Lecture #4 — Design Criteria Physics
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Objective: To understand how the NRC's General Design Criteria limit core physics design in order to maintain the integrity of clad, pressure vessel and containment; and also how those license limits combine with other operating objectives to yield specific PWR design features

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RELATIONSHIP OF SAFETY ANALYSES TO LICENSING AND TECH SPECS

The risk to public health and safety is

Radioactive material

Whose release is prevented by

Clad, pressure vessel & containment

Whose integrity is assured by

Adherence to GDC of 10CFR50, App A

Which is checked by

Analyses of credible transients and accidents

Which give acceptable results for

A range of plant and core characteristics

To which range, operation is restricted by

Technical specifications

Objectives of Reload Analysis

- Design a core that provides desired energy
- Design a licensable core
- Design so core meets operations constraints
- Design an economic core
- Design to meet other management objectives

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What are licensing constraints?

- Tech specs specify limiting values of
  - Power peaking
  - Reactivity coefficients
  - Control rod worths
  - Shut down margin
  - Delayed neutron fraction

Usually use point kinetics

- $\rho = \rho_{doppler} + \rho_{\mathrm{mod}\,temp} + \rho_{\mathrm{X}e} + {}_{controlrods} + \rho_{so\,\mathrm{lub}\,leboron}$
- Calculate individual reactivates
- But each depends on core conditions

What transients are considered?

- Normal operation (start up, shut down, change power level, etc.)
- Type II transients (scram, dropped control rod, unintended dilution, control rod banks out of sequence, etc)
- Type III unlikely but $p > 0$
- Type IV whoops! (LOCA, main steam line break)

Response to transients is combination of:

- Transient response of core
- Transient response of primary and secondary coolant systems
- Automatic controls
- Trip system (reactor and coolant/secondary)

What does a core look like

- Try to maintain 1/8 or 1/4 core sysmmetry
- Modern loading patterns are "in-out"
- Core map conventionally shows:
  - Assembly power (relative to core ave assy = 1)
  - Max pin power within assembly (relative to core ave pin = 1)
  - Sometimes assy absolute burnup
  - Sometimes assy ID or fuel type

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Types of BP

- Pyrex glass (^{10}B) in rods separate from fuel
- WABA (^{10}B) in rods separate from fuel
- B_4C in alumina (^{10}B) in rods separate from fuel
- Erbia - mixed with UO_2
- Gadolinia - mixed with UO_2 (^{155}Gd, ^{157}Gd)
- IFBA (^{10}B) -on pellet surface

To design the core we want, what choices do we have?

- Decide how many burned assys to remove
- Decide which burned assys to remove
- Decide what enrichment for fresh assys
- Decide what type of BP
- Decide how much BP
- Decide where to place BP

To design the core we want, what choices don't we have?

- Fuel mechanical design is usually fixed
- Fuel fabricators have a max enrichement
- Spent fuel pit has a max enrichment
- Usually use only one or two types of BP
- Max burnup (NRC ~ 62gwd/mtu pin)
- Burned fuel can't sustain as high a relative power as fresh fuel

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