PRM-50-93
(75FR03876)

NUCLEAR ENERGY INSTITUTE

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RULEMAKINGS AND
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April 12, 2010

Ms. Annette L. Vietti-Cook
Secretary
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
Attn: Rulemakings and Adjudications Staff

Subject: Industry Comments on Petition for Rulemaking (PRM-50-93); Multi-Rod (Assembly) Severe Fuel Damage Experiments. Docket ID NRC–2009–0554

Project Number: 689

Dear Ms. Vietti-Cook:

The attachment to this letter provides comments from the Nuclear Energy Institute (NEI)[1] on behalf of the nuclear energy industry on the Petition for Rulemaking (PRM-50-93), in response to the *Federal Register* notice of January 25, 2010. This petition, dated November 17, 2009, requests that the NRC amend its regulations regarding the domestic licensing of production and utilization facilities.

Specifically, the petitioner requests that the NRC amend its regulations based on data from multi-rod (assembly) severe fuel damage experiments and promulgate a regulation that will stipulate minimum allowable core reflood rates in the event of a loss-of-coolant accident.

In support of this request, the petitioner cites results from two out of many tests performed over 25 years ago. The first of these tests was performed under non-prototypic conditions well beyond the envelope for current plant designs. Results from the second test were discounted by the original experimenters because of instrumentation problems. Neither one of these tests, whether reviewed in isolation or in combination with the other tests, support the changes to the regulations sought by

[1] NEI is the organization responsible for establishing unified nuclear industry policy on matters affecting the nuclear energy industry, including the regulatory aspects of generic operational and technical issues. NEI's members include all utilities licensed to operate commercial nuclear power plants in the United States, nuclear plant designers, major architect/engineering firms, fuel fabrication facilities, materials licensees, and other organizations and individuals involved in the nuclear energy industry.

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the petitioner. The petitioner's request that the NRC amend regulations regarding the domestic licensing of production and utilization facilities should be denied.

If you have any questions regarding this matter, please contact Gordon Clefton (gac@nei.org; 202-739-8086) or me.

Sincerely,

John C. Butler

Attachment

NEI Comments on Petition for Rulemaking (PRM-50-93)

Petitioner's Request

The petitioner requests that the Nuclear Regulatory Commission (NRC) revise its regulations based on data from multirod (fuel assembly) severe fuel damage experiments. The petitioner also requests that the NRC promulgate a regulation that will stipulate minimum allowable core reflood rates in the event of a loss-of-coolant accident (LOCA).

Specifically, the petitioner states that his interpretation of data from select multirod severe fuel damage experiments indicates that the current regulations at 10CFR Part 50 are non-conservative in their peak cladding temperature limit of 2200 °F (1204°C) and that the Baker-Just and Cathcart-Pawel equations are also non-conservative for calculating the metal-water reaction rates that would occur in the event of a LOCA. The petitioner requests that the NRC revise its regulations at 10CFR50.46(b)(1) and Appendix K to 10CFR Part 50 based on this interpretation. The petitioner also requests that the NRC promulgate a regulation that will stipulate minimum allowable core reflood rates in the event of a LOCA.

Background

The petitioner uses data from select multirod tests in an attempt to demonstrate that the peak fuel cladding temperature as stated by 10CFR50.46(b)(1) is not adequate to protect the cladding from reaching the autocatalytic zirconium-water regime. In addition, the petitioner questions the adequacy of the correlations used in calculating the metal-water reaction rates. These issues are very similar to those the petitioner raised in Docket number PRM-50-76 (Federal Register of August 9, 2002, Volume 67, Number 154). At that time, the NRC concluded that Appendix K of 10CFR Part 50 and the existing guidance on best-estimate Emergency Core Cooling Systems (ECCS) evaluation models are adequate for assessing ECCS performance for US Light Water Reactors (LWRs) using Zircaloy-clad UO_2 at burnup levels authorized in plant licensing bases. It is the Industry's position that the NRC's previous conclusions remain valid.

Zirconium-Water Reaction

One of the key premises of the petitioner's request for rule change is that the Baker-Just and Cathcart-Pawel correlations are non-conservative for calculating the metal-water reaction rates. It is hypothesized that neither correlation predicts the autocatalytic temperature of the zirconium-water reaction. The effects of the exothermic zirconium-water reaction are considered in the ECCS design

because of their potential influence on the thermal and mechanical behavior of the system. A review of related literature concludes that the zirconium-water reaction is relatively slow and corrosion-like under most conditions; however, at very high temperatures a self-sustained reaction can occur.

The Baker-Just correlation is specified in Appendix K of 10CFR Part 50 for the calculation of the energy release rate due to oxidation, hydrogen generation, and equivalent cladding reacted (ECR). The 2200°F cladding temperature limit for LOCA was implemented in order to limit oxygen induced embrittlement. The temperature limit in combination with the 17% ECR limit calculated by Baker-Just was specified to ensure the cladding remains ductile following a LOCA. The Baker-Just correlation, using the current range of parameter inputs, has been shown to be conservative and adequate to assess Appendix K ECCS performance. Data published since the Baker-Just correlation was developed has clearly demonstrated the conservatism of the correlation above 1800°F. Recent tests conducted at Argonne National Laboratory (ANL) and documented in NUREG/CR-6967, "Cladding Embrittlement During Postulated Loss-of-Coolant Accidents" July 31, 2008 (ML082130389) have demonstrated that the correlation over-predicts the zirconium-water reaction by as much as 30% at the limiting temperature (2200°F).

NRC Regulatory Guide 1.157, "Best-Estimate Calculations of Emergency Core Cooling System Performance" allows the use of a best-estimate correlation to calculate the zirconium-water reaction for temperatures greater than 1900°F and recommends the use of the Cathcart-Pawel correlation (NUREG-17, "Zirconium Metal - Water Oxidation Kinetics: IV Reaction Rate Studies"). The NRC, foreign organizations such as JAEA in Japan and CEA in France, and the United States nuclear Industry are currently conducting and evaluating experimental and analytical programs on fuel cladding behavior under LOCA conditions. These programs include both well-characterized isothermal high temperature oxidation tests and integral rodlet tests conducted at temperatures up to 2200°F that have confirmed the predictive capability of the Cathcart-Pawel correlation.

Multirod Severe Fuel Tests

The petitioner relies heavily on the results of two assembly tests with fuel damage, FLECHT Run 9573 and LOFT LP-FP-2. FLECHT Run 9573 refers to one of four Zircaloy clad FLECHT experiments performed in 1969 and reported in WCAP-7665. Westinghouse responded to similar claims in PRM-50-76 in LTR-NRC-02-52 Rev. 1. The petitioner claims that this test demonstrates that the zirconium-water autocatalytic reaction was reached at temperatures below 2200°F. The petitioner's use of autocatalytic is wrong. What occurred is that the oxidation became significantly out of balance with the cooling taking place. The FLECHT Run 9573 was based on extremely severe conditions. Reflood was initiated when the cladding temperature reached 1970°F. This temperature in

combination with a low flooding rate (1.1 in/sec) allowed a temperature excursion leading to failures of the heating elements at about 18 seconds into the transient. At that time, the measured cladding temperature reached 2300°F and the steam temperature was in excess of 2500°F. The high steam temperature was a result of the exothermic reaction between the zirconium and the steam. This reaction occurred at hot spots on the heater rods, on the Zircaloy guide tubes, spacer grids, and steam probe. Metallurgical analyses were performed on specimens extracted from heater rods. The heater rods were exposed to temperatures as high as 2500°F. The measured oxide thickness was within the predicted range calculated using Baker-Just.

From a LOCA perspective, the test conditions of FLECHT Run 9573 were extremely severe and well beyond those conditions which the design of the plants would allow to occur. Depending on the plant design, core reflood starts at cladding temperatures of between 1300°F (or less) and 1600°F; these are significantly lower than in FLECHT Run 9573 and at flooding rates substantially above the 1.1 inch/second of this test. Flooding rates as low as were used in the test are possible only after significant cooling is established within the core.

The LP-FP-2 experiment was the second fission product release and transport test performed in the Loss of Fluid Test (LOFT) facility at Idaho National Engineering Laboratory (INEL) under the sponsorship of the Organisation for Economic Co-operation and Development (OECD). The objective of the test was to provide information on fuel rod behavior, hydrogen generation, and fission product release and transport during a LOCA scenario that resulted in severe core damage. Rapid cladding oxidation was observed when cladding thermocouples reported a temperature of approximately 1430°K (2114°F). The LOFT thermocouples had a reported uncertainty of 5% under ambient conditions but this uncertainty increased during the later stages of the transient because of thermocouple drift and as a result of cladding oxidation and ballooning. Additionally, according to NUREG/IA-0049, the cause of the rapid temperature rise resulted from shunting of the thermocouple leads through a region of high temperature. Thus, there is some uncertainty in the results of this experiment. The reported temperature at the initiation of rapid oxidation is not an accurate depiction of the cladding temperature without some form of interpretation. The petitioner supplies no analytical evaluation of the data to support the claim that the rate of oxidation became excessive below 2200°F.

Reflood Rates

The petitioner bases the claim for a fixed minimum reflood rate on FLECHT Run 9573. As was pointed out above, the test conditions of FLECHT Run 9573 were extremely severe and can be considered beyond those that would be allowed by US plant design. It is also important to understand the past and current role of rod bundle reflood heat transfer tests. In the late 1960s, a mechanistic

understanding of reflood heat transfer did not exist. To develop heat transfer models as expeditiously as possible, the Atomic Energy Commission (AEC) and Industry cooperatively developed the Pressurized Water Reactor (PWR) FLECHT program which was run by Westinghouse. The principal objective was to determine reflood heat transfer coefficients as a function of key initial and boundary conditions, rod elevation, and time after the beginning of reflood. Additionally, the program developed empirical correlations based on that dependency.

There is no reason to establish a new minimum allowable core reflood rate in the LOCA evaluation models as the petitioner is proposing. In the 10CFR50.46 Appendix K Section I.D.5.b, a restriction to use steam cooling for the convective portion of the reflood heat transfer at flooding rates less than one inch per second is already included. In best-estimate models it is indicated (RG 1.157 Section 3.12.4) that "heat transfer calculations that account for two phase conditions in the core during refilling of the reactor vessel should be justified through comparison with experimental data. Best-estimate models will be considered acceptable provided their technical basis is demonstrated through comparison with appropriate data and analyses". Regulatory Guide 1.157 includes the FLECHT experiments as appropriate data for comparison; therefore, the results from the FLECHT experiments have already influenced best-estimate LOCA evaluation models and their allowable core reflood rates.

Conclusions

The petitioner expressed concerns leading to his request that the NRC revise its regulations at 10CFR 50.46(b)(1) and Appendix K to 10CFR Part 50. The petitioner also requested that the NRC promulgate a regulation that will stipulate minimum allowable core reflood rates in the event of a LOCA. The petitioner relies heavily on the results of two assembly tests with fuel damage, FLECHT Run 9573 and LOFT LP-FP-2.

A significant amount of LOCA testing has been conducted, since the completion of these early test programs. Experimental programs have been conducted by numerous organizations on both isothermal oxidation conditions and integral test conditions. The results from these programs to date confirm that Baker-Just is a conservative correlation for the prediction of metal-water reactions and that Cathcart-Pawel provides a best-estimate prediction of oxidation kinetics. These later tests conducted at 2200°F have shown no evidence of rapid oxidation Thus, the petitioner's claim that the autocatalytic runaway regime begins below 2200°F and that the current correlations are non-conservative is not substantiated for conditions where core cooling within the capability of current design exists (i.e., realistic balance of heat addition and removal). In regard to defining a minimum reflood rate, the conditions of FLECHT Run 9573 were

extremely severe and from a LOCA stand point should be considered beyond those possible with current ECCS designs.

Based on these considerations, the lack of scientific evaluation results to the contrary of the referenced experiments, and the counter indications associated with analysis, testing, and evaluation conducted over the last thirty years, it is concluded that the proposed revisions to 10CFR50.46(b)(1) and Appendix K to 10CFR Part 50 are unwarranted.

Rulemaking Comments

From:	REED, Joseph [jsr@nei.org] on behalf of BUTLER, John [jcb@nei.org]
Sent:	Tuesday, April 13, 2010 10:48 AM
Subject:	Industry Comments on Petition for Rulemaking (PRM-50-93); Multi-Rod (Assembly) Severe Fuel Damage Experiments. Docket ID NRC-2009-0554
Attachments:	04-12-10_NRC_Industry Comments on PRM-50-93.pdf; 04-12-10_NRC_Industry Comments on PRM-50-93_Attachment.pdf

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Sincerely,

John C. Butler
Director, Engineering & Operations Support

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From: "BUTLER, John" <jcb@nei.org>
Sender: "REED, Joseph" <jsr@nei.org>
Date: Tue, 13 Apr 2010 10:48:18 -0400
Subject: Industry Comments on Petition for Rulemaking (PRM-50-93); Multi-Rod
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Thread-Topic: Industry Comments on Petition for Rulemaking (PRM-50-93);
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