4.3.6 LWR Control

The need to maintain tight control on the operation of a nuclear reactor is self-evident and this control is maintained using a variety of tools, managerial, mechanical and chemical. In section 3.9 it was observed that control was made much easier, indeed one might say made practical, by the delayed neutrons that extend the neutronic response time of the reactor core by several orders of magnitude. Indeed if the neutron population consisted only of prompt neutrons the calculations of section 3.9 demonstrate that the reactor control system would have to respond in fractions of a second in order to maintain control. The presence of delayed neutrons allows response times of the order of tens or hundreds of seconds in order to maintain control. The corollary is that the prompt neutron population of a reactor must always be maintained well below the critical level in all sections of the reactor core and throughout the history of the fuel load. It is the delayed neutrons that are used to reach criticality and are manipulated to increase or decrease the power level.

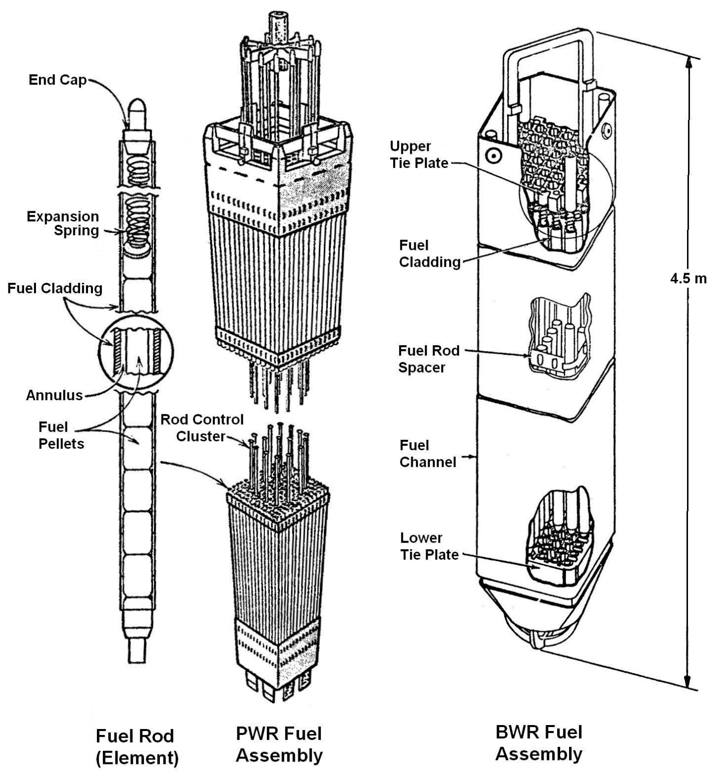

Figure 1: Fuel element and PWR fuel assembly (from Duderstadt and Hamilton 1976) and BWR fuel assembly (from USAEC 1973).

The primary mechanical devices that are used to effect control are the control rods (or structures) that are inserted into channels in the core as described in the preceding section. These are fabricated from material that absorbs neutrons and, when inserted, decrease the reactivity of the core. The materials used include boron, cadmium and gadolinium. As indicated in figure 1 the control rods are usually motor-driven from above and sometimes set to drop into the core without power in emergency situations. A full control rod insertion under emergency conditions is referred to as a *scram* and the process as *scram control*. The control rods are also used to adjust the power output from the reactor and to compensate for the aging of the fuel over longer periods of time (known as *shim control*). Typically a LWR is initially loaded with enough fuel to achieve a multiplication factor, k, (see section 2.3.1) of as much as 1.25 and therefore sufficient control rod insertion is needed to balance the reactor. As fuel life is expended, the insertion is correspondingly decreased.

In addition to the control rods, several other methods are used to adjust the power level of the reactor, to compensate for the aging of the fuel and to balance the power produced in different regions of the core. Absorbing materials are sometimes fixed in the core in order to age with the fuel and even out the long term power production. Another strategy is to dissolve absorbing or *burnable* poison such as boric acid in the coolant.