3. ACR Fuel Design

by Peter G. Boczar, Director Reactor Core Technology Division

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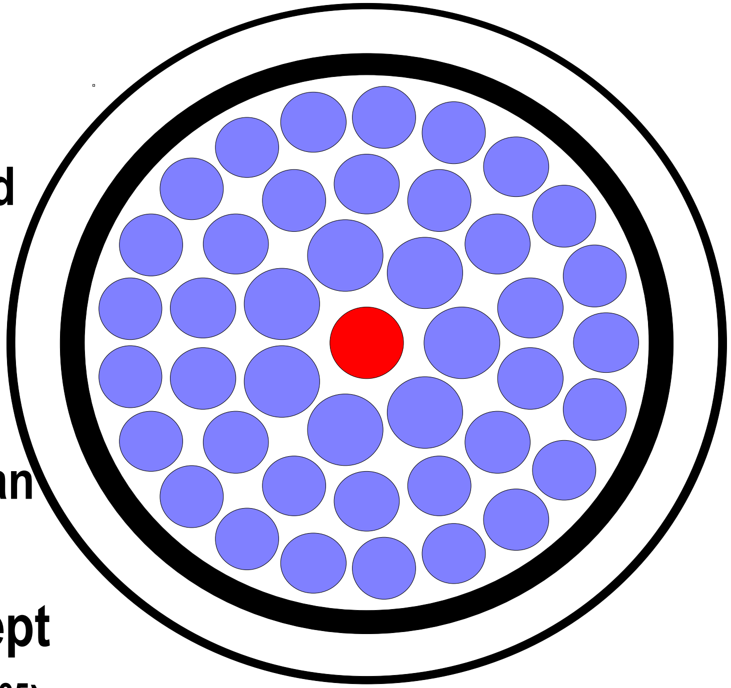
ACR Fuel Design

- **Based on CANFLEX Mk 4**
  - proven design
  - 2 element sizes, 43 elements
  - greater "subdivision" reduces ratings and facilitates achievement of higher burnup
  - "buttons" increase CHF
  - qualified for NU fuel
  - ACR has slightly higher bearing pads than Mk 4 (higher thermal hydraulic margins)
- **Based on Low Void Reactivity Fuel concept**
  - enrichment in outer 42 elements (2.1% U^{235})
  - 7.5% Dy in nat UO_2 in central element



ACR Negative Coolant Void Reactivity

- **Project requirement**
  - negative CVR under all applicable design and operating conditions, accounting for calculation bias and uncertainties
- **Negative void reactivity with light water coolant results from**
  - tight lattice pitch
  - larger gap between pressure tube and calandria tube
  - Dy-doped central element
- **Central poisoned element gives great flexibility in tailoring void reactivity coefficient**
  - enrichment and Dy content are slightly higher than in the original conceptual design

ACR Reference Power/Burnup

- **Nominal powers**
  - time-average maximum powers: 7.3 MW (channel); 850 kW (bundle)
  - instantaneous maximum powers: 7.7 MW (channel); 910 kW (bundle)
  - instantaneous maximum linear element rating: 51 kW/m
- **Nominal burnups**
  - time-average bundle discharge burnup: 21 MWd/kg
    - high enough to provide economic benefit, low enough to be readily achievable
    - burnup could be increased as required in future for higher uranium utilization and lower fuel cycle costs
  - 23 MWd/kg instantaneous maximum bundle discharge burnup
  - time-average element burnups:

    center 5.7; inner 14.9; intermediate 19.5; outer 25.6 MWd/kg
  - instantaneous maximum element burnups:

    center 6.6; inner 16.6; intermediate 21.5; outer 27.9 MWd/kg

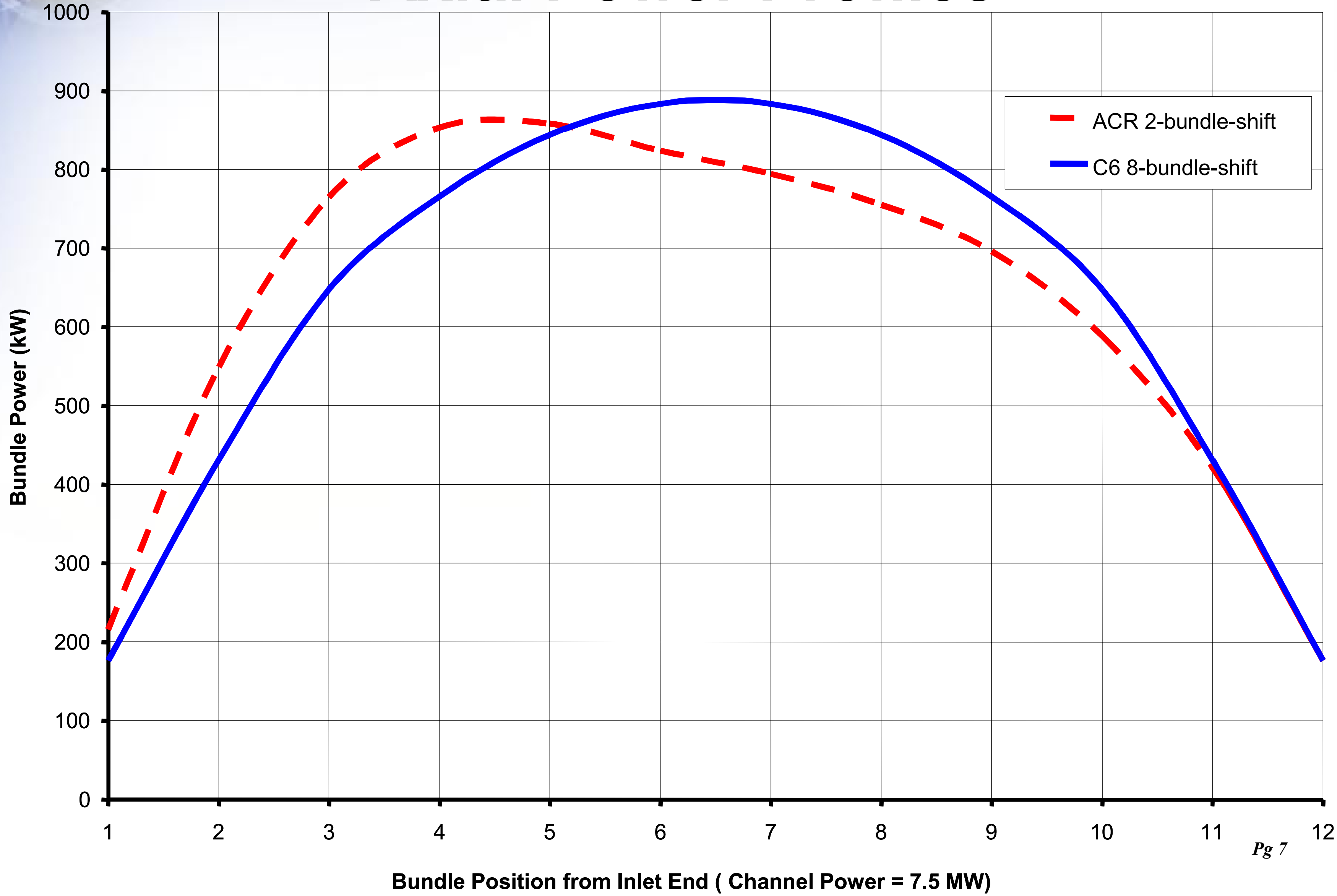
ACR Fuel Design Features to Accommodate Higher Burnup

- CANFLEX reduces peak linear element ratings to facilitate higher burnup
- Optimized pellet design
  - internal element design based on CRL irradiation experience
  - larger chamfers, deeper dishes, shorter pellets
    - reduces clad ridging
    - more internal void for accommodating FGR at higher burnup in smaller elements
- "Low stress" endclosure welds

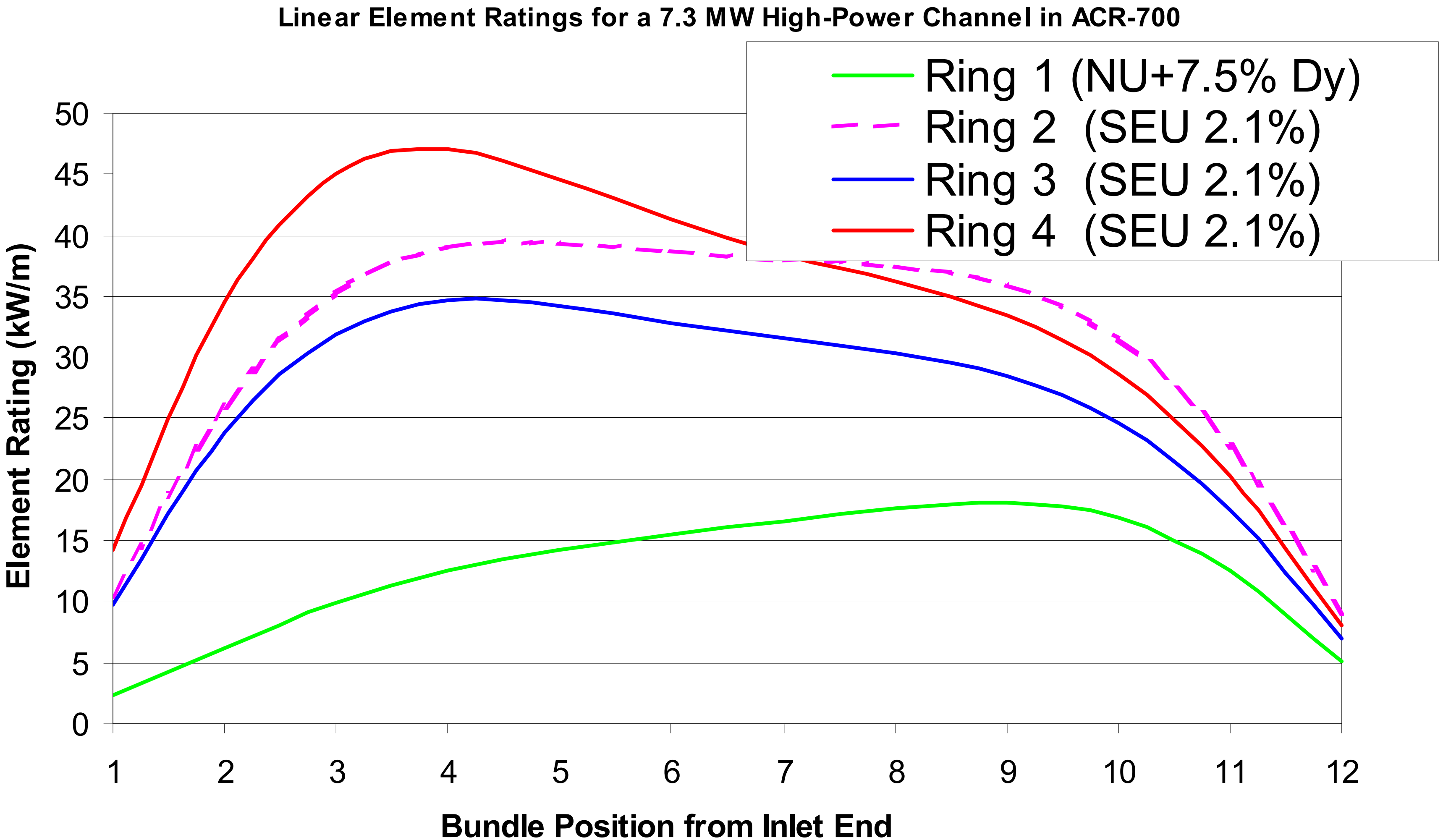
ACR Reference Fueling Scheme

- 2-bundle shift, bi-directional fueling
  - 2.8 channel visits per full power day
  - 5.6 fuel bundles per full power day
- Power peaks at inlet end of channel (bundle 4) and decreases along length of channel
- Excellent axial power distribution for
  - fuel performance
    - only fuel with low burnup experiences power ramp
  - thermal hydraulics
    - higher CHF than with either cosine-shaped or outlet-skewed axial power profile
    - at dryout location, bundle is well balanced for CHF (dryout occurs in inner ring of fuel)

Comparison of ACR and CANDU 6 Axial Power Profiles



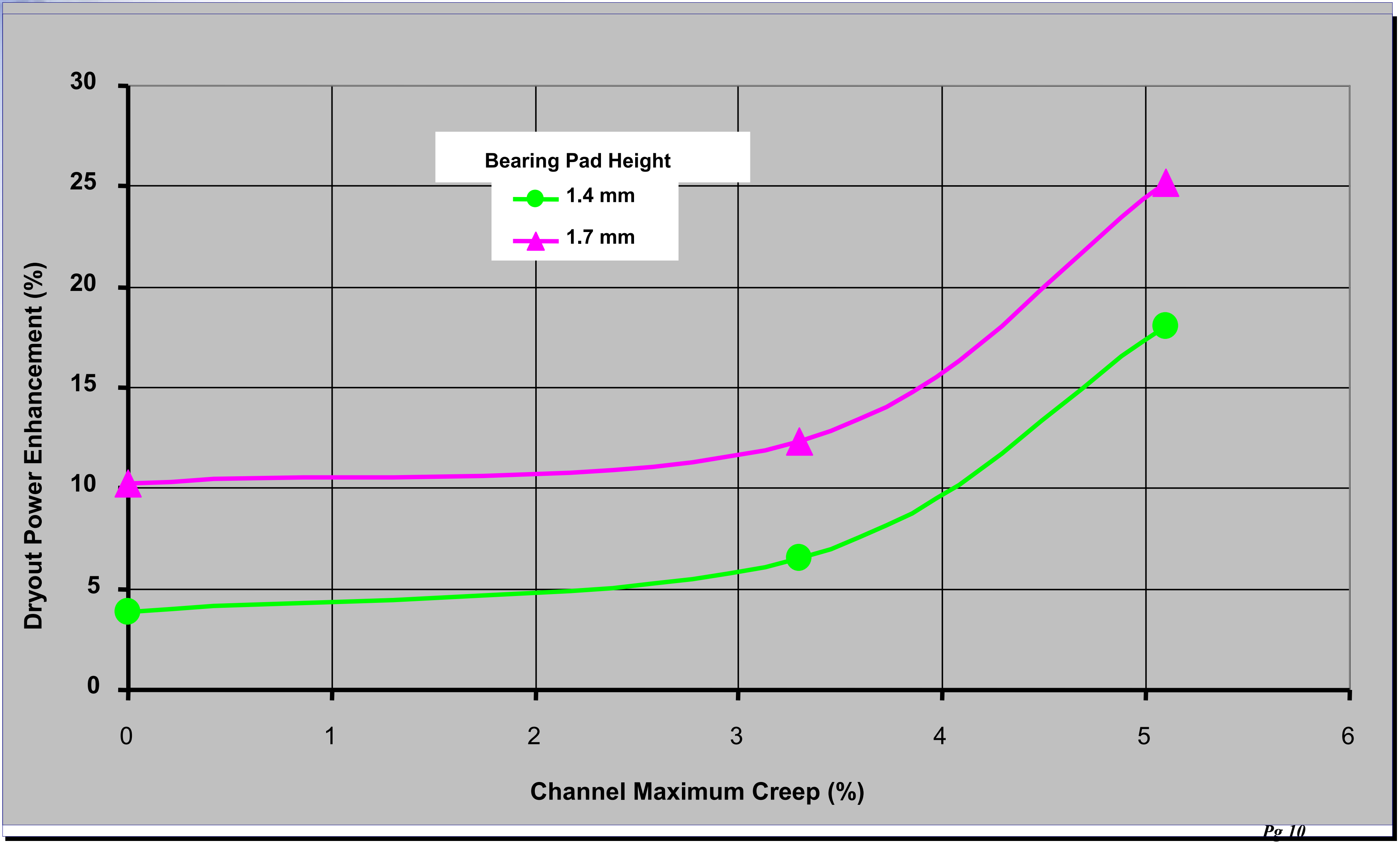
ACR Power Envelope



Other ACR Fuel Design Features

- Driven by changes in
  - fuel channel
  - fuel handling system
  - reactor coolant system
- Bearing pads
  - higher than in CANFLEX Mk 4 to improve CHF
  - longer to provide support during passage over the sealing groove in the endfitting during refueling operations
    - sealing groove is a new feature associated with the improved fuel channel closure plug in the ACR

Effect of Bearing Pad Height on Dryout Power in CANFLEX NU



Other ACR Fuel Design Features (con't)

- Slightly thicker clad
  - to reduce potential of longitudinal ridging with higher coolant pressures and temperatures
  - reduces in-reactor element bow
- Endplate alignment change
  - "flipped endplates" reduce initial element bow
- "Low stress" endclosure welds
- Bruce style "square profile" endcaps
  - to interface with new fuel bundle separators (using Bruce and CANDU 6 technologies)
  - provides axial support to fuel column during on-power refueling

Summary: New ACR Fuel Design Features

(relative to CANDU 6 CANFLEX Mk 4 design)

a) Enriched uranium (2.1% U-235) in 42 elements

b) Dysprosium mixed with NU in center element

c) Taller bearing pads

d) Longer bearing pads

e) Bruce style “square profile” endcaps

f) Thicker fuel clad

g) Fuel pellets optimized for increased void volume (deeper dishes, larger chamfers, reduced l/d)

h) “Low stress” endclosure welds

i) Endplate alignment change

Fuel Design Changes resulting from Changes in Nuclear Design

- NEGATIVE VOID REACTIVITY, EXTENDED BURNUP
  - a) Enriched U-235 in 42 elements
    - Increased reactivity worth per bundle
    - Increased bundle burnup
      - Need to provide for increased fission product inventory
        - g) pellet design optimized for increased voidage
        - h) “Low stress” enclosure welds
      - Need to maintain good dimensional stability for longer periods
        - f) thicker fuel clad to avoid longitudinal ridging
        - i) flipped endplates to reduce initial element bow
  - b) Dysprosium with NU in center element

Summary

- **ACR fuel uses CANFLEX geometry**
  - **enriched uranium in outer elements**
  - **dysprosium mixed with NU in central element**
- **Other relatively minor changes to CANFLEX Mk 4 to accommodate ACR requirements**

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