7.5.2 Chernobyl

The worst nuclear reactor accident occurred in the Ukraine in April 1986 when an old Russian RBMK-1000 boiling water reactor (see figure 1) suffered an intense explosion and fire in the nuclear core. The accident and its aftermath

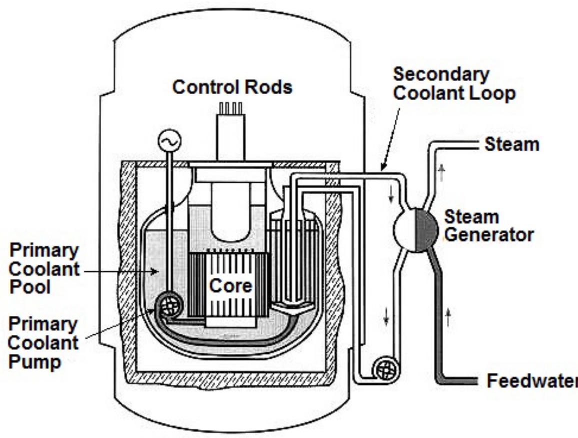

Figure 1: Schematic of Russian BN-600 pool-type LMFBR.

have been extensively documented (see, for example, Knief 1992, Marples 1986, Mould 2000) and exhaustively analyzed.

The accident occurred during a test carried out to determine the feasibility of using energy from the turbine coastdown during a reactor scram as a source of emergency electrical power. The idea was to eliminate the need for costly emergency power systems that would have required either continuously operating diesel generators (the generators could not be started quickly enough to meet the need) or an independent auxiliary cooling system. The plan involved initiating the test at a reduced power level with control rods partially inserted and the bypassing of some safety systems. It was assumed that the start of the reactor trip and the turbine shutdown would coincide. However, a substantial delay in the reactor shutdown due to electricity needs caused a build-up of xenon poison and this was counter-acted by substantial control rod withdrawal. Shortly thereafter, all the primary cooling pumps were activated to ensure adequate cooling after the test. This, in turn, increased the heat transfer, essentially eliminated boiling of the coolant and removed the reactivity margin that might have resulted from the boiling. The combination of low power and high flow led to instability that the operators had trouble controlling. A short time later, the planned test was initiated, the power began to rise, coolant voiding increased and, recognizing the potential consequences, the operators began insertion of all control rods. However, the displacement of the coolant this produced led to increased reactivity and a huge surge in the power level. This was sufficient to cause fuel disintegration and a breach in the cladding that caused

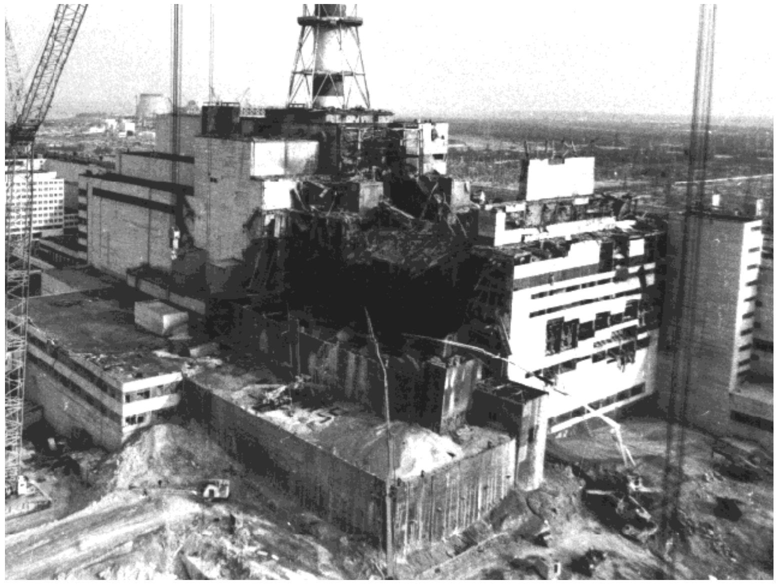

Figure 2: Photograph of the Chernobyl accident site taken shortly after the accident (USNRC 2006).

a huge steam explosion (see section 7.6.4) that lifted the top off the reactor, blew off the building roof and sent a plume of radioactive gases and particulates high into the atmosphere. The intense fire in and exposure of the nuclear core not only resulted in destruction of the reactor and the death of 56 people but also caused radiation sickness in another 200-300 workers and firemen. It also contaminated a large area in Ukraine and the neighboring country of Belarus (see figure 3). It is estimated that 130,000 people in the vicinity of the reactor received radiation above international limits. The photograph in figure 2 demonstrates how extensive the damage was to the reactor building.

This reactor not only did not have a secondary containment structure that might have prevented much death, injury and contamination but it was also of the type that could have a positive void coefficient (see section 7.1.2) that may or may not have been a factor during the lead-up to the fuel disintegration. Eventually, with great difficulty and with considerable risk to human life, the remains of the reactor were covered in concrete. Plans to enclose the whole mess with an additional 107 m tall, semi-cylindrical containment building that will be slid over the top of the damaged reactor building are currently underway (see figure 4).

The Chernobyl disaster demonstrated the serious safety deficiencies in these old Russian nuclear power plants. As in the case of Three Mile Island accident, the sequence of events that led up to the power surge were not adequately anticipated and the bypassing of some of the safety systems may have been a contributing factor. Most notably the lack of several layers of reactor confine-

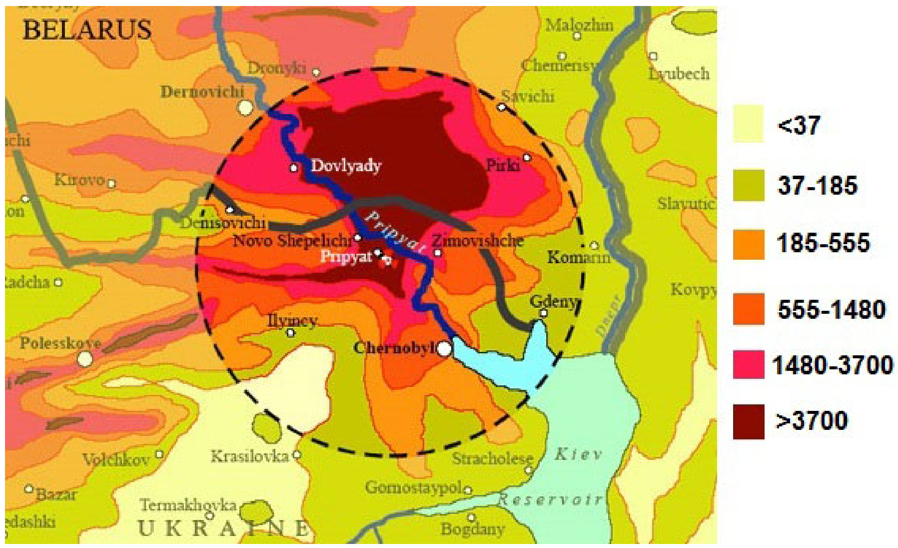

Figure 3: Map of the radioactive deposits (radioactivity of ^{137}Cs in the soil in kBq/m^2) on Apr.27, 1986, and the 30 km exclusion zone around the Chernobyl reactor (UNSCEAR 2000).

Figure 4: Cylindrical entombment structure (left) being prepared for installation over the damaged Chernobyl reactor (center). Photograph reproduced with the permission of the owner, Ingmar Runge.

ment, particularly a carefully designed secondary confinement structure, led to much more severe consequences than might otherwise have been the case. These old reactors have now been removed from service or radically altered and similar hypothetical mishaps have been carefully analyzed to ensure that there could be no repeat of the Chernobyl disaster.