NucE 511

Nuclear Reactor Kinetics and Dynamics

Class 2: Basic Concepts
Simplified Neutron Cycle
Kinetic Equation

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The Basic Concepts

Which is the essential phenomenon in nuclear reactors?

- **The self-sustaining process of neutron induced fission**
The Basic Concepts

What are the main differences between fast and thermal nuclear reactors?

- Neutron energy at which fission reactions are caused
- Isotopes to undergo a fission reaction
The Basic Concepts

Can we use the same basic dynamic principles to describe nuclear fission reactors?

✓ Yes, but there is a very important difference – the time scale of neutron reproduction (due to different fraction of delayed neutrons)

The basic concepts of reactor dynamics are:
1. Reactivity
2. Neutron Generation Time
3. Delayed Neutrons
Reactivity:

Relative departure of the neutron reproduction factor
(multiplication factor) from unity

or

Departure from criticality \[ \rho = \frac{k-1}{k} \]

- Integral property of the reactor
- Can be measured (via $k$), but usually deduced from observation of dynamics behavior
- Depends on:
  1. reactor size;
  2. amounts and densities of various materials;
  3. cross-sections for fission, scattering, absorption
Neutron Generation Time:

Mean time of neutron reproduction in a multiplying medium

- Integral property of the reactor
- Fast reactors: $10^{-7} \div 10^{-8}$ sec
- Thermal reactor: $10^{-3} \div 10^{-4}$ sec
- Depends on:

  Number of scattering collisions before leakage or absorption
Delayed Neutrons:

After a fission event, the reaction products consist of:

1. two radioactive nuclei
2. several prompt neutrons
3. several gamma rays

None of the resultant fission product nuclei can directly emit an additional neutron

→ Some of the fission product nuclei may decay into daughter nuclei for which the excitation energy is larger than the neutron binding energy

→ Such nuclei may then immediately emit a neutron, which has been delayed by the comparatively long time it took such a nucleus to undergo a beta decay

→ Less than 1% of the neutron production in fission
**Delayed Neutrons:**

If all neutrons were prompt, it would be extremity difficult, if not impossible, to control a reactor by conventional mechanical means. WHY?
Simplified Neutron Cycle

\( n(t) \) – number of neutrons in the system at time \( t \)
\( \ell_0 \) – neutron life time (characteristic time)
\( k \) – total number of neutrons (prompt and delayed) produced per neutron lost
\( \beta = \sum_i \beta_i \) – total delayed neutron fraction
\( c_i \) – number of precursors of \( i^{th} \) type
\( \lambda_i \) - decay constant of \( i^{th} \) precursor
\( q \) – external neutron source (#/sec)

- Neutron Leakage
- Non-Fission Absorption
- Neutron Diffusion Lost Rate
- Fission Production Rate
- Neutron Source
- Delayed Neutron Precursors ("Latent Neutrons")
The neutron balance equation is then:
Derivation:
Next Class

*Prompt and Delayed Neutrons*

*Total Delayed Neutron Yields & Yields of Delayed Neutron Groups*