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X?II Degradation to Core Melt

Consideration has been given to the unlikely possibility that all cooling to the core might still be lost and a meltdown of the fuel occurring. Detailed computer analyses have been performed to examine the progression of such a meltdown in the presence of varying degrees of containment engineered safety features (ESFs). ~~summarized in Table 1~~. The ESFs will not significantly affect the progression of a postulated molten core itself but are important in mitigation of radioactive releases.

The major assumptions in these analyses are: (1) all flow and cooling to the core is assumed to stop at 14 days (t_o) after reactor trip; (2) the reactor coolant system (RCS) is water-solid; and (3) decay heat levels and core temperatures are consistent with the 14 days of decay. The progression of the accident is as follows:

- t_o + 28.4 hrs.
  Water level in the RCS has dropped to the top of the core due to boiloff out the pressurizer safety/relief valves.

- t_o + 31.4 hrs.
  Water level continues to drop and fuel temperatures reach the melting point; core melt begins.

- t_o + 36.1 hrs.
  A large fraction of the core (75-80%) has become molten and falls into the vessel lower head; the reactor vessel begins melting.

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- t_o + 36.2 hrs.

  Vessel head fails due to the combined effect of temperature and pressure stresses (the RCS is at ~2500 psia). The molten core drops into the reactor cavity.

Up to this point the containment pressure has been slowly increasing due to steam release from the RCS. In the pessimistic case where the containment spray system and the reactor building cooling system (RBCS) (fan coolers) are assumed not to be operating, containment pressure is about 46 psia at t_o + 36.2 hrs. When the vessel fails, a pressure pulse is generated because of the release of the RCS pressure and rapid steam generation when the molten core falls into the water in the reactor cavity. Containment pressure peaks at about 70 psia. If hydrogen burning occurs at this time, roughly an additional 15 psi would be added to the pressure peak. The combined pressure loadings at the time of vessel failure indicate a critical time in the meltdown progression. If the combined loads were sufficient to fail the containment (an unlikely circumstance), then a significant radioactive release to the environment could occur. However, on a more realistic basis, containment would be expected to sustain this pressure transient.

After a temporary quenching of the molten core by water in the reactor cavity, the core-basemat concrete interaction begins. The progression of the interaction is not significantly affected by the operability of containment ESFs. From the time t_0 + 38.5 hrs. to t_o + 58.5 hrs., the core penetrates roughly 40 cm. into the basemat. During this progression and with containment ESFs operating, the containment pressure rises slowly, but is calculated not to reach the failure pressure of about 130 psia. As such, radioactive releases are very small.

In the pessimistic case where containment ESFs are not operating, the core-concrete interaction causes a steady increase in containment pressure. At time t_o + ∿12 days, pressure has risen to the failure point of the containment (∿130 psia) due to continued steam generation without containment heat removal (i.e., without the reactor building cooling system). Because of the long time periods involved in this accident sequence, the amount of radioactive material released to the environment is calculated to be minor.

Consideration was given to the possibility that hydrogen burning would occur at various times throughout the course of the accident. The magnitudes of the resultant pressure spikes were calculated and added to the existing pressure within the containment. If the hydrogen burns as it is released from the primary system, the rates of energy input into the containment atmosphere are relatively low and the effect on the containment pressure is minor. If, on the other hand, the hydrogen accumulates above flammable limits before ignition and then burns rapidly, significant pressure increases can result. The most critical time of potential hydrogen burning occurs at the time of vessel failure

(t_o + 36.2 hrs.), as discussed above. At this time, the composition of the containment atmosphere is near or barely in the flammable range. Burning of the hydrogen down to the flammability limit would produce a small pressure increment as previously noted. While it appears highly unlikely, the worst combination of hydrogen deflagration (complete reaction) together with steam production from the quenching of core debris would lead to the prediction of containment failure when containment ESFs are not operating. For the cases in which containment cooling functions, analyses indicate that the deflagration of hydrogen does not appear to threaten containment shortly following melt down. However, as time proceeds, the concentration of hydrogen in containment will continue to rise. If the oxygen content of the containment has not been decreased by prior burning, eventually a hydrogen concentration would be achieved which could fail containment. At this time, the air-borne concentration of radionuclides would be very low and the consequences of the additional release would be comparatively minor.

The possibility of steam explosions of sufficient energy to rupture containment was also considered in these analyses. Such explosions might occur at two times: when the molten core falls into the water in the lower vessel head, and when the molten core penetrates the vessel head and falls into water in the reactor cavity. Steam explosion experimental and analytical research in the recent past suggests that such explosions are not likely in a high pressure environment.

Thus a steam explosion is considered highly unlikely to occur when the molten core falls into the lower head (when surrounding pressures are approximately 2500 psia). The effect of a steam explosion occurring when the vessel head is penetrated was next considered; in this case, such an explosion might occur, but that it was judged that containment would not be grossly violated by the limited energetics of such an event.