LECTURE 2: USE OF REACTOR DESIGN CODES

OBJECTIVES:

At the end of this lecture, you will be able to describe the calculations in the following reactor physics activities:

1.   Lattice parameters determination

2.   Reactivity devices parameters determination

3.   Core design

4.   Time dependent simulations

5.   Fuelling simulations

INTRODUCTION

This Lecture is a brief overview of the typical methodology used in the process of designing a CANDU reactor core. The intent is to set the stage for the discussion that will follow where the methods that are used and the reasons for using them will be discussed in more detail. Figure 2-1 shows a simple flow chart of the physics analysis of CANDU power reactors.

Outputs of the Analysis:

1. ⇒ Cross Sections vs. Burnup
   ⇒ Isotopic Composition
   ⇒ Void Effect (Point Model)
   ⇒ Reactivity Coefficients
   ⇒ Power Distribution in Fuel Bundles, etc.

2. ⇒ Control Devices Layout
   ⇒ Power Distribution in the Core
   ⇒ Shutdown Systems
   ⇒ Void Effect, etc.

3. ⇒ Xenon Oscillation Studies
   ⇒ Zonal Overpowers and Detector Location
   ⇒ Sequences of Withdrawal or Insertion of Control Devices, etc.

4. ⇒ Power Pulse
   ⇒ Adequacy of Shutdown Systems, etc.

5. ⇒ Fuelling Schemes
   ⇒ Simulation

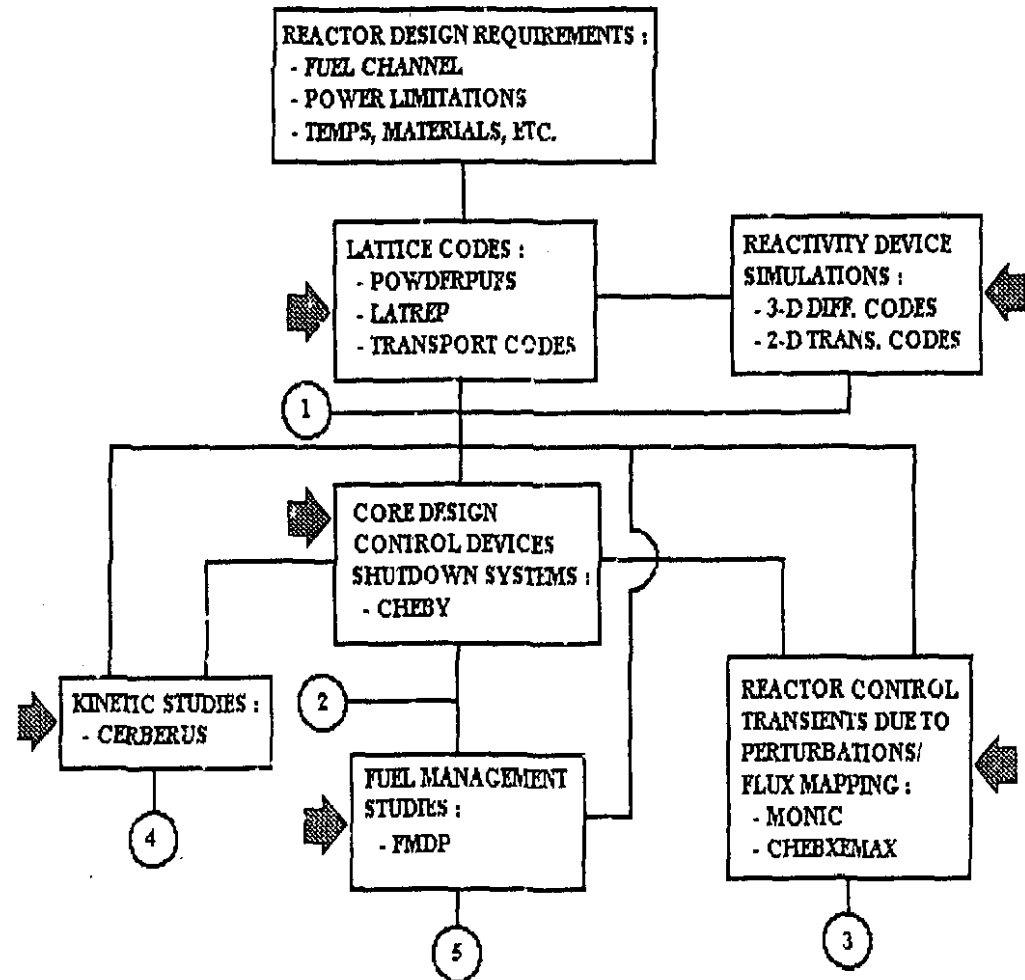   Indicates Feedback Information from Experimental and Power Reactors

Figure 2-1: Simplified Chart of PHW Physics Analysis

ENGINEERING REQUIREMENTS

The establishment of the broad engineering requirements of the core design will depend on the nature of the design and the project.

- If a new reactor design concept is involved, considerable interaction between reactor physics analysis and the engineering design considerations would take place during the establishment of the conceptual design of the plant.

- If the project is a relatively small variant from the reactors previously designed, the basic engineering requirements may be established an the basis of past experience with minimal "conceptual" work being done.

Before the detailed reactor physics analysis of a core design can begin, a preliminary selection of a number of key parameters is required, including:

- size of the core

- number of channels

- design of fuel channel and fuel bundle

- required operating conditions

- preliminary choices of material to be used in the core hardware, etc.

Some of these parameters may well change as a result of the physics analysis and hence an iterative process takes place in order to satisfy both engineering and physics requirements.

Lattice (Cell) Calculations

- In a lattice calculation, a unit cell consisting of a single fuel channel and the appropriate amount of moderator (depending on the pitch) is considered.

- The lattice calculation provides neutronic details of the fuel channel, such as;

  ⇒ the variation of cross sections and isotopic composition with fuel burnup

  ⇒ the reactivity coefficients

  ⇒ the power distribution across the fuel bundle

  ⇒ the macroscopic cross sections to be used in core calculations.

Simulation of Reactivity Devices

- Due to the large number of reactivity devices present in the core, they are generally not represented discretely in the core simulations.

- The properties of a device are smeared over a fairly large parallelepiped one dimension of which is the length of the device.

- These properties are usually obtained by what is known as a supercell calculation, which must be done for each different device.

Core Calculations

- Finite difference diffusion codes are used for core calculations, in two neutron energy groups.

- The number of mesh lines used in the finite difference models depends on the nature of the problem being dealt with.

- In some cases two dimensional calculations are adequate, but three dimensional models are necessary to estimate accurately the power distributions in CANDU reactors.

Kinetic Studies

- Transient behaviour of the reactor may be studied either using a point kinetics approach or by complete three dimensional simulations in both space and time. The latter is important in the final confirmation of performance of the shutdown systems.

Reactor Stability and Control

- Detailed design of the spatial control system (one purpose of which is to control the spatially variable distribution of Xe135) requires a diffusion code with the capability to calculate the variation of xenon concentration in space and time.

- This code must also be able to simulate response of the spatial control system to spatial flux variations caused by perturbations such as withdrawing of adjuster rods or refuelling.

Fuel Burnup And Management

- Obtaining optimum average discharge burnup of the fuel is an important aspect of the physics design of the reactor.

- This requires a diffusion code which is capable of calculating the time history of the flux and power distributions in each fuel bundle from any particular starting point and time.

- The bi-directional feature of fuelling in CANDU reactors permits an averaging of fuel properties so that conceptual studies can be done with much simpler models.

Flux Mapping

- A computer code based on modal analysis is used to simulate the flux mapping software which is incorporated in the reactor control computer so that the positions of the flux mapping detectors can be optimized during the design stage.

- Note that Figure 2-1 also illustrates the interdependence of these various analyses as well as some functions of the specific computer codes that are used.