PRM-50-93
(75FR03876)

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OFFICE OF SECRETARY
RULEMAKINGS AND
ADJUDICATIONS STAFF

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Comments on PRM-50-93

As an introduction to these comments, the following is copied from PRM-50-93:

> Petitioner is submitting this petition, because Petitioner is aware that data from multi-rod (assembly) severe fuel damage experiments (*e.g.*, the LOFT FP-2 experiment) indicates that the current 10 C.F.R. § 50.46(b)(1) PCT limit of 2200°F is non-conservative. Data from such experiments also indicates that the Baker-Just and Cathcart-Pawel equations are both non-conservative for calculating the temperature at which an autocatalytic (runaway) oxidation reaction of Zircaloy would occur in the event of a LOCA. This, in turn, indicates that the Baker-Just and Cathcart-Pawel equations are both non-conservative for calculating the metal-water reaction rates that would occur in the event of a LOCA.

Investigations by P. Hofmann and V. Noak at Forschungszentrum Karlsruhe further confirm the Petitioner's assertion that the Baker-Just equation is non-conservative for calculating the temperature at which runaway oxidation will occur in a LOCA. Their report is, Physico-Chemical Behavior of Zircaloy Fuel Rod Cladding Tubes During LWR Severe Accident Reflood, Part I: Experimental results of single rod quench experiments, FZKA 5846, Institut für Materialforschung, Projekt Nukleare Sicherheitsforschung, Mai 1997.

In FZKA 5846, Hofmann and Noack report:

A series of separate-effects tests is being carried out on Zircaloy PWR fuel rod cladding to study the enhanced oxidation which can occur on quenching. In these tests, performed in the QUENCH rig, ***single tube specimens are heated by induction*** *to a high temperature and then quenched by water or rapidly cooled down by steam injection.*

No significant temperature excursion during quenching occurred such as had been observed for example in the quenched (flooded) CORA-bundle tests /4, 5/. This absence of any temperature escalation is believed to be due to the high radiative heat losses in the QUENCH rig.

The Baker-Just report, ANL-6548, is predominantly based on work by Bostrom, and Lemmon:

W. A. Bostrom, The High Temperature Oxidation of Zircaloy in Water, WAPD-104 (March 1954).

A. W. Lemmon, Jr., Studies Relating to the Reaction between Zirconium and Water at High Temperatures, BMI-1154 (jan 1957)

Bostrom and Lemmon each used induction heating of single specimens. In ANL-6548, Baker and Just did not recognize the high radiative heat losses in the Bostrom and Lemmon work. In contrast, in the CORA bundle tests runaway

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oxidation began in the range of 1100 and 1200 °C. (2012 to 2192°F) and this runaway is described as follows in PRM-50-93, page 26:

There is also experimental data from multi-rod severe accident tests that indicates that the 10 C.F.R. § 50.46(b)(1) PCT limit of 2200°F is non-conservative. For example, the paper, "CORA Experiments on the Materials Behavior of LWR Fuel Rod Bundles at High Temperatures," states:

The critical temperature above which uncontrolled temperature escalation takes place due to the exothermic zirconium/steam reaction crucially depends on the heat loss from the bundle; i.e., on bundle insulation. With the good bundle insulation in the CORA test facility, temperature escalation starts between 1100 and 1200 °C. (2012 to 2192°F), giving rise to a maximum heating rate of 15°K/sec.

[134] P. Hofmann, S. Hagen, **G.** Schanz, G. Schumacher, L. Sepold, Idaho National* Engineering Laboratory, EG&G Idaho, Inc., "CORA Experiments on the Materials Behavior of LWR Fuel Rod Bundles at High Temperatures," in NRC "Proceedings of the Nineteenth Water Reactor Safety Information Meeting," NUREG/CP-0119, Vol. 2, 1991, located at: www.nrc.gov, Electronic Reading Room, ADAMS Documents, Accession Number: ML042230460, p. 77.

And from PRM-50-93, page 44:

It is significant that in the CORA Experiments, at cladding temperatures between 1100°C and 1200°C (2012°F to 2192°F), that the cladding began to rapidly oxidize and cladding temperatures started increasing at a maximum rate of 15°C/sec. (27°F/sec.), because the Baker-Just and Cathcart-Pawel equations calculate that autocatalytic oxidation occurs at approximately 2600°F and approximately 2700°F, respectively;[137] "a rapid [cladding] temperature escalation, [greater than 10°C/sec. (18°F/sec.)], signal[s] the onset of an autocatalytic oxidation reaction.'"[138] Data from the CORA Experiments also indicates that the 10 C.F.R. § 50.46(b)(1) PCT limit of 2200°F is non-conservative. It is also significant that the CORA experiments demonstrated that "[t]he critical temperature above which uncontrolled temperature escalation takes place due to the exothermic zirconium/steam reaction crucially depends on the heat loss from the bundle; *i.e.,* on bundle insulation."[139]

[137] According to the NRC's more than 50 LOCA calculations with RELAP5/Mod3, discussed in "Acceptance Criteria and Metal-Water Reaction Correlations," Attachment 2 of "Research Information Letter 0202, Revision of 10 C.F.R. 50.46 and Appendix K."
[138] F. E. Panisko, N. J. Lombardo, Pacific Northwest Laboratory, "Results from In-Reactor Severe Fuel Damage Tests that used Full-Length Fuel Rods and the Relevancy to LWR Severe Accident Melt Progression Safety Issues," in "Proceedings of the U.S. Nuclear Regulatory Commission: Twentieth Water Reactor Safety Information Meeting," p. 282.
[139] P. Hofmann, S. Hagen, G. Schanz, G. Schumacher, L. Sepold, Idaho National Engineering Laboratory, EG&G Idaho, Inc., "CORA Experiments on the Materials Behavior of LWR Fuel Rod Bundles at High Temperatures," in NRC "Proceedings of the Nineteenth Water Reactor Safety Information Meeting," p. 83.

Comment submitted by

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***Experience:**

Career to date: Commenter's ongoing career spans several decades: General Electric at Hanford Works (1950), Argonne, DuPont Savannah River Plant, General Electric Vallecitos, Westinghouse Pittsburgh, Scandpower Norway, Consulting with Westinghouse at TMI-2, EPRI Nuclear Safety Analysis Center, EPRI Exploratory Research, and now self employed (2010).

Selected Experience pertinent to this comment on PRM-50-93:

PWR FLECHT: Test design, discoveries and reporting as referenced in PRM-50-93.

Presentation at 2003 RELAP5 International Users Seminar, West Yellowstone, Montana
Unmet Challenges for SCDAP/RELAP5-3D. Analysis of Severe Accidents for Light Water Nuclear Reactors with Heavily Fouled Cores. Robert H. Leyse,
www.inl.gov/relap5/rius/yellowstone/**leyse**.pdf

Comment NEI PETITION FOR RULEMAKING: PRM-50-78 (Cladding Materials) September 9, 2002
The petition should be denied because the evaluations of cladding materials do not account for the realities of plant operation under so-called normal conditions as well as the LOCA environment.

PETITION FOR RULEMAKING: PRM-50-76 May 8,2002
Petitioner is aware of deficiencies in Appendix K. **1.** A. 5. The Baker-Just equation does not include any consideration of the complex thermal hydraulic conditions during LOCA including the potential for very high fluid temperatures. Likewise, petitioner is aware of deficiencies in Regulatory Guide 1.157, BESTESTIMATE CALCULATIONS OF ECCS PERFORMANCE, Paragraph 3.2.5.1. The report NUREG-17 does not include any consideration of the complex thermal hydraulic conditions during LOCA including the potential for very high fluid temperatures.

PETITION FOR RULEMAKING: PRM-50-73 September 04, 2001
The specific issue is that 50.46 and Appendix K do not address the impact of crud on coolability during a fast moving (large break) LOCA.

PETITION FOR RULEMAKING: PRM-50-78 September 9, 2002
Regulations are needed to address the impact of fouling on the performance of heat transfer surfaces throughout licensed nuclear power plants.

Current field is microscale heat transfer at ultra-high heat fluxes to pressurized water.

Microscale Heat Transfer to Subcooled Water
LEYSE: MICROSCALE HEAT TRANSFER
doi.wiley.com/10.1111/j.1749-6632.2002.tb05912.x
Or go to: *http://www3.interscience.wiley.com/journal/118947467/abstract*

MICROSCALE PHASE CHANGE HEAT TRANSFER AT HIGH HEAT FLUX. Robert H. Leyse. Inz, Inc. Phani K. Meduri, Gopinath R. Warrier and Vijay K. Dhir ...
boiling.seas.ucla.edu/Publications/Conf_LMWD2003

Rulemaking Comments

From: Gallagher, Carol
Sent: Wednesday, March 24, 2010 4:19 PM
To: Rulemaking Comments
Subject: Comment on PRM-50-93
Attachments: NRC-2009-0554-DRAFT-0003.1[1].pdf

Van,

Attached for docketing is a comment from Robert H. Leyse on PRM-50-93 that I received via the regulations.gov website on 3/24/10.

Thanks,
Carol

Received: from HQCLSTR01.nrc.gov ([148.184.44.79]) by TWMS01.nrc.gov
([148.184.200.145]) with mapi; Wed, 24 Mar 2010 16:18:41 -0400
Content-Type: application/ms-tnef; name="winmail.dat"
Content-Transfer-Encoding: binary
From: "Gallagher, Carol" <Carol.Gallagher@nrc.gov>
To: Rulemaking Comments <Rulemaking.Comments@nrc.gov>
Date: Wed, 24 Mar 2010 16:18:32 -0400
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Thread-Topic: Comment on PRM-50-93
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X-MS-Exchange-Organization-SCL: -1
X-MS-TNEF-Correlator:
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