Savannah River NUCLEAR SOLUTIONS℠

FLUOR DANIEL • NORTHROP GRUMMAN • HONEYWELL

Adding Realism to Spent Nuclear Fuel Dissolving Analysis

Brittany Williamson

Criticality Safety Engineer
Savannah River Nuclear Solutions, LLC
November 9, 2010

ANS Winter Meeting

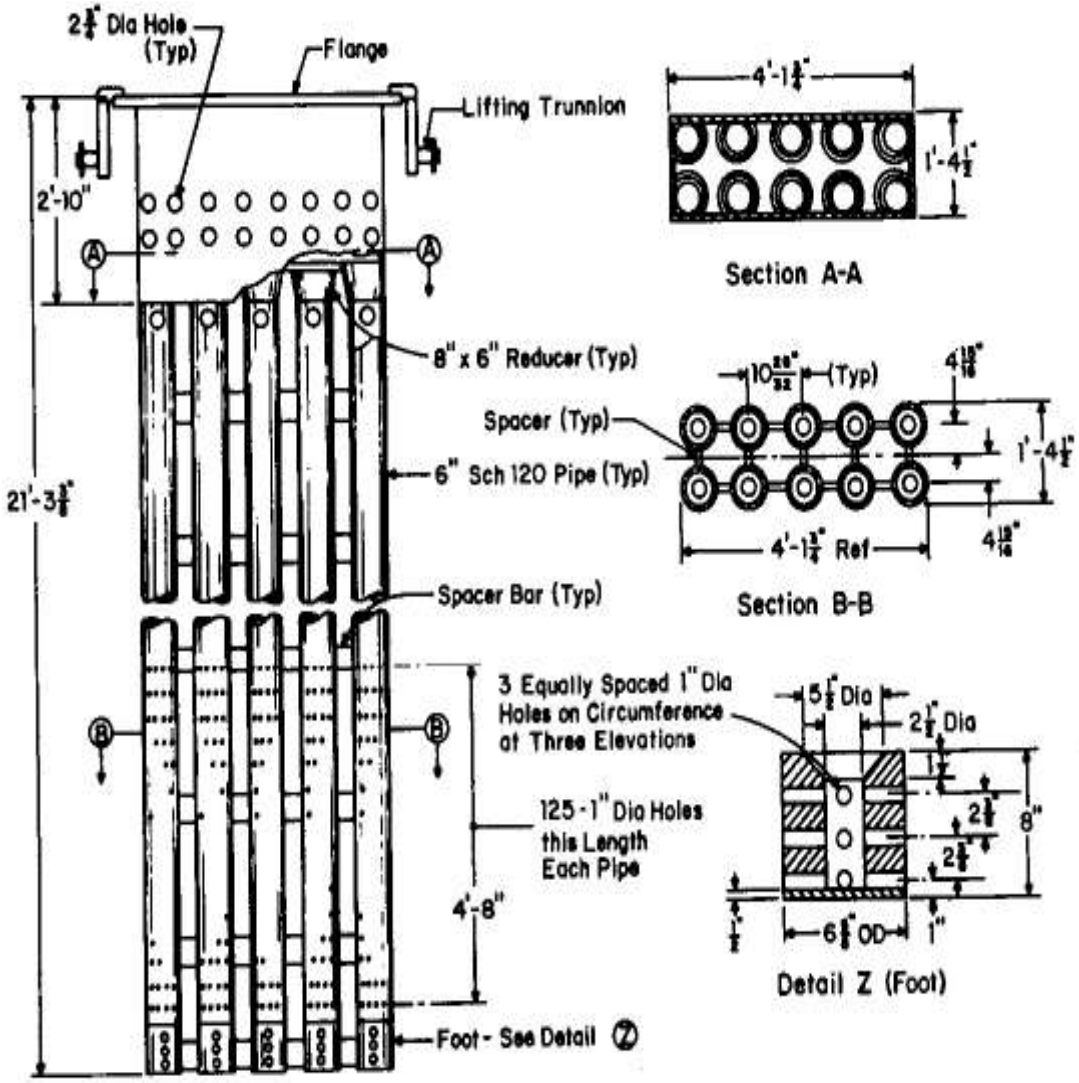
Las Vegas

Introduction

- **H-Canyon**
  - Nation's only remaining full-scale nuclear chemical separations plant
  - Remote operations
  - Recovers U-235 to be used in TVA reactors
- **Used Fuel Project**
  - 10-year campaign to disposition used domestic and foreign Material Test Reactor (MTR) fuel currently stored in L-Area

Dissolving

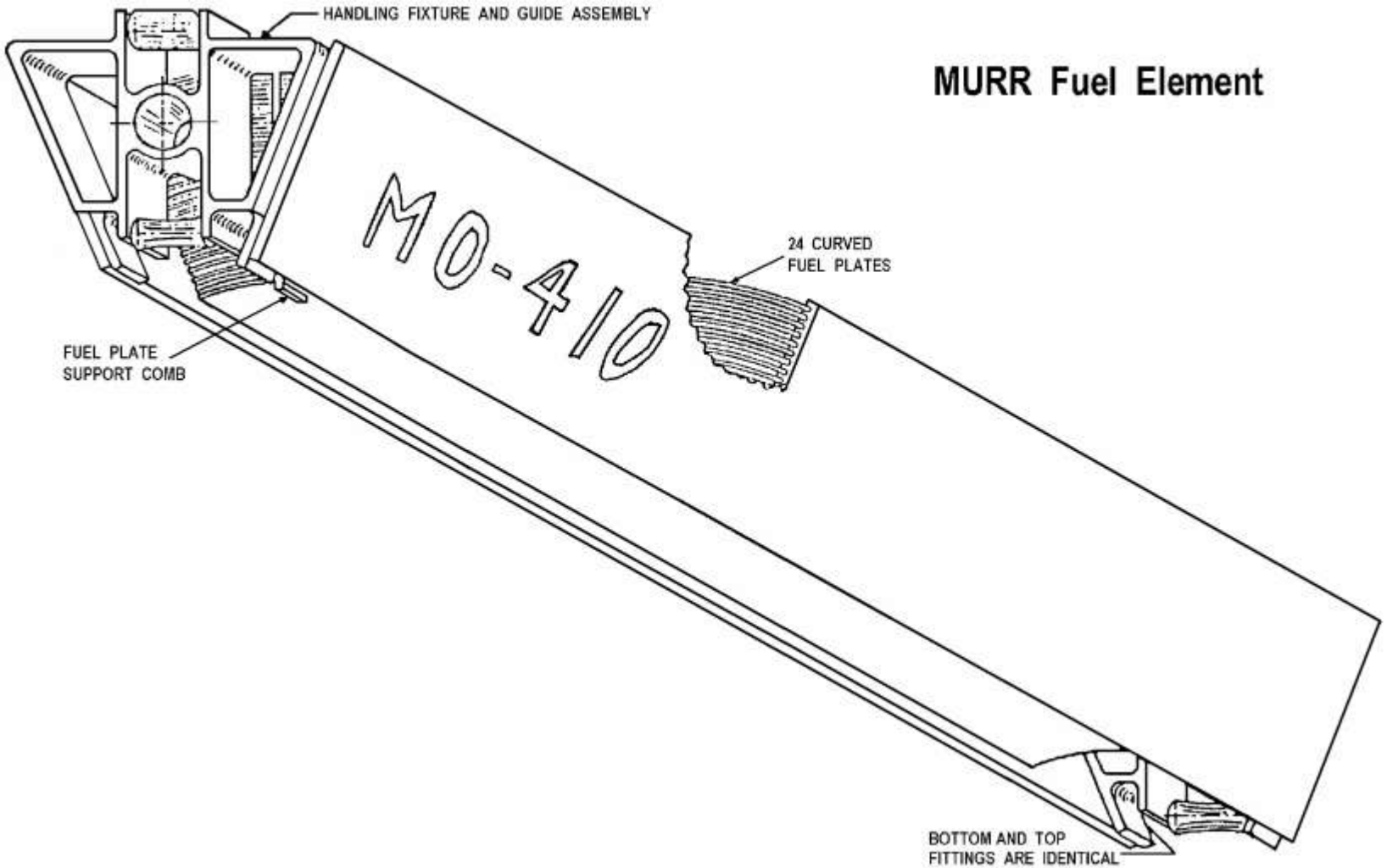
- Nitric acid bath
- 12’D x 8’H tank
- 10-well insert
- Max. 40 kg U-235
- Min. 10,000 L



Used Fuel

- Aluminum clad research reactor fuel
- HEU (93.5% U-235)
- Fuel plates (flat or curved)
- Typical assembly
  - 2’ long fuel region
- Packaged in “L-Bundle”
  - 11’ long
  - 5” diameter
  - 4-5 assemblies per bundle
- University of Missouri Research Reactor (MURR) is the bounding assembly (highest U-235 loading)

MURR


HANDLING FIXTURE AND GUIDE ASSEMBLY
MURR Fuel Element
MO-410
24 CURVED
FUEL PLATES
FUEL PLATE
SUPPORT COMB
BOTTOM AND TOP
FITTINGS ARE IDENTICAL

Historical Approach to Criticality Safety

- **Assumptions**
  - Instantaneously at most reactive condition
    - Up to 450 g/L U-235
  - No material ever leaves the well
  - Material is simultaneously in the wells and bulk solution
- **Recent Improvements**
  - Analytically limit concentration in the wells to 150 g/L U-235
    - Fluid currents in the dissolver
    - Density gradients/mixing

Do the Math

- 5’ of solution (25 L)
- 3.75 kg U-235/bundle
- 150 g/L U-235
- Reality: 8’-10’ of HEU/Al to dissolve
- Reality: 75 g/L U-235

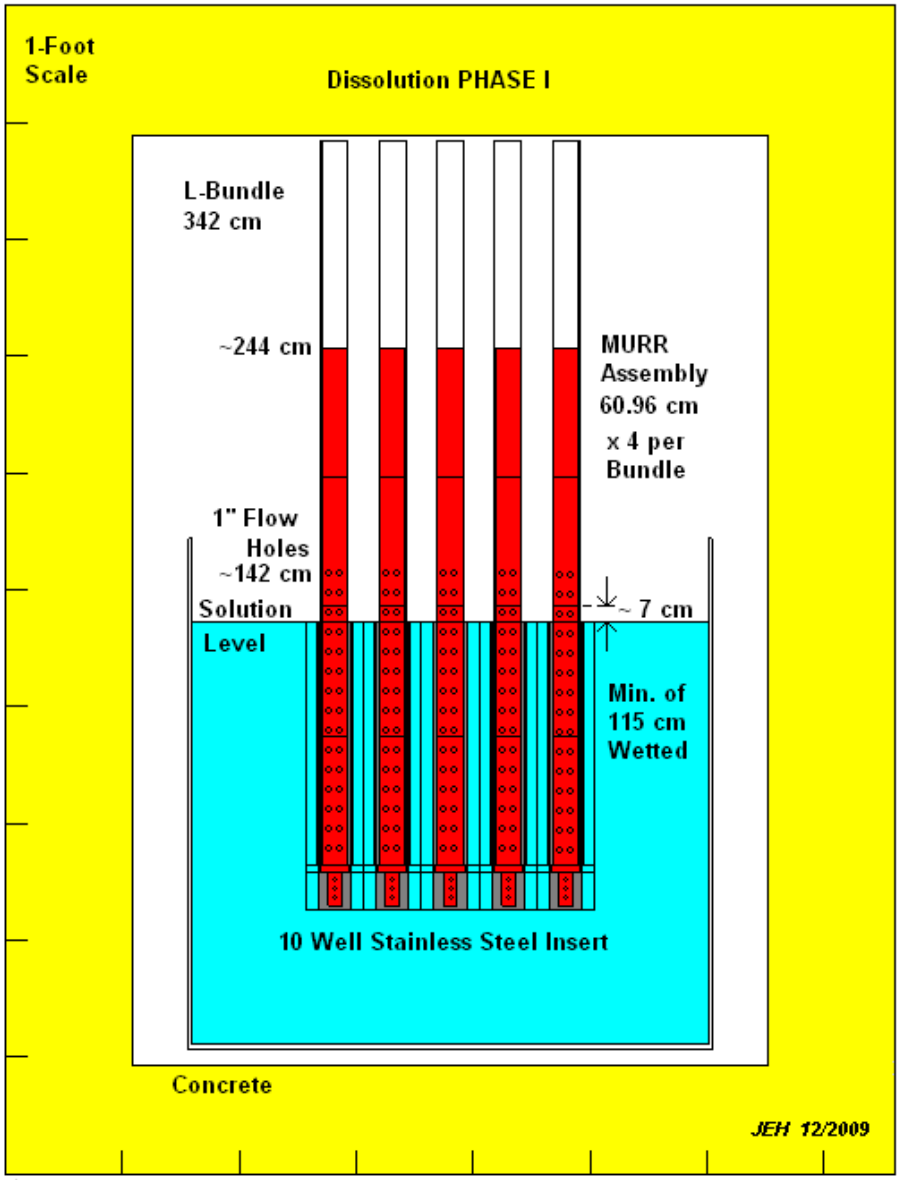
Ask the Question

- Is this the best way?
- SRNS Nuclear Criticality Safety Manual
- "Assumptions used in modeling shall obey the laws of chemistry and physics and be consistent with the actual system configuration, the form and distribution of the fissionable material, and be credible. They should not be taken to the extreme simply to maximize the calculated k_{eff} or to create an upper bound model that is totally unrealistic."

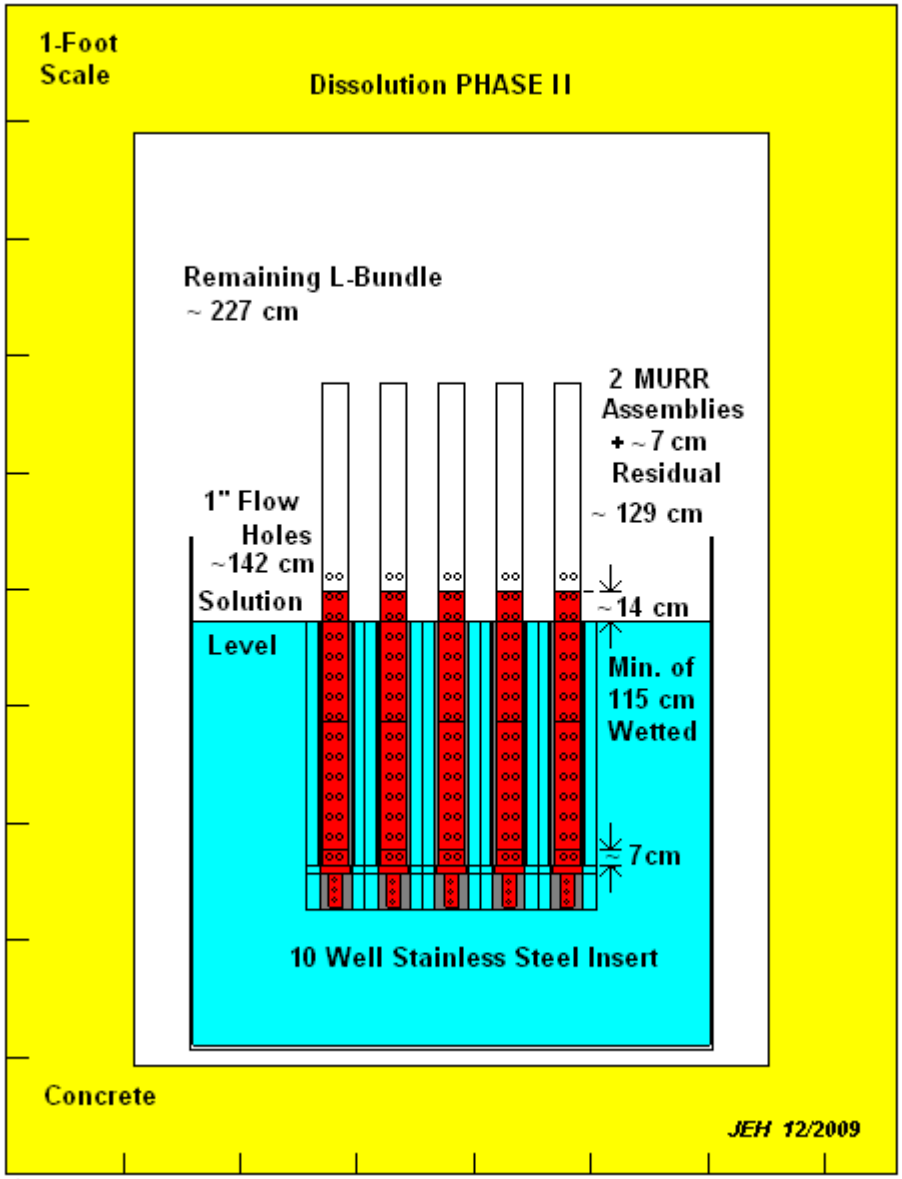
Linear Density Method

- Takes credit for the linear, physical distribution of the fissile mass throughout the entire length of the fuel assembly
- 60 cm-long assembly, 800 g U-235 → 13.3 g/cm (406.4 g/ft)

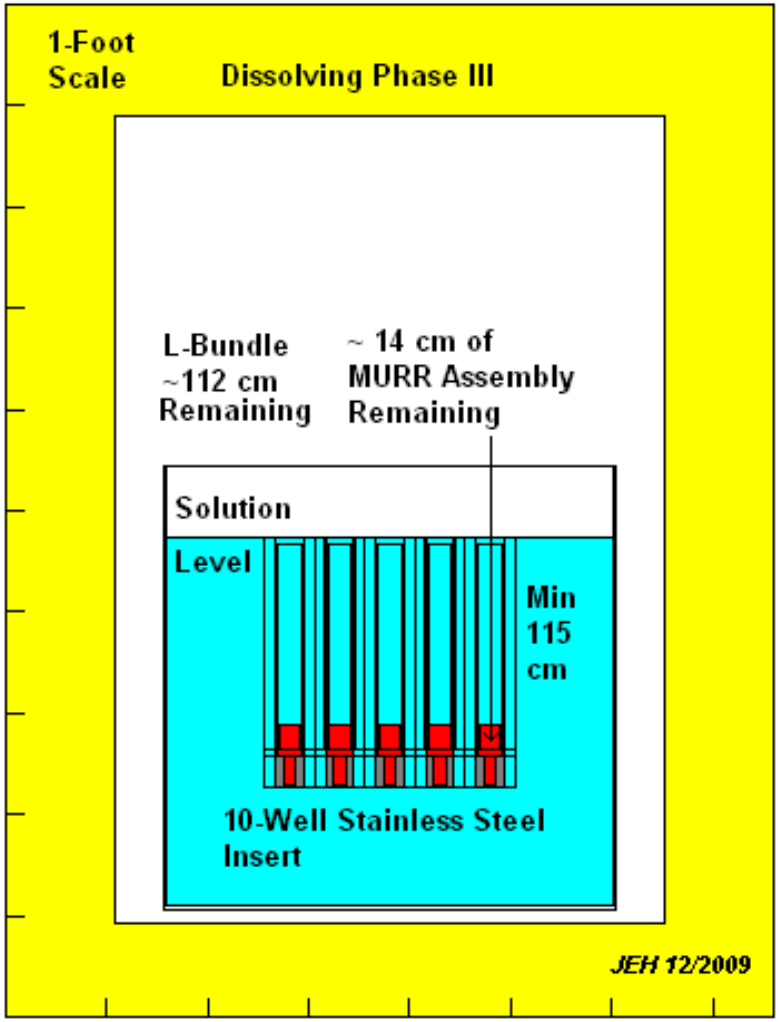
Phases of Dissolution



Phases of Dissolution

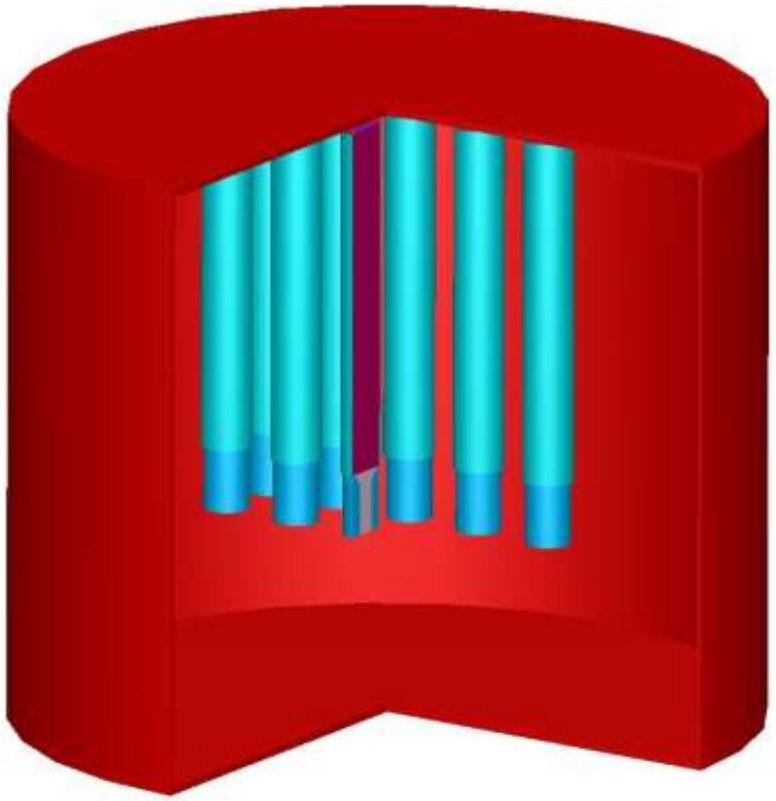


Phases of Dissolution



Analysis

- Performed a search for the highest safe linear density
- SCALE/KENO-VI
- $k_{safe} = 0.96$



Results

- **432 g/ft U-235**
- **Criticality Safety Limit (CSL)**
  - 3.4 kg per well in all 10 wells
- **Historical Method CSL:**
  - 1.0 kg per well in all 10 wells
  - 4.0 kg per well in 6 wells
- **Gain**
  - 340% increase in CSL
  - 66% increase in efficiency (when just considering MURR)

Show Me the Money

- **10 years to process all the used fuel in L-Area**
- **Only 15% of the used fuel in L-Area benefits from an increase in the CSL.**
  - 1.5 years of processing time
- **Currently, only 9 bundles will be shipped to H-Canyon at a time (only 9 wells will be charged, not 10)**
  - Historical approach allowed 6 wells at a time
- **Instead of taking 1.5 years to process the 15%, it will only take 1 year → 6 months of saved time**
- **6 months of H-Canyon time = $100 million**

Is it worth it?

- **Criticality safety shall not be compromised for the sake of expediency, production, or economic pressure.**
- **Conservatisms still present:**
  - Material is instantaneously dissolved
  - All material exists in two places at once
  - No burn-up credit
  - Still meets Double Contingency
  - Enrichment
  - Corrosion
- **Yes, it is worth it!**

Thanks

- Jason Huffer, Co-Author
- SRNS Management

Questions?