.
  - Sand could react with the metal or its oxides, enhancing the fire.
  - Salt or mixtures of organic salt are more suitable.

PRA and Deterministic

No cases reviewed by the FP staff indicated that a fire will occur involving massive zirconium except in high-temperature, corrosive environments.

- PRA: equipment failures, alarms fail, no makeup, lead to spent fuel pool uncovery and zirconium fire.
  - Generic EPRI frequencies - 9.0E-03 /(Rx year)
  - 0.04 (1 month after shutdown)
- Deterministic: Self-sustaining oxidation, ignition, maybe localized melting.
- Low frequency event with high consequences.

Scope and Task of Project

Scenario: Inventory is completely lost due to seismic/heavy load.

- Examine mitigation methods
  - Prevent fuel heatup
  - Suppress a fire should one occur
  - Prevent propagation to surrounding fuel assemblies
- Staff Success Criteria
  - Sufficiency of foam penetration
  - Prevent fuel from reaching its critical temperature
  - Serve as effective fire suppression agent

Phases of Project

- Phase I - Scoping
  - Determine the capability of foam penetration of fuel assembly
    - Temperature range (150 - 200° C)
  - Heated assembly: Heat Transfer Lab @ Columbia University, NY
  - Contractor: NIST willing to oversee project
  - Begin October - Completion early next year
  - Deadline - December 30, 1999 will not be achieved
- Phase II
  - Refer to RESEARCH to examine concerns and perform a more realistic test

Concerns

- NIST
  - Steam will keep re-cycling and condense in the foam, but heat not really removed to the atmosphere to provide effective heat transfer.
  - Steam/heat will eventually escape by channeling through foam.
  - Continuous foam application could delay steam escape.
  - Foam could trap air in a localized area and feed a fire despite foam blanket.
  - Foam would obscure state of fuel assemblies.
  - Environmental concerns for testing foam on sewage treatment plants.

- Others
  - Possibility for hydrogen generation.
  - Water vaporization.
  - No studies to show effect of non-toxic foam on zirconium.
  - Availability of water sources in a seismic event.

Foam Alternatives

- Argon (Inert Gas)
- Reflood
  - Exceed the leakage rate (5,000 gpm)
- Sand
  - Storage
  - No new equipment requirements
- Portable monitor nozzle (500 gpm up to 100 ft)