[7590-01-P]

NUCLEAR REGULATORY COMMISSION

10 CFR Part 50

[Docket No. PRM-50-84]

Mark Edward Leyse; Receipt of Petition for Rulemaking

AGENCY: Nuclear Regulatory Commission.

ACTION: Petition for rulemaking; Notice of receipt.

SUMMARY: The Nuclear Regulatory Commission (NRC) has received and requests public comment on a petition for rulemaking dated March 15, 2007, filed by Mark Edward Leyse. The petition has been docketed by the NRC and has been assigned Docket No. PRM-50-84. The petitioner is requesting that the NRC amend the regulations that govern domestic licensing of production and utilization facilities to require that nuclear power facilities be operated to limit the thickness of crud (corrosion products) layers and/or the thickness of oxide layers on fuel rod cladding surfaces. The petitioner also requests that the requirements pertaining to Emergency Core Cooling System (ECCS) evaluation models be amended to require that the steady-state temperature distribution and stored energy in reactor fuel at the onset of a postulated loss-of-coolant accident (LOCA) be calculated by factoring in the role that the thermal resistance of crud and/or oxide layers on cladding plays in increasing the stored energy in the fuel. Lastly, the petitioner requests that the acceptance criteria for emergency core cooling systems for light-water nuclear power reactors be amended to stipulate a maximum allowable percentage of hydrogen content in cladding of fuel rods.

DATE: Submit comments by (75 days following publication in the *Federal Register*). Comments received after this date will be considered if it is practical to do so, but assurance of consideration cannot be given except as to comments received on or before this date.

ADDRESSES: You may submit comments by any one of the following methods. Please include the following number (PRM-50-84) in the subject line of your comments. Comments on petitions submitted in writing or in electronic form will be made available for public inspection. Because your comments will not be edited to remove any identifying or contact information, the NRC cautions you against including personal information such as social security numbers and birth dates in your submission.

Mail comments to: Secretary, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Attention: Rulemaking and Adjudications staff.

E-mail comments to: SECY@nrc.gov. If you do not receive a reply e-mail confirming that we have received your comments, contact us directly at (301) 415-1966. You may also submit comments via the NRC's rulemaking website at http://ruleforum.llnl.gov. Address comments about our rulemaking website to Carol Gallagher, (301) 415-5905; (e-mail cag@nrc.gov). Comments can also be submitted via the Federal eRulemaking Portal http:www.regulations.gov.

Hand deliver comments to 11555 Rockville Pike, Rockville, Maryland, between 7:30 am and 4:15 pm on Federal workdays.

Publicly available documents related to this petition may be viewed electronically on the public computers located at the NRC Public Document Room (PDR), O1 F21, One White Flint North, 11555 Rockville Pike, Rockville, Maryland. The PDR reproduction contractor will copy documents for a fee. Selected documents, including comments, may be viewed and downloaded electronically via the NRC rulemaking website at http://ruleforum.llnl.gov.

Publically available documents created or received at the NRC after November 1, 1999 are also available electronically at the NRC's Electronic Reading Room at *http://www.nrc.gov/reading-rm/adams.html.* From this site, the public can gain entry into the NRC's Agencywide Documents Access and Management System (ADAMS), which provides text and image files of NRC's public documents. If you do not have access to ADAMS or if there are problems in accessing the documents located in ADAMS, contact the NRC PDR Reference staff at 1-800-397-4209, 301-415-4737 or by e-mail to pdr@nrc.gov.

For a copy of the petition, write to Michael T. Lesar, Chief, Rulemaking, Directives and Editing Branch, Division of Administrative Services, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001.

FOR FURTHER INFORMATION CONTACT: Michael T. Lesar, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Telephone: 301-415-7163 or Toll-Free: 1-800-368-5642 or E-mail: MTL@NRC.Gov.

SUPPLEMENTARY INFORMATION:

Background

The NRC has received a petition for rulemaking dated March 15, 2007, submitted by Mark Edward Leyse (petitioner). The petitioner requests that the NRC amend 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities." Specifically, the petitioner requests that all holders of operating licenses for nuclear power plants be required to operate such plants at operating conditions (*e.g.*, levels of power production, fuel cycle lengths, and light-water coolant chemistries) necessary to effectively limit the thickness of crud (corrosion products) layers and/or oxide layers on fuel rod cladding surfaces. The petitioner believes that new regulations are needed for reactor-operation parameters, uranium-oxide and mixed-oxide fuel and cladding, in order to ensure that cladding is free of unsafe thicknesses of crud and/or oxide, which in turn would help ensure that nuclear power plants operate in compliance with 10 CFR 50.46(b). 10 CFR 50.46(b) stipulates that the calculated peak cladding temperature (PCT) must not exceed 2200°F in the event of a loss-of-coolant accident (LOCA). The petitioner also requests that 10 CFR Part 50, Appendix K, "ECCS Evaluation Models" be amended to require that the steady-state temperature distribution and stored energy in the fuel at the onset of a postulated LOCA be calculated by factoring in the role that the thermal resistance of crud and/or oxide layers on cladding plays in increasing the stored energy in the fuel. Lastly, the petitioner requests that § 50.46 be amended to stipulate a maximum allowable percentage of hydrogen content in fuel cladding.

The NRC has determined that the petition meets the threshold sufficiency requirements for a petition for rulemaking under 10 CFR 2.802. The petition has been docketed as PRM-50-84. The NRC is soliciting public comment on the petition for rulemaking.

Discussion of the Petition

The petitioner states that layers of crud and oxide on cladding surfaces of nuclear fuel rods could cause the temperature of fuel rods to increase up to 300°F to 600°F during power plant operations. The petitioner also states that during a LOCA, the thermal resistance of insulating layers of crud and oxide on cladding, and increased fuel temperatures will cause the PCT to be higher than if the cladding were clean. The petitioner believes that if a large break (LB) LOCA occurred at a nuclear power plant that operated with heavy crud and oxide layers, there is a high probability that the PCT would exceed the 2200°F limit in § 50.46(b)(1). The petitioner states that increased hydrogen content in cladding contributes to cladding embrittlement. The petitioner believes that § 50.46 should also be amended to specify a maximum allowable percentage of hydrogen in cladding.

The petitioner states that in 2001, the Indian Point Unit 2 facility had a PCT of 2188°F during a computer simulated LB LOCA. The petitioner believes that if heavy crud and oxide layers were present and included in the calculation, it is "highly probable" the calculated PCT would have exceeded the 2200°F limit, perhaps by hundreds of degrees Fahrenheit. The petitioner states that if the 2200°F limit was exceeded during actual operation, the cladding could lose its physical integrity and result in a core meltdown that would release radioactive material and contaminate the environment. The petitioner states that in 1995, the Three Mile Island Unit 1 facility (TMI-1) operated with crud deposits on the surface of fuel rods that raised the cladding temperature by 180 to 270°F or greater over the typical operating temperature of 346°C during Cycle 10. The petitioner believes that if an actual LB LOCA had occurred at TMI-1, the crud and oxide layers on the cladding would have caused the PCT to exceed 2200°F.

The petitioner states that because corrosion is not detected during plant operation, a significant length of time passes before corrosion progresses enough to perforate cladding and cause an increase in "offgas" activity meaning that heavily corroded fuel rods are often operated at full power for significant periods of time and could cause the cladding to fracture during the reflood period and lose structural integrity. The petitioner concludes that this could compromise the structural soundness and the ability to keep the core cooled and illustrates the impact that the thermal resistance of heavy layers of oxide and crud on cladding would have during a LOCA.

The petitioner cites a September 30, 2003, Advisory Committee on Reactor Safeguards (ACRS) meeting transcript stating that the thickness of crud deposited on the cladding during pressurized water reactor (PWR) plant operation is often not known because "a great deal of PWR crud comes off the cladding during reactor shutdown." The petitioner notes that crud deposits on cladding in PWRs have been measured at up to 125μm thick. The ACRS found that a crud layer with steam blanketing would have "extremely poor conductivity" and that crud is "difficult to characterize" because its thermal conductivities "depend on [its] morpholog[ies]." The petitioner also cites an Electric Power Research Institute (EPRI) study to be completed in 2008 that will attempt "to determine the effect of tenacious crud on fuel surface heat transfer." The petitioner notes that this study is for crud in a boiling water reactor (BWR) but believes the results can also be applied to PWRs.

The petitioner also notes that the EPRI study found that Zirconium dioxide (ZrO2) has a low thermal conductivity and is used industrially as an insulating material. The petitioner cites an EPRI-sponsored study entitled, "Taming the Crud Problem: The Evolution," presented at the

Advances in Nuclear Fuel Management II Conference in October 2003 which states that: "Oxide can form, with or without the benefit of crud, in the presence of sustained cladding temperatures. Like crud, formation of an oxide layer inhibits heat transfer causing accelerated corrosion which can potentially lead to fuel failure."

The petitioner describes a fuel rod that failed at TMI-1 during Cycle 10 that may have had about a 200μm-thick layer of crud and oxide. The petitioner believes that if a LB LOCA occurred during this fuel cycle, the layer of crud and oxide would have inhibited effective heat transfer and likely caused the PCT to exceed 2200°F, possibly causing a meltdown. The petitioner also reiterates that in 2001, the Indian Point Unit 2 facility had a PCT of 2188°F in a computer simulated LB LOCA. The petitioner believes that if Indian Point Unit 2 had cladding conditions similar to those of TMI-1 Cycle 10, it is highly probable the PCT would also have been greater than 2200°F. The petitioner states that TMI-1 is not the only PWR to experience crud-induced corrosion failures. In 1997, the Palo Verde Unit 2 and Seabrook facilities both had the same problem.

The petitioner cites NUREG-1230, "Compendium of ECCS Research for Realistic LOCA Analysis" and states that the stored energy in the fuel increases because cladding encased in heavy amounts of crud and oxide cannot transfer heat efficiently to coolant during the blowdown phase of the event. The petitioner states that the increased stored energy caused by heavy crud and oxide layers on fuel cladding and the delay in the transfer of the heat to the coolant cause the cladding to be subjected to extremely high temperatures for much longer than if the cladding was clean (free of crud and oxidation) at the onset of the LOCA. The petitioner believes that this would result in more degradation of the fuel and embrittlement of cladding. The petitioner also states that when the cladding reacts with steam, an exothermic reaction occurs that generates additional heat on the cladding.

The petitioner cites an ACRS meeting transcript from February 2, 2007, in which an

NRC staff member explained that a basic LOCA transient calculation includes an oxidation limit and involves time and temperature. The petitioner also notes that NUREG-1230 states that embrittled cladding can fragment upon contact with emergency cooling water in a severe accident. The embrittlement is a function of temperature, time, the supply of steam and zircaloy, and can lead to the loss of effective cooling, making it relevant to fuel rod safety. The petitioner also notes that NUREG-1230 also states, “[the] amount of residual thermal energy [in the fuel rod] influences the *time* required to quench the reactor core with emergency cooling water [emphasis added].”

The petitioner states that absorption of hydrogen would also contribute to a loss of cladding ductility during a LOCA along with cladding degradation and massive oxidation. He cites a failed fuel rod from the TMI-1, Cycle 10 event when hydrogen absorption caused hydrided material to break away from the outer portions of the cladding. The petitioner believes that the effects of increased stored energy due to a heavy crud layer in the fuel and the severity of cladding oxidation, embrittlement, and resulting fuel degradation during an actual event would be substantially greater than in an ECCS calculation based on clean cladding.

The petitioner also states that little or no evidence exists that crud has ever been properly factored into PCT calculations for postulated LOCAs. He cites a June 17, 2003, Idaho National Engineering and Environmental Laboratory document that he believes stated that crud has not been applied to severe accident codes because it has not been demonstrated to be necessary and that users have not chosen to consider effects of crud. The petitioner also cites the 2002 annual report on ECCS evaluation from the Callaway facility that he believes proves that “little attention” was placed on effects of heavy crud on thermal resistance. The petitioner states that most cladding that experienced crud-induced corrosion failures recently at PWRs involved high-power, one-cycle fuel. He cites the TMI-1, Cycle 10 and Callaway, Cycle 6 events as examples and notes that the effects of crud can occur quickly. The cladding perforation at

TMI-1 was detected only 121 days into the cycle.

The petitioner states that the values of the stored energy in BOL fuel or fuel with burnups between 30 to 35 GWd/MTU are used to calculate PCTs during postulated LOCAs. The petitioner also believes it is significant that the stored energy of fuel sheathed in cladding with heavy crud and oxide layers is substantially higher than fuel of the same burnup rate sheathed in clean cladding that he states is used in PCT calculations performed for postulated LOCAs and during safety evaluations of the certification process of newer designs such as the Westinghouse AP 1000 reactor. The petitioner believes that the AP 1000 PCTs were not calculated for the maximum stored energy that fuel can reach during operation and that recent experiences with fuel at TMI-1, Palo Verde Unit 2, and Seabrook were not considered in PCT calculations performed during recent power “uprates” at other nuclear power facilities.

The petitioner states that axial offset anomaly (AOA) or crud-induced power shift (CIPS) are phenomena caused by crud on cladding and can indicate how frequently crud affects nuclear power plant operation. The petitioner also states that AOA occurs in PWRs when crud deposits on cladding contain enough boron to reduce the rate of fission in the vicinity of the crud. He cites NRC Information Notice 97-85, “Effects of Crud Buildup and Boron Deposition on Power Distribution and Shutdown Margin” that describes how AOA causes power distribution shifts toward the bottom of the reactor core as a result of reduced fission in the upper reactor core. The petitioner states that although crud deposits must be at least 35μm thick for AOA to occur, it is possible that crud deposits thicker than 35μm do not cause AOA because not all crud deposits contain enough boron to cause this phenomenon. The petitioner also states that according to a 2002 Department of Energy report on nuclear energy plant optimization, the thickest layer of crud measured in a PWR was 125μm thick that caused AOA but not cladding perforation and that as of 2003, more than 30 fuel cycles in 16 PWRs had exhibited AOA.

The petitioner also cites a 2006 EPRI report that acknowledged that crud has contributed to AOA at many power plants since the 1980s because fuel cycle operation and power up rates have increased appreciably and that excessive crud deposits create operational difficulties. According to a Westinghouse Electric Company official, AOAs are detectable and closely monitored to ensure that adequate shutdown margins can be maintained. Also, a plant can be operated at a lower power level if necessary. The petitioner cites the TMI-1, Cycle 10 event as an example that illustrates how low levels of boron can result in a slight AOA even though enough crud was present to induce fuel failure from corrosion. The petitioner states that if a heavy crud layer was detected during plant operation that did not cause an AOA, it is unlikely that the operation power level would be reduced because the thermal resistance of the crud and how it would raise the PCT during a LOCA would likely not be considered problematic.

The petitioner describes what he believes was a crud-induced cladding corrosion failure of fuel in a BWR at the River Bend facility during Cycle 8 from 1998-99. The petitioner states that the fuel failure occurred when crud nearly bridged the gap between adjacent rods and believes it is significant that most of the failed rods were high-power, one-cycle rods (much like the recent corrosion-induced PWR fuel failures during the TMI-1 Cycle 10, Palo Verde Unit 2 Cycle 9, and Seabrook Cycle 5 events). The River Bend Cycle 8 fuel failure resulted from thick layers of crud, augmented with copper that accelerated the oxidation process to produce a local steam blanketing and high heat transfer resistance that created perforations in the fuel cladding according to the “Recent GE BWR Fuel Experience” report published in 2000 by the American Nuclear Society and the NRC inspection report pertaining to this event. The petitioner concludes that the combined effects of crud and oxide layers increased the cladding temperatures from around 560°F to temperatures approaching 1200°F.

The petitioner states that if a LOCA had occurred during this event, the PCT could likely have exceeded the 2200°F limit specified in § 50.46. The petitioner acknowledges that the NRC Licensee Event Report (LER) 50-458/99-016-00 states that the PCT was calculated to have been 1700°F or less and demonstrates a substantial margin to the 2200°F limit. However, the petitioner states that the LER ignores NRC guidelines for calculating the equivalent cladding reacted (ECR) and believes that the PCT would have exceeded 1700°F during a LB LOCA. The petitioner states that in 2000 when this LER was filed there was not much knowledge about values for the thermal conductivity of crud and how crud layers should be modeled in severe accident codes and believes this lack of knowledge still exists in 2007. The petitioner reiterates there is little or no evidence that crud has ever been properly factored into PCT calculations for simulated LOCAs at nuclear power plants.

The petitioner states that essentially the same cladding condition occurred again at the River Bend facility between October 2001 to March 2003 during the Cycle 11 refueling event after a GE Nuclear Energy official had stated that heavy crud buildup during the Cycle 8 event was unique and had occurred only once in over 1000 reactor years of operation. He cites a paper presented at the 2004 International Meeting on LWR Fuel presented by the American Nuclear Society, "Fuel Failures During Cycle 11 at River Bend." This paper stated that this fuel rod failure was caused by accelerated oxidation of the cladding resulting from unusually heavy deposits of tenacious crud that diminished heat transfer in local areas of the cladding surface. The petitioner notes that the failures occurred in high power, one-cycle rods where heavy crud and oxide layers were present. The petitioner believes that the PCT during a LB LOCA would have exceeded the 2200°F limit specified in § 50.46 and means that the ECCS design basis for River Bend is non-conservative for calculating the PCT for a postulated LOCA when heavy crud and oxide layers exist on cladding.

The petitioner disputes GE Nuclear Energy's conclusion that because the heavy crud deposits on fuel rods at the River Bend facility occurred at the lower elevations of the fuel assembly and the more limiting axial elevations during a postulated LOCA occur at the upper elevations of a fuel assembly where at River Bend the crud characteristics were normal, the heavy crud deposits would have no significant effect on the fuel response to a postulated LOCA. The petitioner states that the cladding surface temperatures during the River Bend events reached 1200°F, far above the specified licensing basis of about 578°F. The petitioner believes that the higher temperatures due to the heavy crud and oxide layers would result in less coolant flow than for clean cladding, would cause the cladding to be subjected to extremely high temperatures for a substantially longer duration than used in the licensing basis, and result in more fuel degradation. The petitioner also believes that the degradation of fuel and cladding would further obstruct reflood coolant flow, delay transfer of stored energy to the coolant during quench, and that during a LOCA there would already be severe cladding degradation, massive oxidation, and absorption of hydrogen that would contribute to a loss of cladding ductility. The petitioner has concluded that these factors mean that the River Bend facility operated in violation of §50.46(b) during cycles 8 and 11 of refueling. The petitioner also states that the Browns Ferry facility operated from April 2001 to March 2003 with thick oxide layers at the upper elevations of the fuel rods and believes it is significant that the heavy crud and oxide layers that caused overheating and cladding perforations at TMI-1 during cycle 10 were located at upper elevations of fuel assemblies.

The petitioner cites a 2004 paper, “An Integrated Approach to Maximizing Fuel Reliability” stating that a lack of understanding exists about the interplay of materials, fuel duty, and water chemistry variables and reports that crud or corrosion related fuel failures occurred at BWRs in six of the years between 1997 to 2004. The petitioner also cites an EPRI document, “2006 Portfolio 41.002 Fuel Reliability” which states that the fuel failure rate has increased in both BWRs and PWRS during the last couple of years due to extended and more aggressive fuel cycle operation. The petitioner states that although the nuclear industry observed that it appeared that nodular corrosion had been eliminated from BWR fuel cladding in 2000, by 2004 it had reemerged at several BWRs. The petitioner believes this is a result of increasing fuel duty by extending the length of fuel cycles and that problems with crud and oxide will continue unless the NRC implements regulations to ensure that BWRs and PWRs do not operate with high levels of crud and oxidation on cladding that cause violations of § 50.46(b).

The petitioner states that Appendix K to 10 CFR Part 50, "ECCS Evaluation Models" requires stored energy in nuclear fuel to be calculated to yield the highest PCT. The petitioner believes that Appendix K should require thermal conductivity of layers of crud and oxide to be factored into calculations of the stored energy in the fuel. The petitioner states that because a heavy crud layer would increase the quantity of stored energy in the fuel, the PCT would also increase above that of fuel with the same burnup sheathed in clean cladding. The petitioner also states that instructions specified in Appendix K for calculating the quantity of stored energy that contains heavy layers of crud and oxide are non-conservative.

The petitioner notes that values of stored energy in BOL fuel or fuel with burnups between 30 to 35 Gwd/MTU are used to calculate PCTs during postulated LOCAs. However, the petitioner cites a January 2007 ACRS Subcommittee on Materials, Metallurgy, and Reactor Fuels during which a Westinghouse official cited data from LOCA calculations showing that single cycle fuel with burnups from zero to approximately 20 or 25 GWd/MTU yielded the highest PCTs. Westinghouse also stated that at burnups of about 30 GWd/MTU, there is approximately a ten percent reduction in achievable power, which yields PCTs approximately 100°C lower than those of fresh fuel. The petitioner concludes it is significant that an ECCS design based on Appendix K requirements is non-conservative and hazardous for calculating the quantity of stored energy in one-cycle fuel that has heavy crud on the cladding.

The petitioner states that an increase in hydrogen content in cladding contributes to cladding embrittlement. The petitioner cites an April 4, 2001, ACRS Reactor Fuels Subcommittee meeting during which an expert from Argonne National Laboratory stated that a reduction of ductility occurs when hydrogen levels reach about 600 to 700 parts-per-million (ppm) in Zircaloy cladding. According to the petitioner, another expert from the Atomic Energy Research Institute stated that a threshold for a reduction of ductility in Zircaloy cladding occurs at even a lower hydrogen level of about 150 to 200 ppm. The petitioner also cites the TMI-1 Cycle 10 event that included massive hydrogen absorption in fuel cladding. The petitioner notes that hydrogen content in the cladding of a rod that did not fail measured 700 ppm at TMI-1 and that this level of hydrogen content in one-cycle cladding is similar to the 800 ppm level measured in fuel cladding at the H.B. Robinson, Unit 2 facility, a PWR. The petitioner states that some of the cladding at TMI-1 Cycle 10 contained levels of hydrogen that Argonne National Laboratory found would have caused a loss of cladding ductility in addition to the embrittlement resulting from excessive oxide levels.

The Petitioner's Proposed Actions

The petitioner states that new regulations are needed for reactor operation parameters, uranium-oxide and mixed-oxide fuel, and fuel cladding to ensure that cladding does not contain unsafe amounts of crud and oxide to help ensure that nuclear power plants operate in compliance with 10 CFR 50.46(b). The petitioner also states that nuclear power plant licensees should be required to factor the thermal resistance effects of crud and oxide layers on cladding into calculations of PCTs for postulated LOCAs at their facilities. Also, the NRC needs to consider effects of crud and oxide when reviewing power plant operations reports under 10 CFR 50.46, and before approving power uprates at existing facilities and new nuclear power plant designs, such as the recently certified Westinghouse AP1000 design.

The petitioner requests that Appendix K to Part 50 be amended to require that the steady state temperature distribution and stored energy in the fuel at the onset of a postulated LOCA be calculated by factoring in the role that the thermal resistance of crud and oxide layers on cladding plays in increasing the stored energy in nuclear fuel. The petitioner also states that Appendix K should specify instructions to more accurately calculate the role that thermal resistance of crud and oxide layers on cladding plays in determining the stored energy in the fuel and the PCT during a postulated LOCA.

Lastly, the petitioner requests that § 50.46 be amended to include a requirement that stipulates a maximum allowable percentage of hydrogen content in cladding because there is extensive evidence that excessive hydrogen levels and oxidation on cladding contributes to cladding embrittlement. The petitioner concludes that the requested amendments should also apply to any NRC-approved, best-estimate ECCS evaluations used instead of Appendix K calculations. The petitioner believes its requested amendments would ensure that nuclear power facilities prevent unsafe amounts of crud and oxide layers on cladding from occurring during operation to reduce risks to plant workers and the public, and help nuclear power facility operations to comply with 10 CFR 50.46(b).

Dated at Rockville, Maryland, this 15th day of May 2007.

For the Nuclear Regulatory Commission.

/RA/

Annette L. Vietti-Cook,
Secretary of the Commission.