CHAPTER 1

Introduction

SPACE TIME KINETICS has for object the analysis of the behavior of the neutron population in a multiplying medium (such as a nuclear reactor) as a function both of space and time simultaneously. This constitutes a very complex task, whose execution requires many resources of all kinds. The very nature of the problem requires utilizing advanced numerical techniques on computers. For example, at each time interval, a complete spatial problem must be solved. If the spatial discretization method is not well optimized, it will become very expensive to do such calculations. Furthermore, time discretization will have repercussions on the stability of the solutions, so that all the resources of numerical analysis come into play.

Steady State Calculations

The initial conditions normally used for in space-time kinetics are those of the initially stationary core, without any perturbations. This implies a criticality search. As such, special numerical methods have to be set -up in oder to solve for the initial fluxes. A review of the methods of static reactor physics is done for completeness.

The power method is used for the fundamental eigenvalue search. Because of the widespread use of this method, it is examined closely, but without the mathematical rigor that a study of the Perron-Frobenius theorem would require.

A similar point of view is taken for the examination of some of the more common iterative processes for the solution of large linear equation systems. Very specialized methods have been invented over the years to accelerate the process, and we don't cover them at all...

Instead, the main thrust behind this review is to give the reader a general knowledge of the field so that he may understand the underlying structure of the large computer codes in use today for static reactor analysis. Such knowledge is necessary if meaningful analysis is to be done with these modern tools.

Space-Time Kinetics

The parameters that affect the dynamic behavior of a nuclear vary on time scales that are quite different from each others, which complicates a lot the situation at hand. For example, a safety system shut-off rod insertion, the change in isotopic composition of the reactor material (burn-up effects), instantaneous (Doppler broadening) and delayed (heat transfer affecting the densities) feedbacks effects, all act at rates that are very different one from the others. All these effects combined together make the space-time kinetics problem non-linear, since some of the driving parameters depend on the solution itself. Luckily, approximations whose accuracy have been verified time and again permit a linearization: it consists of taking into account sequentially instead of simultaneously the parameters that depend implicitly on the flux. In certain situations, this de-coupling will be performed during the transient simulation itself, whereas other cases will permit the de-coupling outside of the transient. Such an approach requires obtaining the flux first, followed by the calculation of the parameters (temperatures, densities...) that depend on the flux. A non linear problem is thus transformed in a series of linear problems, but whose coefficients become time dependent.

This document reviews the different methods to determine the space and time behavior of the neutron flux in a nuclear reactor. The effects of the parameters, such as the temperatures, densities, isotopic compositions on the nuclear cross-sections will be supposed known or given in advance.