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5.0 Potential for Criticality

5.1 Evaluation of the Potential for Criticality

There are several scenarios in which the potential for criticality from spent fuel pool accidents exists:

(1) A compression or buckling of the stored assemblies could result in a more optimum geometry (closer spacing) and thus create the potential for criticality (see report titled "Assessment of the Potential for Criticality in Decommissioned Spent Fuel Pools" which is included as Appendix 7). Although not a problem for high-density PWR or BWR racks because of sufficient fixed neutron absorber plates to mitigate any reactivity increase, or for low-density PWR racks if soluble boron is credited, compression of a low-density BWR rack could lead to a criticality since it contains no soluble or solid neutron absorbing material. High-density racks are those that rely on both fixed neutron absorbers and geometry to control reactivity. Low-density racks rely solely upon geometry for reactivity control. In addition, all PWR pools are borated whereas BWR pools contain no soluble absorbing material. If both PWR and BWR pools were borated, criticality would not be achievable for a compression event.

(2) If the stored assemblies are separated by neutron absorber plates (e.g., Boral or Boraflex), loss of these plates could result in a potential for criticality for BWR pools. For PWR pools, the soluble boron would be sufficient to maintain subcriticality. The absorber plates are generally enclosed by cover plates (stainless steel or aluminum alloy). The tolerances within a cover plate will tend to prevent any appreciable fragmentation and movement of the enclosed absorber material. The total loss of the welded cover plate is not considered feasible.

Boraflex has been found to degrade in spent fuel pools due to gamma radiation and exposure to the wet pool environment. Because of this, the NRC issued Generic Letter 96-04 to all holders of operating licenses, concerning Boraflex degradation in spent fuel storage racks. Each addressee that uses Boraflex was requested to assess the capability of the Boraflex to maintain a 5% subcriticality margin and to submit to the NRC proposed actions to monitor or confirm that this 5% margin can be maintained for the lifetime of the storage racks. Many licensees have subsequently replaced the Boraflex racks in their pools or have reanalyzed the criticality aspects of their pools assuming no reactivity credit for Boraflex.

(3) If sufficient fuel rod cladding damage occurred such that many of the fuel pellets became loose in the pool, the pellets might be rearranged into a configuration that could lead to a potential for criticality. If the storage rack remained intact, that would tend to keep the pellets in separate regions and there would be no credible means for criticality. However, if there is large-scale cladding damage as well as damage to structural parts of the pool, this could allow a large fraction of the pellets to reassemble into a minimum leakage configuration in one region causing a potential for criticality.

If a loss of cladding integrity occurred, for example, because the cladding is brittle and could easily upon the impact from a foreign object (another assembly or fuel handling tool), it is highly unlikely that the damage would be very extensive. Thus, the number of

fuel pellets available to form some unfavorable configuration with a potential for criticality is considered quite remote, especially since spent fuel typically contains fission product absorbers and a relatively small percentage of fissile material. Therefore, the combination of both the limited extent of the expected damage and the need for a large amount of the optimally configured fuel suggests the potential for criticality is negligible for this case.

5.2 Evaluation of the Potential for Criticality From Personnel Actions in Response to an Accident

Without moderation, fuel at current enrichment limits (no greater than 5 wt% U-235) cannot achieve criticality no matter what the configuration. If it is assumed that the pool water is lost, a reflooding of the storage racks with unborated water or fire-fighting foam may occur due to personnel actions. However, both PWR and BWR storage racks are designed such that they remain subcritical if moderated by unborated water in the normal configuration. The phenomenon of a peak in reactivity due to low-density (optimum) moderation (fire-fighting foam) is not of concern in spent fuel pools since the presence of relatively weak absorber material such as stainless steel plates or angle brackets is sufficient to preclude neutronic coupling between assemblies. Therefore, personnel actions involving refilling a drained spent fuel pool containing undeformed fuel assemblies would not create the potential for a criticality.

5.3 Potential for Criticality Summary

Most of the fuel stored in spent fuel storage racks has been removed from reactor cores because it has lost sufficient reactivity to be useful in producing a self-sustaining chain reaction and in producing power. In addition, the reactivity of stored assemblies has continuously decreased even further during long-term storage due primarily to Pu-241 decay and Am-241 growth. However, the racks in a decommissioned plant will also contain some number of more reactive fuel assemblies (on the order of one third core) which has been discharged from the final cycle of operation. Most scenarios that could result in inadvertent criticality of stored spent fuel assemblies are considered to be highly unlikely. However, as discussed in Subsection 5.1(1) above and in the staff's report (Appendix 7), the compression of low density BWR storage racks was identified as a scenario that could lead to criticality. Therefore, we recommend the following compensatory measures. Either one of these will be necessary to provide reasonable assurance that a compression event of a low density storage rack will not lead to a criticality accident.

1. The most reactive fuel assemblies (most likely the fuel from the final cycle of operation) could be scattered throughout the pool, or placed in high density racks, if available; or
2. The storage pool, regardless of reactor type, could be borated.