FEDERAL REGISTER NOTICE

[7590-01-P]

NUCLEAR REGULATORY COMMISSION

10 CFR Part 50

[Docket Nos. PRM-50-73 and PRM-50-73A]

Mr. Robert H. Leyse; Denial of Petition for Rulemaking

AGENCY: Nuclear Regulatory Commission.

ACTION: Denial of petition for rulemaking.

SUMMARY: The Nuclear Regulatory Commission (NRC) is denying two related petitions for rulemaking submitted by Mr. Robert H. Leyse (PRM-50-73 and PRM-50-73A). The petitioner requested that the NRC revise its regulations to address the effect of crud on the cooling of the reactor core under the turbulent coolant flow conditions of a loss-of-coolant-accident (LOCA), and during normal operations. Crud is a colloquial term for corrosion and wear products (rust particles, etc.) that become radioactive (i.e., activated) when exposed to neutron irradiation. The petitioner states that crud buildup during normal operations and its detachment and resuspension during a LOCA could obstruct flow of coolant, resulting in inadequate cooling and ultimately leading to melting of the nuclear fuel. In addition, the petitioner requested that the NRC amend its regulations to include comparisons to applicable experimental data that address the impact of crud deposits on the ability to cool fuel rods.

ADDRESSES: Copies of the petitions for rulemaking, the public comments received, and the NRC's letter of denial to the petitioner may be examined, and/or copied for a fee, at the NRC's Public Document Room, located at One White Flint North, 11555 Rockville Pike, Public File

Area 01 F21, Rockville, Maryland. These documents are also available electronically at the NRC's Public Electronic Reading Room on the Internet at http://www.nrc.gov/reading-rm/adams.html. From this site, the public can gain entry into the NRC's Agencywide Document Access and Management System (ADAMS), which provides text and image files of NRC's public documents. For further information contact the PDR reference staff at 1-(800) 387-4209, (301) 415-4737 or by e-mail to pdr@nrc.gov.

FOR FURTHER INFORMATION CONTACT: Alan K. Roecklein, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, telephone (301) 415-3883, e-mail akr@nrc.gov.

SUPPLEMENTARY INFORMATION:

Background

Section 50.46 specifies the performance criteria against which the emergency core cooling system (ECCS) must be evaluated. Appendix K to Part 50 provides the required and acceptable features of ECCS evaluation models. The criteria are: 1) peak cladding temperature that cannot be exceeded, 2) the maximum cladding oxidation thickness, 3) the maximum total hydrogen generation, 4) assurance of a core geometry that can be cooled, and 5) assurance of abundant long term cooling. The regulations also state that assessments of cooling performance following postulated LOCAs must be calculated in accordance with an acceptable evaluation model and that in applying the model, comparisons to applicable experimental data must be made.

The petitioner identified numerous elements of the specified ECCS evaluation procedures and the evaluation model that he believed need to include additional comparisons to applicable experimental data.

The Petitions

The petition for rulemaking designated PRM-50-73 addressing potential crud interference with coolant flow during a fast-moving (large-break) LOCA, was sent to the NRC September 4, 2001, and the notice of receipt of the petition and request for public comment was published in the *Federal Register* (FR) on October 12, 2001 (66 FR 52065). The public comment period ended on December 26, 2001. On November 5, 2001, the supplemental petition, designated PRM-50-73A, was sent by the same petitioner alleging crud interference with coolant flow during normal operations. The notice of receipt of the second petition was published on January 29, 2002 (67 FR 4214). The public comment period ended on April 15, 2002. Five letters of public comment were received on PRM-50-73 and seven letters were received on PRM-50-73A. The NRC staff determined that the two petitions should be addressed as one action.

PRM-50-73

The petitioner stated that §50.46 and Appendix K to Part 50 do not address the impact of crud on core cooling during a fast-moving (large-break) LOCA. The petitioner noted that a licensed power reactor had operated with heavy crud deposits on many of the fuel rods. The petitioner stated that had a fast-moving (large-break) LOCA occurred before shutdown for refueling, extensive blockage of flow channels within the fuel bundles would have developed, leading to a degradation of core cooling and compromising defense-in-depth. The petitioner further stated that significant crud deposits could lead to an extensive fuel failure during full-

power operation and that the amount of failed fuel would then lead to a decision to shut down the reactor as the inventory of radioactive material in the reactor coolant reached the limits allowed by the technical specifications.

PRM-50-73A

The petitioner stated that §50.46 and Appendix K to Part 50 do not address the impact of severe crud deposits on fuel bundle cooling during normal power operations. The petitioner stated that a licensed power reactor had operated with unusually heavy crud deposits which, had they been allowed to build, would likely have blocked flow channels, interfered with core cooling and led to significant damage to structural components of the core. The petitioner requested that §50.46 and Appendix K be revised to include consideration of the impact of crud deposits on fuel bundles during normal operations.

Public Comments on the Petitions

PRM-50-73

The five letters of public comment received were opposed to this petition. Framatome ANP, a nuclear vendor, did not agree that crud would collect within the core as the petitioner suggested, nor that it would pose blockage problems. Framatome discussed the effects of crud for the sections of the regulations addressed by the petition, and stated that for each section, the effects of crud are adequately addressed. In Framatome's experience, typical crud formed on the surface of fuel cladding does not have the consistency to create coolant flow blockage during either normal operation or blowdown (i.e., a LOCA). Framatome ANP stated that thermal transients in the cladding and movement resulting from strain might promote crud

breakoff from the cladding but would produce small pieces that would be further broken down by the turbulence and velocity of the blowdown flow rates.

Exelon Nuclear, a power reactor licensee, stated that the petitioner's requested action was not necessary because 10 CFR 50.46 already requires that the cooling performance of the ECCS following postulated LOCAs meet certain acceptance criteria. Exelon stated that NRC regulatory guidance and approved ECCS evaluation models already address crud and other phenomena that could potentially impact performance relative to the acceptance criteria. Furthermore, Exelon Nuclear stated that it and its predecessors have over 30 years of experience in monitoring fuel performance in numerous nuclear power plants (NPPs) and that they have identified only one cycle, in one unit, with crud induced failures. Exelon further stated that corrective actions taken after those observed failures have resulted in no further failures due to crud at this or any other Exelon unit. In Exelon's experience, crud is powdery, and its characteristics, in terms of size or strength, indicate that it would not block the coolant flow channels and lead to fuel failures.

In general, Exelon asserted, industry experience related to significant crud deposits has been that they are isolated cases, and that after extensive root cause evaluations, effective corrective actions have prevented recurrence. Exelon also stated that crud deposits are effectively controlled through the use of the Electric Power Research Institute (EPRI) Chemistry Guidelines.

Westinghouse Electric Company, LLC, a nuclear vendor, opposed the petition based on its extensive poolside and laboratory examinations of crud deposits on fuel rods used in pressurized-water reactors (PWRs), including cases in which abnormally high levels of crud

could be detected during normal operation. Its results showed that it would be virtually impossible for any significant amount of the crud to contribute to flow blockage in the event of a large-break LOCA. Westinghouse also stated that most of any crud released would become suspended particles that would not affect core coolant flow. In one cited case, a water chemistry change resulted in a sudden release of all the accumulated crud in the core. A very small change in reactor coolant flow was observed as a result of this release.

GE Nuclear Energy, a nuclear vendor, opposed the proposed change on the basis that the event described in the petition was a unique event, not typical of crud buildup in boiling water reactors (BWRs). Even with that unusual buildup the core remained in a configuration that could be cooled throughout the cycle and would have remained in a configuration that could be cooled in the event of a LOCA. GE also stated that the safety evaluation concerning this event showed that, even with crud deposition, there would be substantial margin to the 2200 °F peak cladding temperature acceptance criterion specified by 10 CFR 50.46.

The Nuclear Energy Institute (NEI), an industry group representing all U.S. commercial nuclear power plants, plant designers, architect/engineering firms, and fuel cycle facilities, opposed the petition. NEI stated that existing NRC regulations establish performance criteria for maintaining core cooling and specify realistic ECCS evaluation models that address potential impacts on these performance measures. NEI stated that numerous thermal-hydraulic phenomena are addressed in the technical evaluation models. However, the regulations are not overly prescriptive in terms of phenomena to be addressed, which allows for advances in the technical database and updating of the evaluation procedures without the need for rulemaking. Fuel performance and other performance measures are monitored routinely to ensure that core evaluation models accurately reflect real conditions.

NEI stated that considerable data has been accumulated on crud deposits and their impact on coolant flow properties. The data do not support the postulated existence of characteristics that might lead to a substantial blockage of flow. NEI believes that the provisions of 10 CFR 50.46 and Appendix K provide an adequate mechanism for ensuring that coolant flow and fuel performance are thoroughly monitored and maintained.

PRM 50-73A

Of the seven letters of public comment received in response to PRM-50-73A, two were submitted by the petitioner, and provided additional information and related technical support for his assertions in PRM-50-73 and PRM-50-73A. The other five letters opposed the request for rulemaking contained in PRM-50-73A.

NEI noted that it had commented on the initial PRM-50-73 and provided a copy of the initial NEI comment letter. With respect to the changes to the regulations for normal operating conditions requested in this supplemental petition, NEI stated that the changes are not needed. In NEI's view the NRC Standard Review Plan (SRP) specifies a comprehensive set of acceptance criteria that specifically address the impact of fuel crud deposits and ensure that fuel design limits are not exceeded during any conditions of normal operation, including the effects of anticipated operational occurrences. NEI stated that any accumulation of crud that interfered with coolant flow would be detected quickly by pressure drop monitoring throughout the reactor cooling system.

A consortium of nuclear power plants, Strategic Teaming and Resource Sharing (STARS), supported the arguments against the petition presented by NEI and stated that STARS opposed the subject petition. STARS stated that chemistry controls and core design

constraints are in place to reduce susceptibility to heavy crud deposition and that during operation, chemistry indicators and core power measurements are evaluated continuously for evidence of heavy crud deposition or movement. STARS also stated that visual inspections of fuel assemblies during refueling have found no evidence of heavy crud deposits. STARS stated that it does not believe that nuclear safety would be enhanced by adopting the requested rulemaking.

GE Nuclear Energy stated that the supplemental petition for rulemaking held no technical merit. GE stated that the requested revision of the ECCS evaluation basis and criteria is based on a single event that occurred at one plant during one cycle of operation; that the unique condition of heavy crud buildup has occurred only once in over 1,000 reactor years of BWR operation, and the postulated scenario (rapid and uncontrollable fuel and core melt) is not a credible scenario as shown by the damage characteristics observed for the cited event; and that the postulated inability to effectively detect and mitigate the occurrence of a heavy-crud-induced fuel damage condition during normal operation is invalid, as was adequately shown by the responsible and effective actions taken by the affected plant.

Tennessee Valley Authority (TVA), a nuclear power plant licensee, stated that the requested revisions in the supplemental petition are unnecessary because current regulations adequately address the impact of fuel crud deposits on the cooling of nuclear fuel during normal reactor operations. In addition, TVA supported the comments submitted by NEI.

Westinghouse Electric Company opposed the action requested in PRM-50-73, stating that the postulated scenario leading to rapid core melting is completely speculative and is not supported by technical or scientific data. Westinghouse also noted that the regulations

recommended for modification in PRM-50-73A are not related to normal operating conditions, but rather apply to LOCAs.

NRC Technical Evaluation

The NRC reviewed each of the petitioner's claims and provides the following analysis.

1. The petitioner stated that a licensed power reactor operated with unusually heavy crud deposits on many of the fuel 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 crud control incentives and methods are effective.

5. In PRM-50-73A, the petitioner contended that if the deposits continued to build during normal reactor operation, a severe crud buildup might form. Blockage of the flow within the fuel bundles would likely develop and overheating of the cladding would trigger an autocatalytic [i.e., self-propagative] zirconium-water reaction. Subsequently, the petitioner stated that buildup could initiate substantial and rapid localized core melting while the reactor is at (full) power. Further, the petitioner contended that a reactor may be operated within its licensing basis and the technical specifications during the transition from unusually heavy crud to severe crud. The petitioner made a hypothesis that the increase of the off-gas system activity would not be regarded as an indicator of a possible heavy crud deposition and, therefore, the plant would continue to operate until the transition from heavy crud deposition to a severe level occurs.

Crud build-up is generally a very slow process. With water chemistry control, the transition time from heavy crud to severe crud deposition will be on the order of weeks. Even before the formation of a heavy crud layer, the elevated cladding temperature due to crud can cause crud-assisted corrosion which usually results in pin-hole type fuel cladding damage. The longer the rod experiences the elevated temperature caused by the crud, the more damage to the fuel rod cladding would occur. With only a few fuel rods damaged, the off-gas activity would increase. Abnormally high activity readings in the off-gas system require operators to take action to mitigate fuel cladding damage. In several cases at different operating reactors, the operators were able to adjust the control rod pattern to lower the local power peaking factor around the damaged fuel bundles after the high off-gas system activity reading was observed even though the activity levels were below the technical specifications limit. Therefore, observed practice shows that fuel cladding damage due to excess crud formation is readily detectable during normal operation, and effective mitigation measures have been taken by operators.

Under conditions where heavy crud deposition occurs, fuel damage could eventually lead to cladding cracks or ballooning effects. The crud layer may then break off and fuel pellets will be cooled directly by the water, thus lowering the cladding temperature. Although the elevated cladding temperature could theoretically trigger a metal-water reaction in a very limited area of the fuel cladding, the crud also shields the cladding from the water and causes significant resistance to the metal-water reaction. Therefore, the NRC has concluded that the petitioner's concern about autocatalytic zirconium-water reactions is not valid.

Furthermore, the NRC has not found any evidence to support the petitioner's view that the off-gas activity would stay below the technical specification limit while the heavy crud deposition continues. Operating experience has shown that if a reactor operates continuously

under heavy crud conditions, the cladding damage will result in higher off-gas activity readings that are quickly noted by the plant operators. It is highly unlikely that the off-gas activity would remain undetected by plant operators. Recent operating experience at plants with leaking fuel demonstrates that plant operators quickly take action to suppress fuel leaks, and in many cases, shut down the reactor to inspect and replace leaking fuel.

Finally, crud formation is one of many items which are required to be considered for both LOCA and transient safety analyses, and existing regulations and the NRC Standard Review Plan already provide adequate guidance on addressing the impact of crud on plant safety.

NRC Strategic Performance Goals

The NRC has evaluated the advantages and disadvantages of the rulemaking requested by the petitioner with respect to the four NRC Strategic Performance Goals as follows:

1. Maintaining Safety: The NRC believes that the requested rulemaking would not make a significant contribution to maintaining safety because current regulations and regulatory guidance already address the effect of crud-related parameters on core cooling, because no existing data suggests that the amount of crud normally deposited on reactor fuel can significantly interfere with coolant flow, and because the probable cause of the single event at River Bend Station noted by the petitioner, namely a transient coolant chemistry excursion with high iron and copper levels, is known and has been corrected. The NRC believes that existing regulations, guidance and practices provide for monitoring, detecting and correcting any possible crud effects on core cooling before any significant safety problems could occur.

2. Enhancing Public Confidence: The NRC believes that the proposed revisions would not enhance public confidence. First, the NRC has concluded that the petitioner's contentions lack an adequate technical basis. Second, current regulations and guidance already address the effects of normal crud accumulation on core cooling. The petitioner's request in effect would require that substantial, additional consideration be given to abnormally heavy accumulations of crud as a potential source of coolant flow obstruction, which is a condition that has never been observed. Taking such an unnecessary action may actually detract from public confidence in the NRC as an effective regulator.

3. Improving Efficiency, Effectiveness, and Realism: The proposed revisions would not improve efficiency, effectiveness, and realism because licensees would be required to generate unnecessary additional information as part of the development of their ECCS evaluation models and the NRC would need to evaluate the licensee's data and analysis. The NRC staff believes that this additional consideration is unnecessary because the petitioner's scenarios are not supported by a technical basis. The additional NRC staff and licensee effort would not improve efficiency or effectiveness. In addition, the NRC resources expended to promulgate the rule and supporting regulatory guidance would be significant and is unnecessary.

4. Reducing Unnecessary Regulatory Burden: The requested rule would increase licensee burden by unnecessarily requiring significant additional testing and analysis of ECCS effectiveness.

Reasons for Denial

The Commission is denying the petitions for rulemaking. Section 50.46 currently requires a nuclear power plant applicant/licensee to address the impacts of the core geometry change on cooling in ECCS analyses. An acceptable implementation of this requirement has

been documented in the Commission's Standard Review Plan, which specifically addresses the potential buildup of crud and its effects for ECCS analyses and transient analyses. The petitioner's hypothetical discussion of fuel clad performance with severe levels of crud buildup was not supported by modeling, experimental results or operational data sufficient to demonstrate that fuel with high crud levels will actually behave in the manner postulated by the petitioner. The NRC believes that there are other phenomena the petitioner failed to consider that would tend to reduce metal-water reactions and counteract autocatalytic reactions even if the extreme conditions postulated by the petitioner could be reached. The operating experience at several nuclear power plants that have experienced fuel failures shows that fuel degradation has progressed in a manner which is controllable. The event (River Bend) identified by the petitioner as evidence of the likelihood of high crud levels occurred only once at that plant and has not been repeated there, or at any other plant in the United States. Finally, technical specifications for monitoring of reactor coolant activity and the requirements in 10 CFR Part 20 to maintain occupational exposures as low as reasonably achievable have resulted in licensee operational practices for early identification of coolant activity increase due to crud deposits before they build to the levels postulated by the petitioner. The Commission considers that the petitioner's hypothetical discussion of a mechanism preventing early detection of abnormal activity levels is not credible. For these reasons, the Commission has determined that the petitioner's bases for requesting rulemaking have not been substantiated.

For these reasons, the Commission denies PRM-50-73 and PRM-50-73A.

Dated at Rockville, Maryland, this 9th day of July, 2003.

For the Nuclear Regulatory Commission

/RA/
Annette Vietti-Cook,
Secretary of the Commission