Chapter 1

BASIC TOPICS AND NOMENCLATURE

1-1 Basic Time-Dependent Phenomena in Nuclear Reactors

Time-dependent phenomena in nuclear reactors may be subdivided into three distinctively different classes. The time constants of the individual phenomena in the three classes differ by orders of magnitude. In addition, different physical phenomena are treated in each class; it is not just a case of the same phenomenon occurring at different speeds:

1. short time phenomena, which typically occur in time intervals of milliseconds to seconds; in special cases, the time intervals may extend to many minutes

2. medium time phenomena, which occur over hours or days corresponding to the mean buildup and decay times of certain fission products that strongly affect the reactivity

3. long time phenomena, with variations developing over several months or years.

These time-dependent phenomena basically include changes in the neutron flux as well as causally related changes in the reactor system, i.e., composition or temperature. The causal relationship between the neutron flux and the physical reactor system may occur in either direction; that is, changes in the composition or temperature of the system may cause a change in the flux, or changes in the flux may alter the composition or temperature and thus the density and absorption characteristics of the system. Changes in the system can also be externally induced, for example, by the motion of an independent neutron source, or of control or shutdown rods, resulting in neutron flux changes. If the flux changes cause changes in the reactor and these changes subsequently "act back" on the flux, the phenomenon is termed "feedback".
The "short time phenomena" include more or less rapid changes in the neutron flux due to intended or accidental changes in the system. The latter changes may influence the flux through feedback. Short time phenomena include flux transients important for:

1. accident analysis and safety
2. experiments with time-dependent neutron fluxes
3. reactor operation, such as startup, load change, and shutdown (even though some startup procedures may take hours)
4. analysis of stability with respect to neutron flux changes.

"Medium time phenomena" are generally associated with the buildup burnup, and beta decay of two fission products (\(^{135}\text{Xe}\) and \(^{149}\text{Sm}\)) in thermal reactors. These two fission products have very high thermal neutron capture cross sections and thus require special attention in thermal reactors. Since the treatment of medium time phenomena is methodologically different from kinetics, it is not addressed in this course.

"Long time phenomena" include particularly the burnup and buildup of fissionable isotopes, as well as the buildup, beta decay, and burnup of most of the fission products. In the fast neutron energy range, the cross sections of all fission products are so small that they do not affect the flux and the reactivity as strongly as in thermal reactors.

Other long time phenomena occurring in reactors that have only a minimal effect on the neutron flux include swelling of the structural material, changes in the fuel pellets due to burnup, etc.

Since short, medium, and long time phenomena are physically different phenomena resulting in different sets of equations, different concepts and solution approaches are utilized. These are the strongest reasons for separating these time phenomena into three different categories with different names.

### 1-2 Kinetics versus Dynamics

The nomenclature used in textbooks and publications for the different categories of time-dependent phenomena in nuclear reactors is not unique. The two basic names in use are *kinetics* and *dynamics*. A few authors (e.g., Ref. 1) subsume *all* time-dependent phenomena under "dynamics," including burnup and buildup of isotopes. Most authors, however, consider long time phenomena to represent a separate category, namely "fuel cycle problems." The latter widely used practice is followed in this text.

Essentially three names are in use for the class of *short* time phenomena:
1. kinetics, for the entire class of short time phenomena (e.g., Ref. 2)
2. dynamics, also for the entire class of short time phenomena (e.g., Ref. 3)
3. dynamics, as a general heading for the entire class of short time phenomena, with two subheadings: (a) kinetics, for short time phenomena without feedback and (b) dynamics, in the narrower sense, for short time phenomena with feedback (e.g., Ref. 4).

The latter nomenclature is used in this book since it is probably in more widespread use and the structure of the problem seems to suggest such a nomenclature. It is convenient to have a special name for the range of problems (kinetics problems, kinetics equations) in which only the time behavior of neutrons need be considered. If feedback is important, the system of kinetics equations must be completed by another, often larger, set of equations describing the various feedback effects. It is convenient to have a different name for the completed set of equations (dynamics equations, dynamics problems). Since the completed set of equations describes the general problem, dynamics is also used as a general heading.

This text is concerned with the short time variations of the neutron flux as a function of time, i.e., with the typical topics of kinetics and dynamics.

**Review Questions**

1. Describe briefly the three categories of time dependencies occurring in nuclear reactors.
2. State three areas of kinetics or dynamics applications.
3. Considering the nomenclature, what do various authors consider to be the subject of "dynamics" or "kinetics"?
4. What is the main difference in the balance equations for the neutron flux in reactor dynamics and fuel cycle analysis?

**REFERENCES**

3. D L Hetrick, *Dynamics of Nuclear Reactors*, The University of Chicago Press,