WHAT IF THE CORE MELTED?

Sidebar 2:

The consequences of severe core damage may impose stresses on the containment building greater than heretofore envisioned. This last barrier to escape of radioactive fission products remained intact during the accident at the Three Mile Island Unit 2 reactor, but the President's Commission investigated its response to variations of the accident involving even worse core damage, The assumption of core damage, including fuel melting, presents several possibilities for breaching the structural integrity of the containment: a hydrogen explosion, a steam explosion, and interaction between molten fuel and the containment's concrete base. On the whole, the Commission's findings were reassuring, but further studies of the effects of severe core damage on containment integrity are continuing.

HYDROGEN EXPLOSION. During the Three Mile Island accident, reaction of steam and zirconium in the fuel-rod cladding produced a significant amount of hydrogen. Burning of some of this hydrogen in the containment created a pressure spike of about 2 bars, which is well below the design limit (about 4 bars) of the containment. The Commission considered the response of the containment to burning or detonation of the maximum amount of hydrogen, that is, the amount produced by reaction of all available zirconium. They concluded that burning of the hydrogen would not overstress the containment and, with less certainty, that detonation would impose a maximum load on the containment close to but below its structural limit.

Because the Three Mile Island containment building is stronger than some, these conclusions are not applicable to all light-water reactors. However, the problem of hydrogen detonation could be solved by installation of igniters in the containment to prevent accumulation of much more than a burnable mixture of hydrogen and air. Such igniters are being installed at the Sequoyah reactor, part of the Tennessee Valley Authority electrical system.

STEAM EXPLOSION. The term "steam explosion" refers to the violent (but nonchemical) interaction between hot molten metal and water. Such explosions have been observed in the metal and paper industries. They are accompanied by forceful discharge of water (and sometimes metal) from the zone of interaction. In some instances, surrounding structures have been damaged.

If molten fuel should fall into water remaining in the reactor vessel, a steam explosion could occur and damage the vessel and the containment by two mechanisms. One is generation of a high-pressure shock wave, as in a chemical explosion. But a steam explosion differs from a chemical explosion in two important respects: the peak pressure is lower by orders of magnitude and the risetime of the pressure pulse is considerably longer. Several studies indicate that a steam explosion would not cause vessel failure by this mechanism, and hence would not damage the containment.

The other mechanism involves the upward acceleration of a water and/or a fuel slug by expanding steam. Given sufficient energy, the slug could dislodge some portion of the upper vessel, which in turn could crash into the containment. This scenario requires simultaneous contact of sufficient quantities of molten fuel and water and in addition, highly efficient transfer of heat between fuel and water. It is considered very unlikely that either of these requirements can be satisfied.

The Commission's conclusion that a steam explosion would not cause failure of the containment is the same as that reached by a Swedish scientific committee in 1980 and is applicable to all light-water reactors.

FUEL CONCRETE INTERACTIONS. If massive core melting is assumed, failure of the vessel is likely and would lead to deposition of debris, consisting of molten fuel and structural materials, on the concrete base of the containment. Estimates of the time required for penetration of the base range from a minimum of 3 days to a maximum of infinity. Solidification of the debris, which is estimated to occur within 1 to 2 days, would slow but not halt erosion of the concrete and would reduce mobility of the fission products.

If penetration of the base should occur, interactions with the underlying bedrock are not significantly different from those with concrete; the site's geology would influence the ultimate fate of the fission products,

Gaseous products of the fuel-concrete interactions are predicted to overpressurize the containment only under extreme conditions, such as lack of containment sprays or decay-heat-removal capability. In addition, the hydrogen produced is not predicted to cause failure. ■