7.4 Safety Systems

The safety systems installed in modern nuclear reactors for electricity generation have three basic purposes: (1) to control the reactivity of the reactor, to maintain it in a marginally critical state during power production and to shut the reactor down when that is required (2) to cool the fuel and prevent overheating and (3) to contain all radioactive substances and radiation even in the event of radical, hypothetical accidents. While a detailed description of each of these strategic objectives is beyond the scope of this text, it is appropriate to comment on each individually.

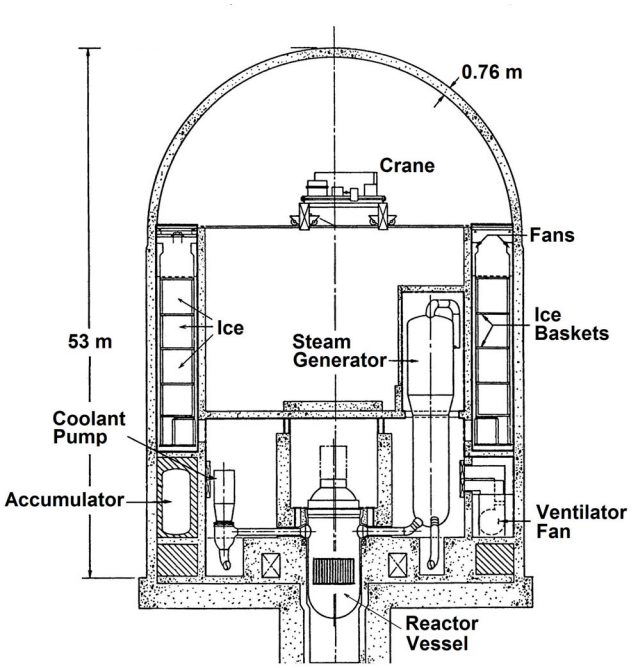

Figure 1: Typical PWR primary coolant loop and containment system. Adapted from USAEC (1973).

Though the control of a nuclear power plant is a complex and multi-faceted issue (see, for example, Schultz 1955), the reactivity of a normally operating reactor is primarily controlled by the insertion or withdrawal of the control rods whose effect was demonstrated in section 3.7.4. One of the most reassuring features of water cooled and moderated nuclear reactors (in effect most of the present commercial reactors) is that any overheating of the core that is sufficient to vaporize the cooling water within it will automatically result in a decrease in the reactivity (since thermal neutrons are not being fed back to the fuel) and consequently a shutdown of the nuclear reactor core. Of course, the fuel will still produce decay heat and therefore special cooling systems are needed to prevent

the decay heat from causing an excessive overheating of the core.

Consequently, all modern nuclear reactors are equipped with redundant *Emergency Core Cooling Systems (ECCS)* that force cooling water into the primary containment vessel and the core in the event of an uncontrolled build-up of heat. Some of these systems are passive (needing no power so they function in the absence of emergency generating power) and some are active. In addition, the containment structure (see figure 1) is designed to prevent any escape of radioactive substances even if the primary containment were to fail or leak. As described in section 7.1.3, extensive multiphase flow analyses and simulated experiments (see, for example, Hochreiter 1985) have been carried out in order to evaluate the effectiveness of these cooling systems following a postulated LOCA.