Imparting Realism to the Criticality Evaluation of a BWR Fuel Assembly Package

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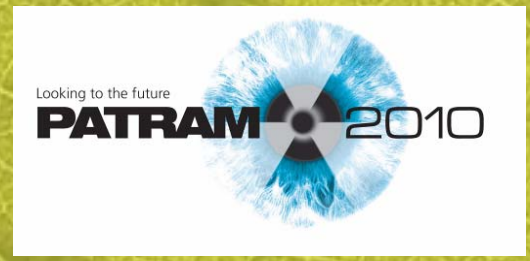
London, UK



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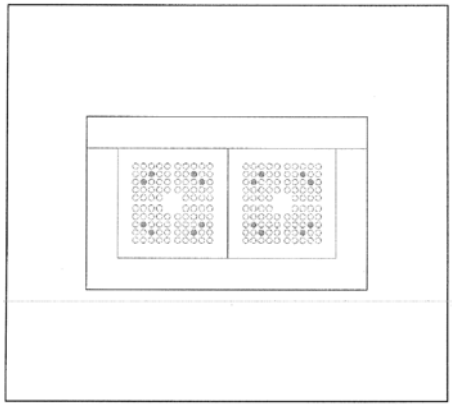
Summary view of nuclear criticality safety



NUCLEAR CRITICALITY SAFETY

IDENTIFICATION OF POTENTIAL CRITICALITY

RISK KNOWN AND ACCEPTABLE

CRITICALITY PARAMETERS

NUCLEAR ANALYSIS

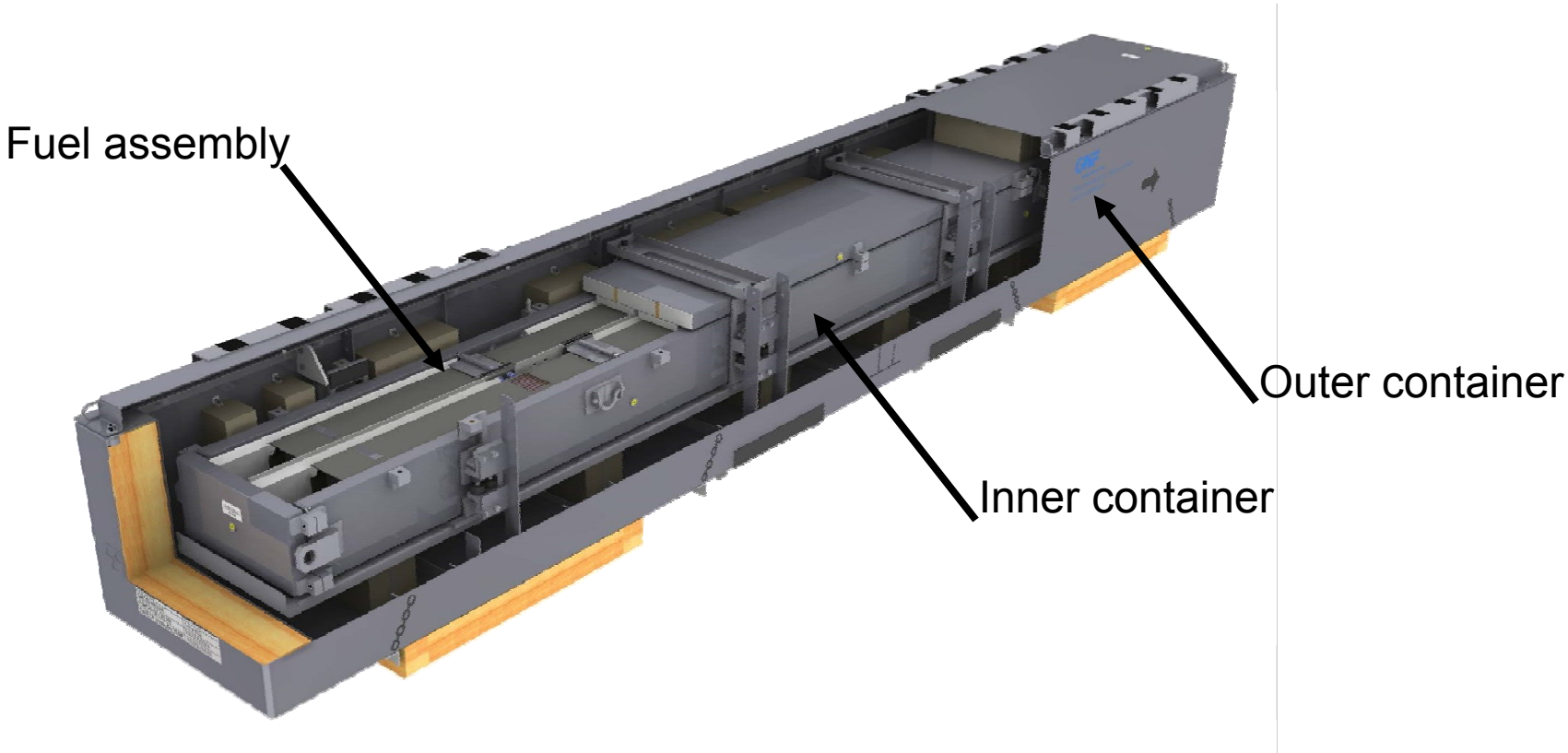
Source: L.B. Shapport, et. Al., The Radioactive Materials Packaging Handbook, Chapter 10. Criticality Safety, Figure 10.1 Summary view of nuclear criticality safety

Identification of Potential Criticality

1. *Realistic* criticality parameters for packaging and contents

2. *Credible* nuclear analysis for individual package and package arrays

BWR Fuel Assembly Package

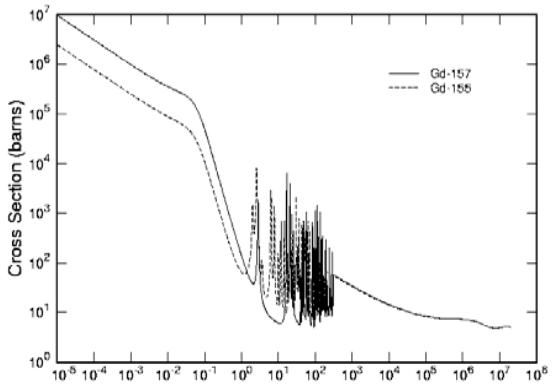


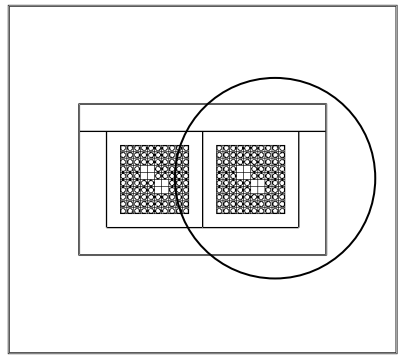
1. Realistic Criticality Parameters

a. Neutron absorption

b. Geometry – *confinement boundary*

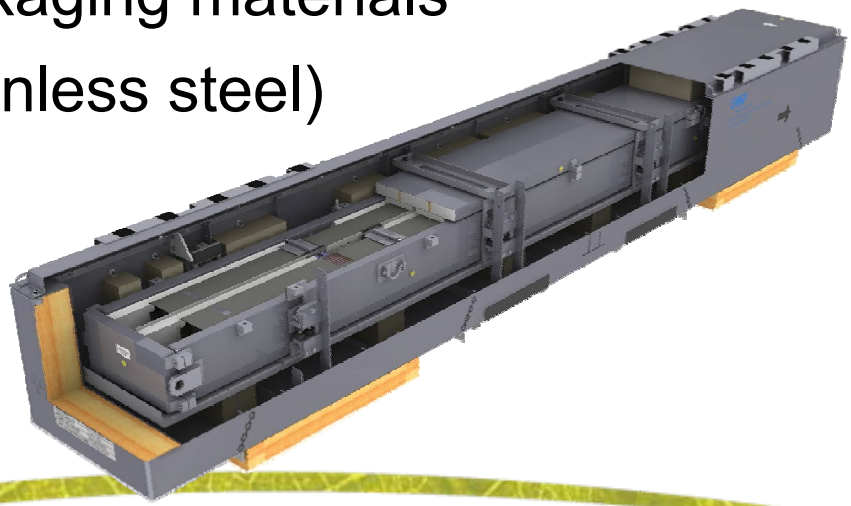
c. Moderation

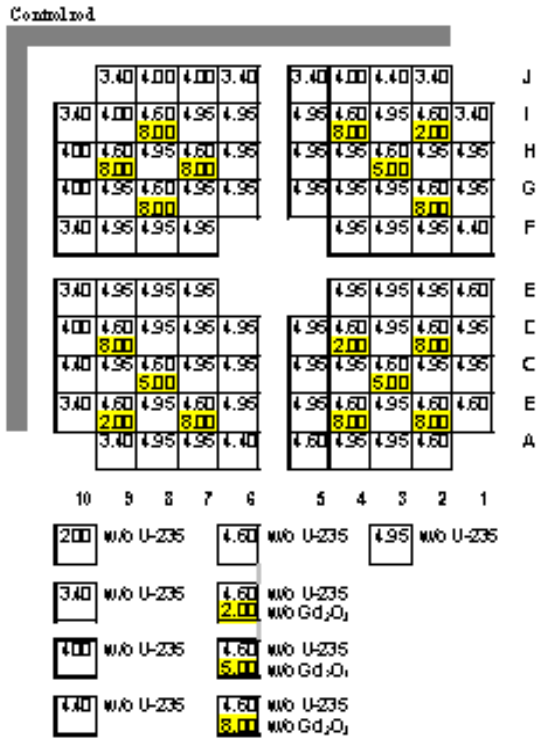




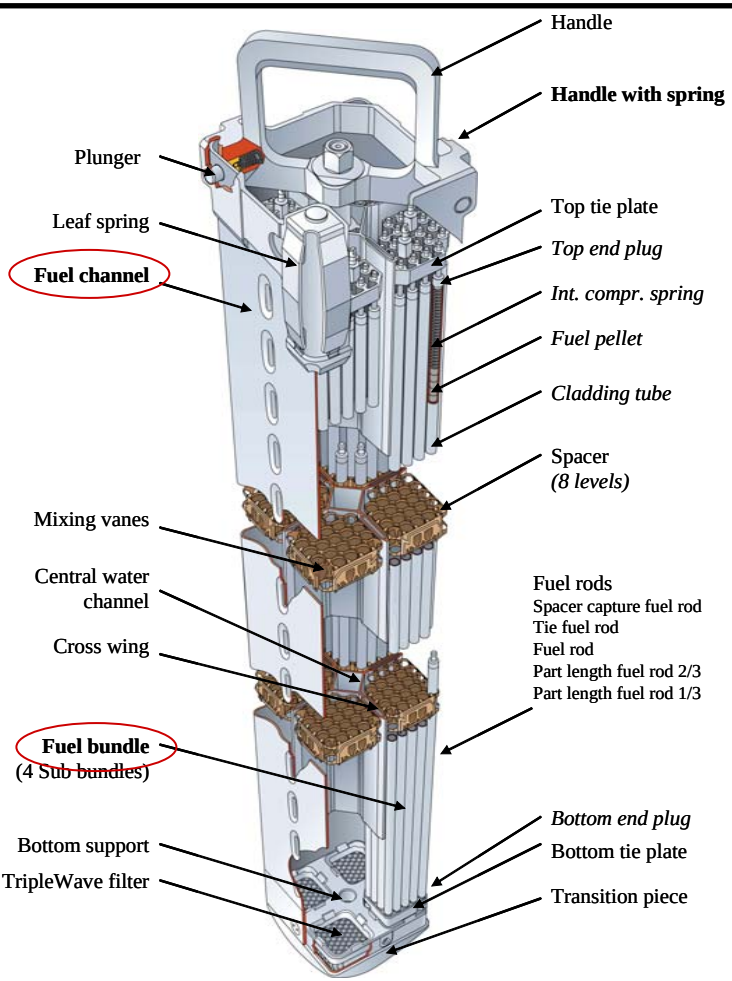
1.a. Neutron absorption

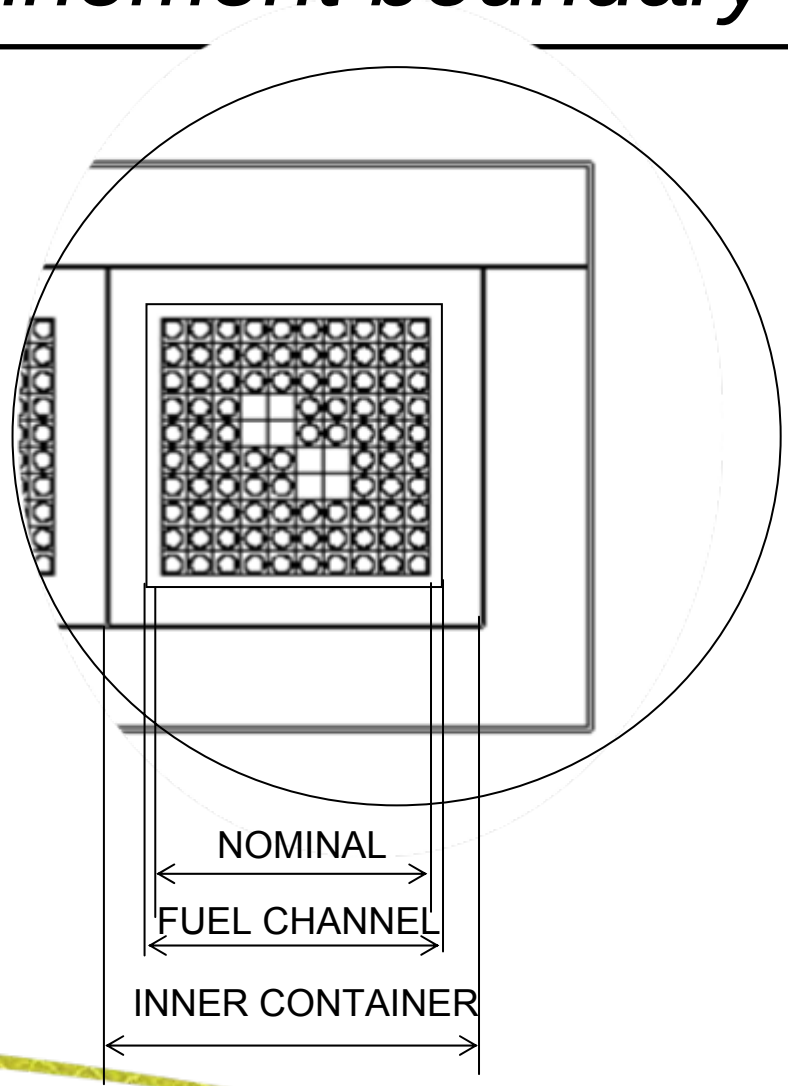
- burnable neutron absorbers (gadolinia-urania oxide fuel rods)
- packaging materials (stainless steel)





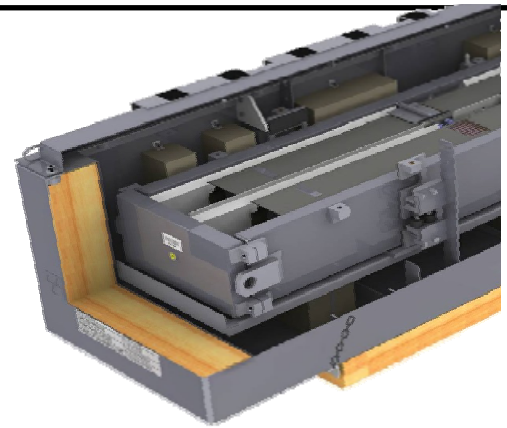
1.b. Geometry – *Confinement boundary*





1.c. Moderation

- Internal moderation
  (paper honeycomb,
  balsa wood, polyethylene)



- External moderation consistent
  with transport conditions
  and laws of nature

Define realistic ranges for criticality parameters that include intermediate material compositions.

2. Nuclear analysis

a. Constrained representation of **geometry and materials**

b. Adequate **optimization of reactivity**

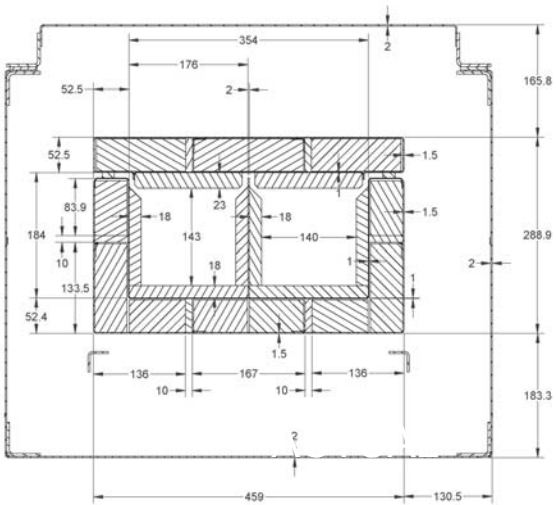
c. Upper safety limit with **adequate margin of subcriticality**

d. Reasonable **allowance for uncertainties**

2.a. Geometry and materials

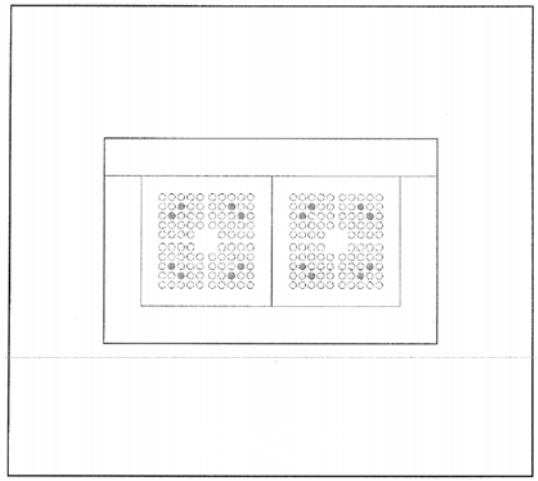
"Art of nuclear criticality safety"

ACTUAL PACKAGE



STYLIZE

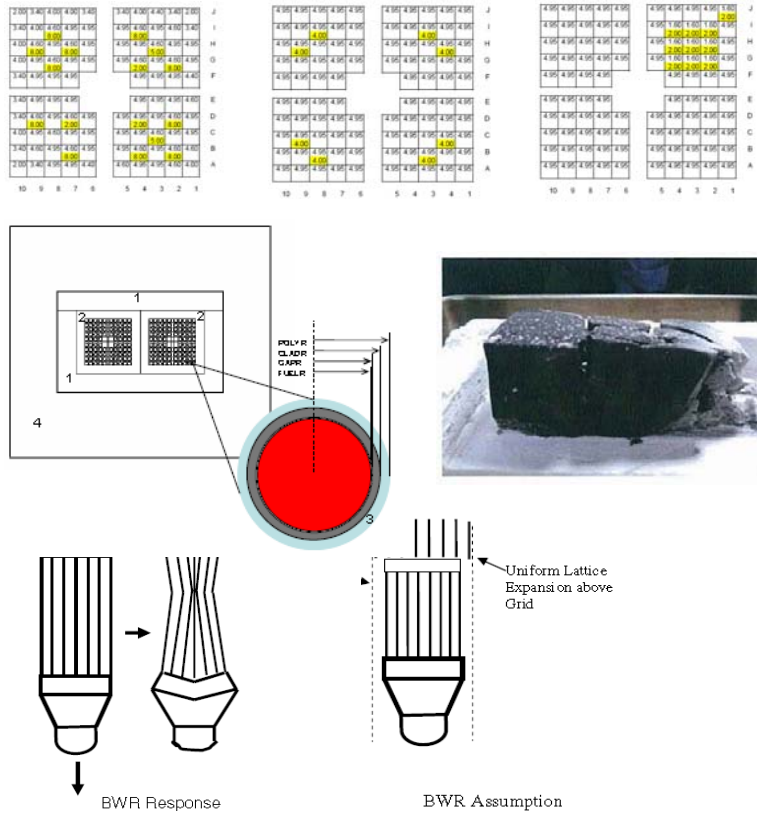
REALISTIC MODEL



mod·el **\mä-dəl** a system of postulates, data, and inferences presented as a mathematical description of an entity or state of affairs ; *also* **:** a computer simulation based on such a system

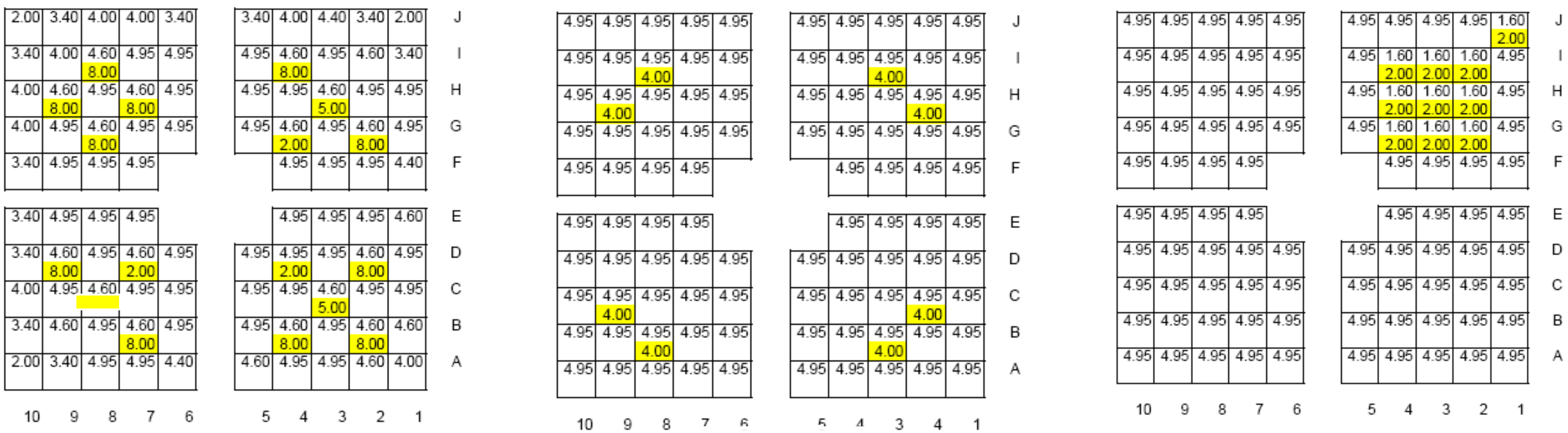
2.b. Optimization of reactivity

- *Burnable absorber rod distribution*
- P*ackaging material behavior during a fire*
  - Polyethylene redistribution
  - Balsa wood charring
- *Fuel bundle lattice expansion*



Burnable absorber rod distribution

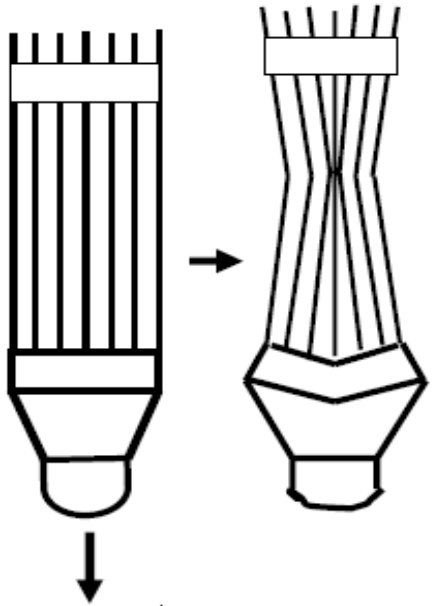
ACTUAL DESIGN → *REALISTIC CONSTRAINTS* ← ABSTRACT



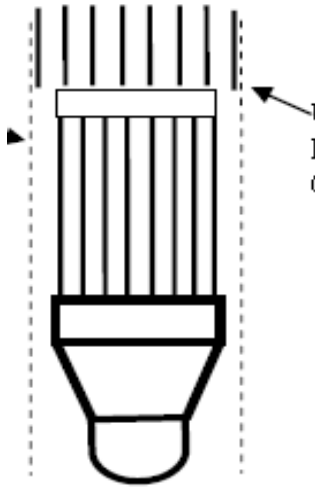
k_{eff}

LOWEST *ACCEPTABLE* *HIGHEST*

Fuel bundle lattice expansion



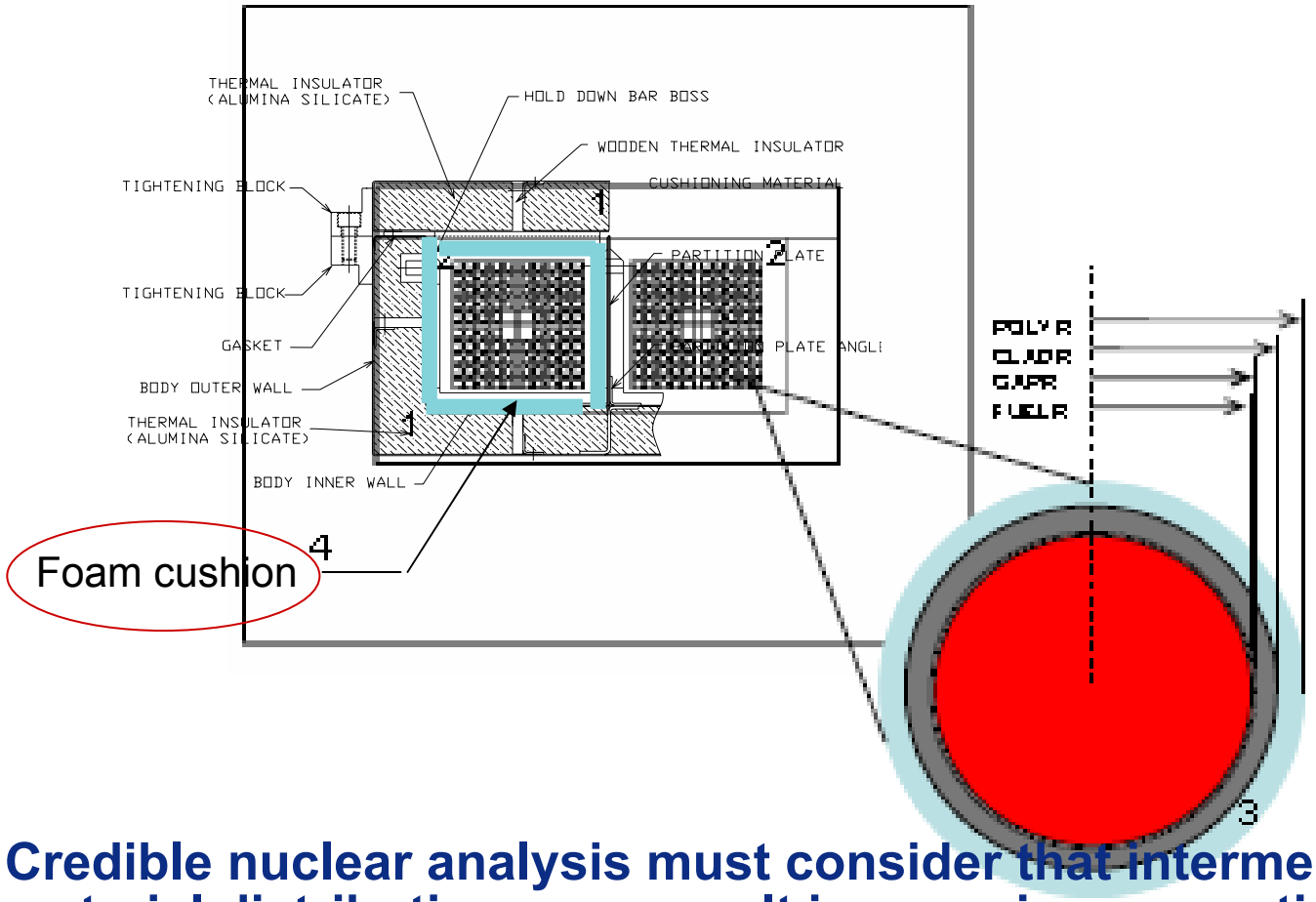
BWR Response



BWR Assumption

Source: Peter C Purcell , "Method To Evaluate Limits Of Lattice Expansion In Light Water Reactor Fuel From An Axial Impact Accident During Transport ," *Proceedings of the 15th International Symposium on the Packaging and Transportation of Radioactive Materials PATRAM 2007*, Miami, Florida, USA (October 2007)

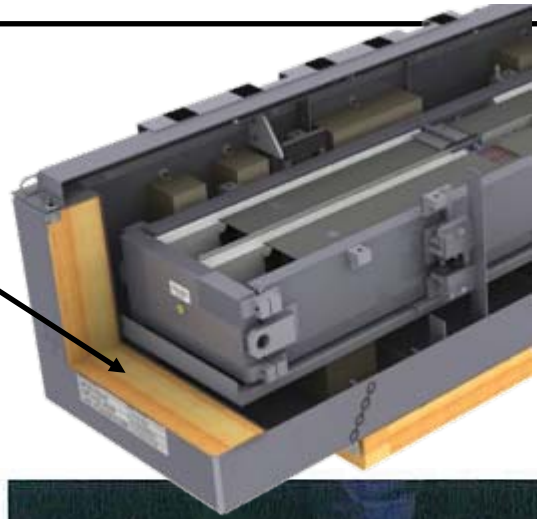
Redistribution of polyethylene during a fire



Credible nuclear analysis must consider that intermediate material distributions can result in a maximum reactivity.

Charring of Balsa wood under thermal test conditions

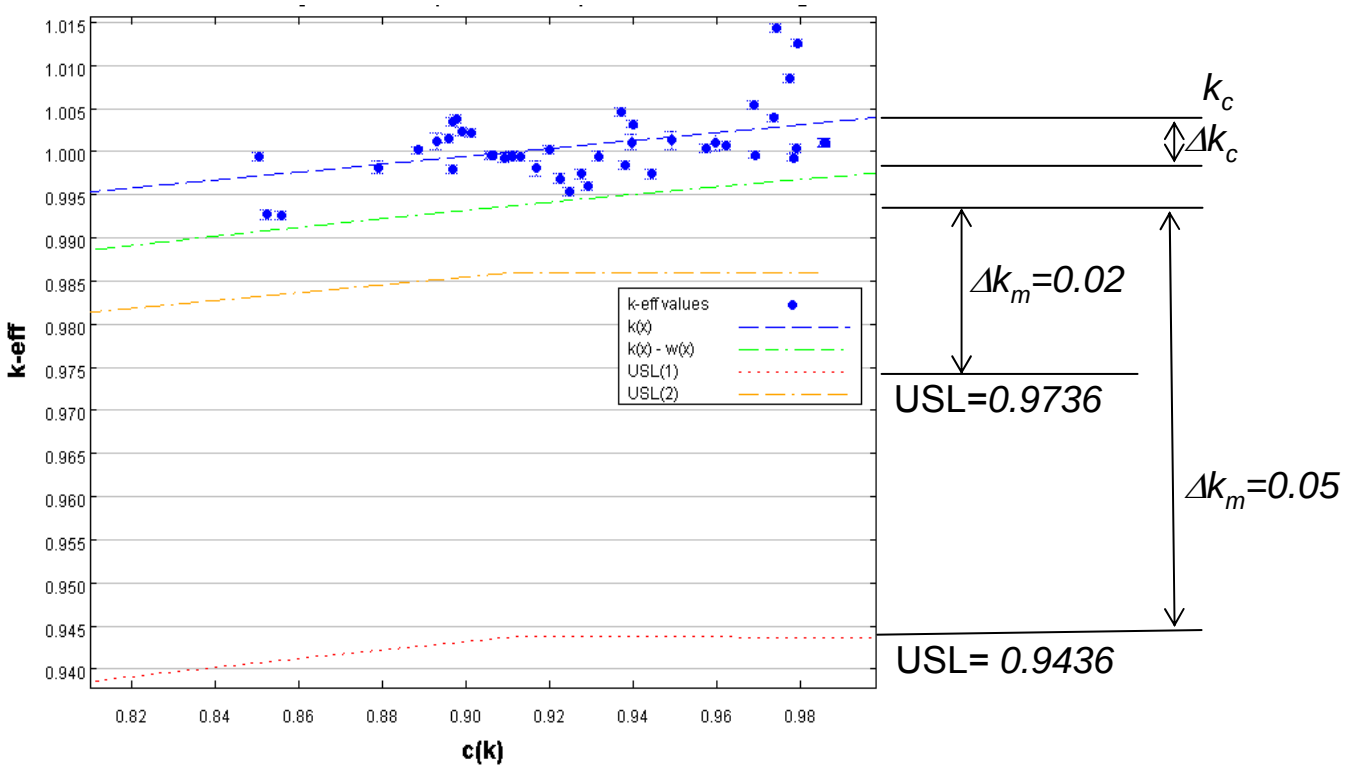
Balsa wood impact limiter



Incomplete combustion results in formation of char

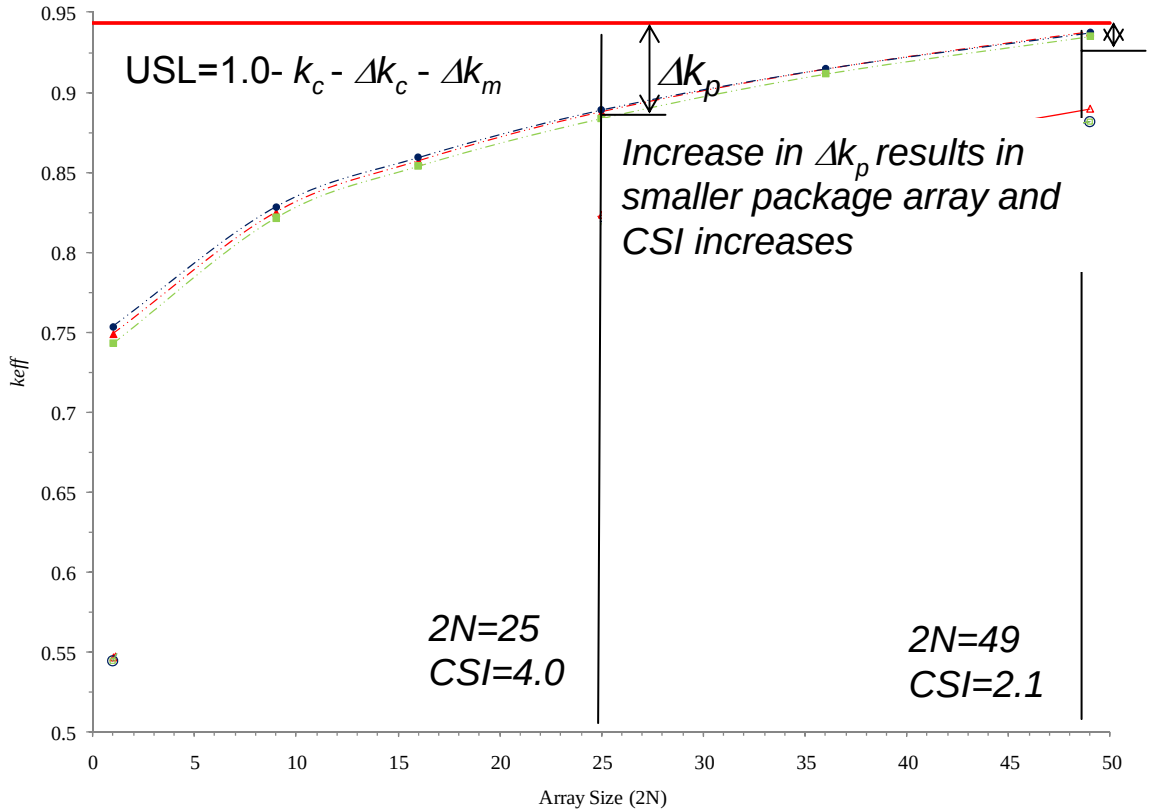
Credible nuclear analysis must consider that intermediate material compositions can result in a maximum reactivity.

3) Margin of subcriticality- USL



Provide technical justification for an administrative margin, instead of defaulting to the use of an arbitrary value for Δk_m.

4) Allowance for Uncertainties - Δkp



Δk_p

$$\Delta k_p = 2\sigma + \Sigma\Delta k_u \cong \Sigma\Delta k_u$$

Uncertainty	Δk_u
Inner container spacing within outer container	***0.005***
Outer container dimensions	***0.015***
Polyethylene foam cushion redistribution	***0.004***
Material and fabrication tolerances	***0.022***
Total $\Sigma\Delta ku$	***0.046***

Analyze and understand the allowance for uncertainties in geometry and materials (Δk_u) .

Conclusions

- *Define realistic ranges for criticality parameters that include intermediate material compositions.*
- Consider credible intermediate material conditions (distribution and composition) that can result in a maximum reactivity.
- *Provide technical justification for an administrative margin, instead of defaulting to the use of an arbitrary value for* adminsitrative margin (Δk_m).
- Analyze and understand the allowance for uncertainties in geometry and materials.

Safe transport of radioactive materials is best served when based upon realistic criticality parameters and credible nuclear analysis.

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