YUCCA
MOUNTAIN
PROJECT

Studies

Approach to Repository Criticality Analysis

Presented to:
Nuclear Waste Technical Review Board

Presented by:
Hugh A. Benton
Manager, Waste Package
M&O/Framatome Cogema Fuels
Yucca Mountain Site Characterization Project
Las Vegas, Nevada

October 23, 1997

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Outline

- Regulation regarding criticality
- Locations of possible criticalities
- Burnup credit
- Disposal criticality analysis methodology
- Criticality control design options
- Consequences if a criticality event occurred

Criticality Control Regulation

- **10 CFR 60.131 (h) treats postclosure criticality same as preclosure**
- **Safety of workers paramount during preclosure - requires deterministic evaluation**
- **Probabilistic approach is appropriate in evaluating risk of criticality after waste package breach**

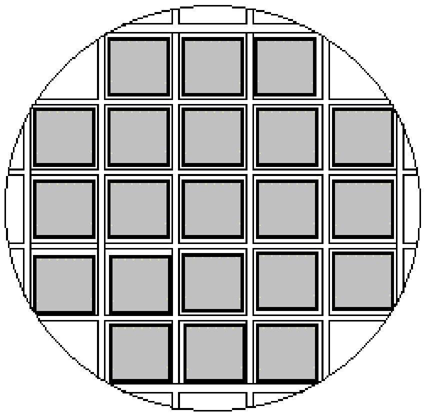
Location of Possible Criticality Events

- In canister (e.g. DOE spent fuel)
  - Intact basket, intact fuel
  - Intact basket, degraded fuel
  - Degraded basket and fuel
- In waste package
  - Degraded basket / canister
  - Fragmented fuel in bottom of container

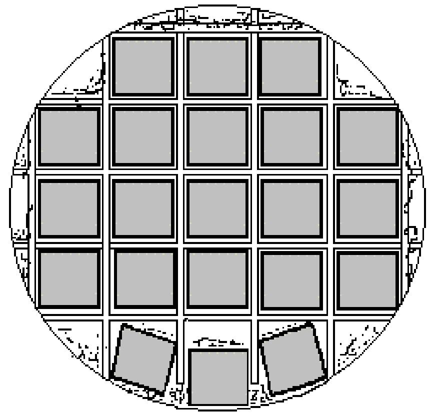
Location of Possible Criticality Events
(continued)

- **In near-field**
  - **Fuel fragments in invert under waste package location**
  - **Fuel degradation products in invert**
- **In far-field**
  - **Fuel degradation products in fractures**
  - **Fuel degradation products precipitated in reducing zones**

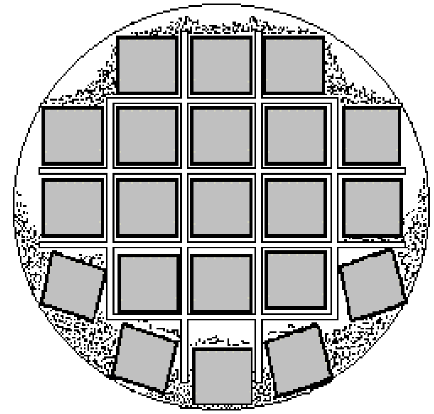
Waste Package Degraded Internal Configurations for Commercial PWR SNF
(Schematic)



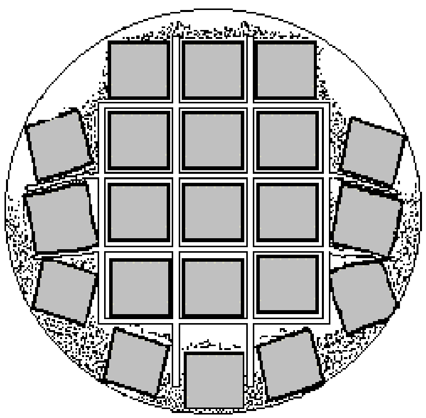
Initial Configuration



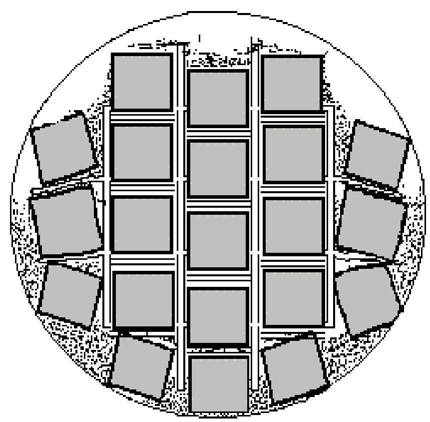
Side Guide Failure



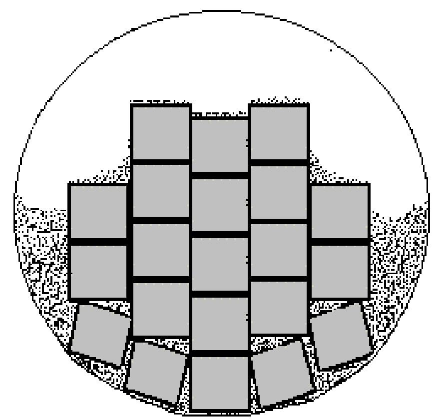
Corner Guide Failure



Long Criticality Control Plates Bend at Ends



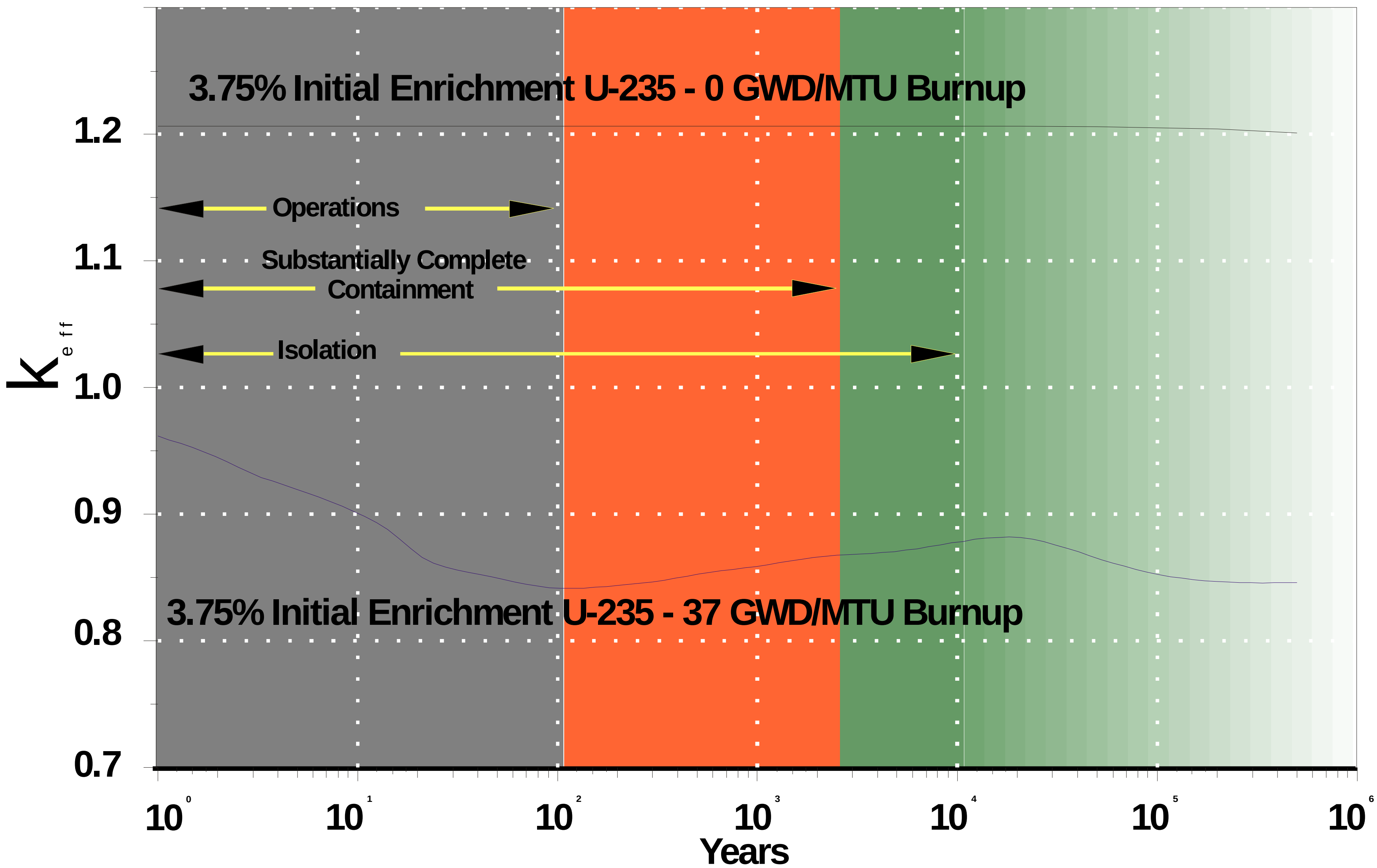
Fully Collapsed Basket with Partial Criticality Control Plate Degradation



Fully Degraded Basket

Time Effects on Criticality Potential

21 PWR Waste Package Design
No Additional Neutron Absorbers Added
Fully Moderated, Constant Basket Geometry



Burnup Credit

- Intrinsic criticality control feature of spent fuel
- Function of time and power level of reactor operation
- Accounts for net depletion of fissionable isotopes
- Includes increase in principal neutron absorbing isotopes
- Basic feature of waste package design
- NRC has not generally sanctioned its use

Neutronics Model Development

- **Validation of models**
- **Establish input parameters**
- **Define range of applicability of the models**

Benchmark Data

- Laboratory Critical Experiments
  - Measured/extrapolated critical conditions made in laboratories
  - Used for criticality safety code validation
- Commercial Reactor Criticalities
  - Measured critical conditions made at commercial reactors
  - Used for reactor design code validation
- Chemical Assays
  - Measurements of isotopic concentrations in samples of spent nuclear fuel
  - Used for depletion code validation

Criticality Control Design Options

- Supplemental neutron absorber material
  - Boron, gadolinium, hafnium, silver-indium-cadmium
  - Plates or rods
  - Account for degradation over time
- Control of geometry
  - Flux traps
- Filler material
  - Moderator displacing material such as steel shot
  - Dilute fissile material with depleted uranium
  - Adds cost and time for loading operations
- Fissile mass limit
  - Limit amount of fissile material per waste package
  - Increases number of packages and repository area
- Other criticality control material

Consequences if a Criticality Event Occurred

- **Initial**
  - **Increase in temperature of water**
  - **Steam expelled from waste package - relative humidity increases**
  - **Slight decrease in fission products and decrease in fissionable material**
- **Subsequent**
  - **Reduction in water around fuel stops criticality event**
  - **At least several years to collect enough water to reach criticality again**
- **Event not noticeable outside repository**

Degraded Mode Criticality Analysis - Worst Case Scenarios

- **Internal to waste package**
  - 85% of PWR fuel cannot support criticality
  - 2-4 assemblies must be immersed in water
  - Criticality only possible if neutron absorber separated from fuel
  - Iron oxide functions as neutron absorber
- **External to waste package**
  - Geochemical interactions very unlikely to accumulate critical mass
- **No known mechanism for ponding of water in drift insufficient quantity to cause criticality**

Summary

- Criticality analysis methodology documented in topical report in 1998
- Methodology dependent on credit for burnup and probabilistic approach
- Designs will prevent criticalities before waste package breach
- Probability of criticality after breach very low
- Consequences of criticality small and localized