

rods, which could lead to restricted coolant flow and ultimate core meltdown.

The event referred to by the petitioner occurred at the River Bend Station in 1999. A coolant chemistry excursion occurred with relatively high iron and copper levels, leading to unusually heavy crud deposition. As the licensee event report (LER 50-458/99-016-00) indicated, the occurrence of this event was unusual and only happened once. The NRC staff has not found any other nuclear power plants that experienced this unusually heavy crud formation. Although a thin oxidation layer appears in almost every operating reactor, the staff considers heavy crud build up to be extremely rare. Therefore, the probability of a large break LOCA occurring while some of the high power fuel bundles have severe crud deposition is significantly lower than that of the LOCA alone and thus reduces the estimated risk of this scenario.

2. The petitioner contended that if a fast moving LOCA had occurred with severe crud deposited on some high power fuel bundles, extensive blockage of the flow channels within the fuel bundles would likely have developed. In addition, he stated that during a blowdown, the redistribution of crud into any or all of several restricted channels would result in substantial flow blockage. The petitioner postulated that the crud would break off during a LOCA to form a blockage at the down stream fuel grid locations.

The operating experience relative to significant crud deposits has been that the observed crud is powdery or fluffy. During a large-break LOCA, even if crud broke off, only small solid particles are expected to be carried downstream. No data was provided in the petition to support the petitioner's rationale for crud blockage. The NRC also reviewed records of licensee event reports and found no test data or documents supporting the assumption that the crud might break off and form a flow blockage. Therefore, the NRC believes that the petitioner's concerns about the flow blockage due to crud are not supported by technical or scientific data.

3. The petitioner stated that if severe crud existed within the fuel bundles, the crud could lead to a loss of cooling with consequent overheating of zirconium and rapid autocatalytic zirconium-water reactions of the fuel cladding.

The NRC agrees that heavy crud could cause higher-than-normal fuel cladding temperatures due to the additional heat transfer resistance during normal operation and postulated accidents. In

particular, the porous form of crud could function as an insulator between the zirconium cladding and the coolant. If the metal-water reaction is assumed to occur, this additional layer of material would also form a shield between the coolant and the cladding material that would reduce the metal-water reaction rate. Should the metal-water reaction occur, the steam from the coolant stream would need to penetrate inward through the crud layer in order to reach the cladding, and the resulting hydrogen generated at the cladding surface would need to penetrate outward through the crud. Therefore, compared to a bare metal surface at the same temperature, a fuel rod with a layer of crud would be expected to have a reduced metal-water reaction rate, thus reducing the additional heat generated by the metal-water reaction. It would be inappropriate to consider only the additional heat transfer resistance and assume zero reduction of the metal-water reaction rate. Some locations where the crud has cracks would not see the reduction of the metal-water reaction. However, at these locations, it is expected that the steam would directly cool the bare metal surface and form a colder surface region before the temperature rose high enough to trigger the metal-water reaction. Therefore, the NRC has concluded that the petitioner's concern about autocatalytic zirconium-water reactions is not valid.

4. The petitioner asserted that 10 CFR 50.46 does not address the impact of crud on core cooling during the large-break LOCA.

Section 50.46 (b)(4) provides a requirement regarding the cooling of the core. This section states: "Calculated changes in core geometry shall be such that the core remains amenable to cooling". In addition, Section I.C.3 of Appendix K to part 50 states: "The following effects shall be taken into account in the conservation of momentum equation: \* \* \* (3) area change momentum flux \* \* \* (6) pressure loss resulting from area change \* \* \*". Many phenomena and mechanisms may cause a change in core geometry (e.g., the rod ballooning effect, thermal expansion, crud buildup). It is not necessary for the regulation to explicitly include all the possible mechanisms causing a change in core geometry.

Although the scenario of a large break LOCA coinciding with heavy crud formation is considered a low probability event, NRC's Standard Review Plan (SRP) for ECCS has already defined detailed requirements to monitor the effect of crud deposits. The SRP outlines a comprehensive set of

acceptance criteria that serve to demonstrate compliance with regulatory requirements. Three acceptance criteria that specifically address the impact of fuel crud deposits are provided below:

*SRP Section 4.2 Fuel System Design, Acceptance Criterion II.A.1.(d)*

"Oxidation, hydriding, and the buildup of corrosion products (crud) should be limited. Allowable oxidation, hydriding, and crud levels should be discussed in the Safety Analysis Report and shown to be acceptable."

*SRP Section 4.4 Thermal and Hydraulic Design (II. Acceptance Criteria)*

"8. The effects of crud should be accounted for in the thermal-hydraulic design by including it in the CHF [critical heat flux] calculations in the core or in the pressure drop throughout the RCS [reactor coolant system]. Process monitoring provisions should assure the capability for detection of a three percent drop in the reactor coolant flow. The flow should be monitored every 24 hours."

*SRP Section 4.4 Thermal and Hydraulic Design (III. Review Procedures)*

"The reviewer ensures that adequate account is taken of the effect of crud in the primary coolant system, such as in the calculation of CHF in the core, heat transfer in the steam generators, and pressure drop throughout the RCS."

The NRC staff believes that these guidelines adequately address the impacts of fuel crud on normal reactor operation and ECCS performance during a large break LOCA.

In addition, strong incentives exist for the nuclear industry to control crud buildup. Excessive crud formation could lead to operation at reduced power levels or even shutdown if coolant activity levels (suspended activated corrosion products) were to exceed technical specifications. Activated crud deposition throughout plant systems increases dose-rates that result in costly increases in worker doses. Because the industry is required to demonstrate efforts to maintain occupational doses as low as is reasonably achievable (ALARA), the NRC believes that incentives for optimizing power output and minimizing occupational doses are strong. EPRI water chemistry guidelines that the industry follows provide effective methods to control crud formation and buildup. Occupational doses over the past fifteen years have declined, and sustained power output levels have increased, suggesting that