PRM-50-105
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RULEMAKINGS AND
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August 22, 2012

Annette L. Vietti-Cook
Secretary
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Rulemakings and Adjudications Staff

COMMENTS ON PRM-50-105; NRC-2012-0056

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COMMENTS ON PRM-50-105; NRC-2012-0056

I. STATEMENT OF PETITIONER'S INTEREST

On March 15, 2007, Mark Edward Leyse, Petitioner submitted a petition for rulemaking, PRM-50-84 (ADAMS Accession No. ML070871368). PRM-50-84 was summarized briefly in American Nuclear Society's *Nuclear News*'s June 2007 issue[1] and commented on and deemed "a well-documented justification for...recommended changes to the [United States Nuclear Regulatory Commission ("NRC")] regulations"[2] by Union of Concerned Scientists. In 2008, NRC decided to consider the issues raised in PRM-50-84 in its rulemaking process.[3] And in 2009, NRC published "Performance-Based Emergency Core Cooling System Acceptance Criteria," which gave advanced notice of proposed rulemaking, addressing four objectives: the fourth being the issues raised in PRM-50-84.[4]

PRM-50-84 requests that NRC make new regulations: 1) to require licensees to operate light water reactors under conditions that effectively limit the thickness of crud (corrosion products) and/or oxide layers on fuel cladding, in order to help ensure compliance with 10 C.F.R. § 50.46(b) emergency core cooling systems ("ECCS") acceptance criteria; and 2) to stipulate a maximum allowable percentage of hydrogen content in fuel cladding.

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[1] American Nuclear Society, *Nuclear News*, June 2007, p. 64.

[2] David Lochbaum, Union of Concerned Scientists, "Comments on Petition for Rulemaking Submitted by Mark Edward Leyse (Docket No. PRM-50-84)," July 31, 2007, located at: www.nrc.gov, Electronic Reading Room, ADAMS Documents, Accession Number: ML072130342, p. 2.

[3] Federal Register, Vol. 73, No. 228, "Mark Edward Leyse; Consideration of Petition in Rulemaking Process," November 25, 2008, pp. 71564-71569.

[4] Federal Register, Vol. 74, No. 155, "Performance-Based Emergency Core Cooling System Acceptance Criteria," August 13, 2009, pp. 40765-40776.

Additionally, PRM-50-84 requests that NRC amend Appendix K to Part 50—ECCS Evaluation Models I(A)(1), *The Initial Stored Energy in the Fuel*, to require that the steady-state temperature distribution and stored energy in the 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. PRM-50-84 also requested that these same requirements apply to any NRC-approved best-estimate ECCS evaluation models used in lieu of Appendix K to Part 50 calculations.

Petitioner also coauthored the paper, "Considering the Thermal Resistance of Crud in LOCA Analysis."[5]

Petitioner has submitted PRM-50-105 to request that NRC require all holders of operating licenses for nuclear power plants ("NPP") to operate NPPs with in-core thermocouples installed at different elevations and radial positions throughout the reactor core to enable NPP operators to accurately measure a large range of in-core temperatures in NPP steady-state and transient conditions. In the event of a severe accident, in-core thermocouples would enable NPP operators to accurately measure in-core temperatures, providing crucial information to help operators manage the accident; for example, indicating the time to transition from emergency operating procedures ("EOP") to implementing severe accident management guidelines ("SAMG").

II. RESPONSE TO NUCLEAR ENERGY INSTITUTE'S COMMENTS ON PRM-50-105

In these comments, Petitioner responds to Nuclear Energy Institute's (NEI) comments on PRM-50-105, "Industry Comments on Petition for Rulemaking: In-core Thermocouples at Different Elevations and Radial Positions in Reactor Core (NRC-2012-0056)," dated August 2, 2012.[6]

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[5] Rui Hu, Mujid S. Kazimi, Mark Leyse, "Considering the Thermal Resistance of Crud in LOCA Analysis," American Nuclear Society, 2009 Winter Meeting, Washington, D.C., November 15-19, 2009.

[6] Gordon A. Clefton, Senior Project Manager, Engineering and Operations Support, Nuclear Generation Division, NEI, "Industry Comments on Petition for Rulemaking: In-Core Thermocouples at Different Elevations and Radial Positions in Reactor Core (NRC-2012-0056),"

A. NEI Seems to Be Unaware of the Fact that In-Core Thermocouples have Been Tested and Used in Nuclear Reactors for Decades

In NEI's comments on PRM-50-105, NEI states:

> In some [nuclear power plant] designs, in-core thermocouples could be more susceptible to failures and misdiagnosis than core exit thermocouples...because of proximity to thermal and radiation sources.[7]

In-core thermocouples have been tested and used in nuclear reactors for decades, as the primary component of in-core gamma thermometers, which are "device[s] used for measuring the gamma flux in a nuclear reactor."[8] (See Appendix A for a depiction of a cross section of a gamma thermometer.)

"Instrumentation and Control Systems," Chapter 7 of "ESBWR Design Control Document," states that gamma thermometers—the present Radcal design[9]—have been installed in various nuclear reactors since 1979.[10] For example, Radcal gamma thermometers were installed in pressurized water reactors ("PWR") in Palisades Nuclear Plant and Arkansas Nuclear One Units 1 and 2 in the 1980s. (See Appendix B for a table listing a number of the facilities that have installed in-core Radcal gamma thermometers.)

Radcal gamma thermometers have also been installed in boiling water reactors ("BWR"). GE Hitachi Nuclear Energy, "Licensing Topical Report: Gamma Thermometer System for LPRM Calibration and Power Shape Monitoring," states that "[t]here have been three in-plant tests of [gamma thermometer] sensors in BWRs thus far. The first test was at Limerick 2 and lasted for two cycles, a total of four years. The

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August 2, 2012, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML12216A082.

[7] *Id.*, p. 1.

[8] GE Hitachi Nuclear Energy, "Licensing Topical Report: Gamma Thermometer System for LPRM Calibration and Power Shape Monitoring," NEDO-33197-A, Revision 3, Class I, October 2010, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML102810320, p. 1.

[9] R. H. Leyse, R. D. Smith: "Gamma Thermometer Developments for Light Water Reactors," IEEE Transactions on Nuclear Science, Vol.N5.26, No. 1, February 1979, pp. 934–943.

[10] GE Nuclear Energy, "ESBWR Design Control Document," Tier 2, Chapter 7, "Instrumentation and Control Systems," 26A6642AW, Revision 1, January 2006, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML060520260, pp. 7A-6, 7A-7.

second test, which was at Tokai 2, lasted for a single cycle of one year duration."[11] The third test was conducted at Kashiwazaki-Kariwa 5.[12]

GE Hitachi Nuclear Energy certainly seems to be satisfied with the in-core performance of Radcal gamma thermometers—which each have two thermocouples—because GE Hitachi Nuclear Energy has plans to install Radcal gamma thermometers in the Economic Simplified Boiling Water Reactor ("ESBWR").

(It is noteworthy that a 2009 Idaho National Laboratory ("INL") report, "High Temperature Irradiation-Resistant Thermocouple Performance Improvements," states that INL has "developed and evaluated the performance of a high temperature irradiation-resistant thermocouple...that contains doped molybdenum and a niobium alloy. Data from high temperature (up to 1500°C), long duration (up to 4000 hours) tests and on-going irradiations at INL's Advanced Test Reactor demonstrate the superiority of these sensors to commercially-available thermocouples. However, several options have been identified that could further enhance their reliability, *reduce their production costs, and allow their use in a wider range of operating conditions*" [emphasis added].[13]

The INL report also states that high temperature irradiation-resistant thermocouples can be developed for specific customer needs and varied conditions.[14])

B. NEI Seems to Be Unaware of the Fact that GE Hitachi Nuclear Energy has Plans to Install In-Core Thermocouples in the ESBWR

GE Hitachi Nuclear Energy's licensing topical report, "Gamma Thermometer System for LPRM Calibration and Power Shape Monitoring," states that there are plans to install seven gamma thermometers at different elevations at 64 radial positions

[11] GE Hitachi Nuclear Energy, "Licensing Topical Report: Gamma Thermometer System for LPRM Calibration and Power Shape Monitoring," NEDO-33197-A, p. 25.
[12] *Id.*
[13] Joshua Daw, *et al.*, Idaho National Laboratory, "High Temperature Irradiation-Resistant Thermocouple Performance Improvements," INL/CON-09-15267, Sixth American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control, and Human-Machine Interface Technologies, April 2009, p 1.
[14] *Id.*

throughout the reactor core of the ESBWR.[15] Thermocouples would be the primary component of the gamma thermometers installed in the reactor core of the ESBWR.

Each gamma thermometer has two thermocouples; therefore, GE Hitachi Nuclear Energy has plans to install 896 in-core thermocouples in each ESBWR reactor.

(See Appendix C for a depiction of four gamma thermometers at different elevations in an instrument tube; and see Appendix D for a depiction of where instrument tubes, in which gamma thermometers would be placed, would be positioned throughout the ESBWR reactor core.)

C. According to GE Hitachi Nuclear Energy Maintaining In-Core Thermocouples Would Cause Virtually No Radiation Dose to Workers

In NEI's comments on PRM-50-105, NEI claims that the "[u]se of in-core thermocouples would result in [a] higher [radiation] dose to workers both to implement plant modifications and to maintain the proposed system with minimum if any benefit to plant safety."[16]

It seems that GE Hitachi Nuclear Energy would disagree with NEI's claim that the use of in-core thermocouples would result in a higher radiation dose to plant workers. According to GE Hitachi Nuclear Energy, "A [gamma thermometer] system...has no moving parts, no under vessel tubing, *virtually no radiation dose* to maintenance since it is a fixed in-core probe, and is expected to be very reliable"[17] [emphasis added]. In-core thermocouples could certainly be placed inside of instrument tubes, distributed throughout the reactor core, like gamma thermometers are; hence, according to GE Hitachi Nuclear Energy, in-core thermocouples would cause virtually no radiation dose to workers during maintenance.

(It also follows that GE Hitachi Nuclear Energy claims that in-core thermocouples would be very reliable, because thermocouples are the primary component of gamma thermometers.)

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[15] GE Hitachi Nuclear Energy, "Licensing Topical Report: Gamma Thermometer System for LPRM Calibration and Power Shape Monitoring," NEDO-33197-A, p. 8.
[16] Gordon A. Clefton, "Industry Comments on Petition for Rulemaking: In-Core Thermocouples at Different Elevations and Radial Positions in Reactor Core (NRC-2012-0056)," p. 1.
[17] GE Hitachi Nuclear Energy, "Licensing Topical Report: Gamma Thermometer System for LPRM Calibration and Power Shape Monitoring," NEDO-33197-A, p. 1.

D. PRM-50-105 Provides Evidence that In-Core Thermocouple Readings Would Help Operators Manage an Accident

In NEI's comments on PRM-50-105, NEI claims:

> The petitioner provides no basis that actions taken by operators would be more effective than actions taken based on existing [core exit thermocouples ("CET")]. Specifically, there is no evidence to show that temperatures sensed at a single core location could be used more effectively than actions based on average CET temperatures.[18]

First, NEI seems to misunderstand what PRM-50-105 requests. PRM-50-105 does not request that in-core thermocouples be only installed at a single core location.

PRM-50-105 requests that NRC require all holders of operating licenses for NPP to operate NPPs with in-core thermocouples installed at different elevations and radial positions throughout the reactor core to enable NPP operators to accurately measure a large range of in-core temperatures in NPP steady-state and transient conditions.

Second, PRM-50-105 discusses data from experimental programs conducted at four different facilities, in which either a simulated or actual reactor core had temperature measurements taken by both in-core thermocouples and core exit thermocouples (discussed on pages 5-11 of PRM-50-105). (Such data has been thoroughly documented in a 2010 OECD Nuclear Energy Agency report, "Core Exit Temperature (CET) Effectiveness in Accident Management of Nuclear Power Reactor.")

Two of the main conclusions from the data from such experiments, simulating design basis accidents, are that core exit temperature measurements display in *all cases* a significant delay (up to several hundred seconds) and that core exit temperature measurements *are always* significantly lower (up to several hundred Celsius) than the actual maximum cladding temperature.[19]

PRM-50-105 also reports that in the LOFT LP-FP-2 experiment, in which an actual reactor core was caused to have a severe accident, core-exit temperatures were measured at around 800°F when in-core thermocouples measured fuel cladding

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[18] Gordon A. Clefton, "Industry Comments on Petition for Rulemaking: In-Core Thermocouples at Different Elevations and Radial Positions in Reactor Core (NRC-2012-0056)," p. 1.
[19] Robert Prior, *et al.*, OECD Nuclear Energy Agency, Committee on the Safety of Nuclear Installations, "Core Exit Temperature (CET) Effectiveness in Accident Management of Nuclear Power Reactor," NEA/CSNI/R(2010)9, November 26 2010, p. 128.

temperatures exceeding 3300°F. Therefore, after the onset of the rapid zirconium-steam reaction, core-exit temperatures were measured at around 800°F.[20]

Furthermore, PRM-50-105 reports that in the LOFT LP-FP-2 experiment, "during the rapid oxidation phase [core-exit temperatures] appeared essentially to be disconnected from core temperatures."[21]

It is clear from such experimental data that in-core thermocouple measurements would be superior to core exit thermocouple measurements for diagnosing the condition of a reactor core in the event of a severe accident. After all, in the experiments described above, it was the in-core thermocouple measurements which revealed how much lower the core exit temperatures were than the in-core temperatures.

In NEI's comments on PRM-50-105, NEI also claims:

> The proposed additional instrumentation is relevant only to postulated core conditions where CETs indicate some small amount of sub-cooling while in-core thermocouples might indicate locally higher temperatures with less sub-cooling. Where CET sub-cooling is minimal, operators are trained to take action to increase this margin. *Existing procedures and a predetermined CET value concurrently provide adequate indication for plant operators to transition from emergency operating procedures (EOPs) to implementing severe accident management guidelines (SAMGs)*[22] [emphasis added].

First, NEI is incorrect that the use of in-core thermocouples would be "relevant only to postulated core conditions where CETs indicate some small amount of sub-cooling." As stated above, experimental data has demonstrated that core exit temperature measurements display in *all cases* a significant delay (up to several hundred seconds) and that core exit temperature measurements *are always* significantly lower (up to several hundred Celsius) than the actual maximum cladding temperature.[23]

Second, as can be concluded from the information discussed in PRM-50-105, a predetermined core exit temperature value (1200°F for PWRs in the United States) would *not* be adequate for signaling the point for plant operators to transition from EOPs to

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[20] *Id.*, pp. 49-50.
[21] *Id.*, p. 50.
[22] Gordon A. Clefton, "Industry Comments on Petition for Rulemaking: In-Core Thermocouples at Different Elevations and Radial Positions in Reactor Core (NRC-2012-0056)," p. 2.
[23] Robert Prior, *et al.*, "Core Exit Temperature (CET) Effectiveness in Accident Management of Nuclear Power Reactor," NEA/CSNI/R(2010)9, p. 128.

implementing SAMGs. (A predetermined core exit temperature value of 1200°F is used because Westinghouse, among others, assumes that, in a severe accident, a condition of inadequate core cooling would have occurred if the core exit thermocouple readings were to exceed 1200°F.[24])

As stated above, in the LOFT LP-FP-2 experiment, in which an actual reactor core was caused to have a severe accident, core-exit temperatures were measured at around 800°F when in-core thermocouples measured fuel cladding temperatures exceeding 3300°F.[25] Clearly, providing instructions for plant operators to wait for a core exit temperature value of 1200°F to signal the point to transition from EOPs to implementing SAMGs is inadequate—or possibly unsafe; plant operators could implement harmful procedures because they did not know the actual condition of the reactor core.

This is clearly a significant problem which neither NRC nor the nuclear industry has addressed. In NEI's comments on PRM-50-105, NEI demonstrates that it would prefer to ignore the experimental data—thoroughly documented in a 2010 OECD Nuclear Energy Agency report—that indicates there are significant problems with relying on core-exit temperatures in order to attempt mitigating a severe accident.

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[24] Robert J. Lutz, Jr., "Post Accident Monitoring Instrumentation Re-Definition for Westinghouse NSSS Plants," WCAP-15981-NP-A, Revision 0, September 2008, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML103560687, p. 60.

[25] Robert Prior, *et al.*, "Core Exit Temperature (CET) Effectiveness in Accident Management of Nuclear Power Reactor," NEA/CSNI/R(2010)9, pp. 49-50.

III. CONCLUSION

If implemented, the regulations proposed in PRM-50-105 would help improve public and plant-worker safety.

Respectfully submitted,

/s/

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Dated: August 22, 2012

Appendix A Figure 1-1, Cross Section of a Gamma Thermometer[1]

[1] GE Nuclear Energy, "Licensing Topical Report: Gamma Thermometer System for LPRM Calibration and Power Shape Monitoring," NEDO-33 197, Revision 0, eDRF 0000-0041-9907, Class I, September 2005, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML052700450, p 3.

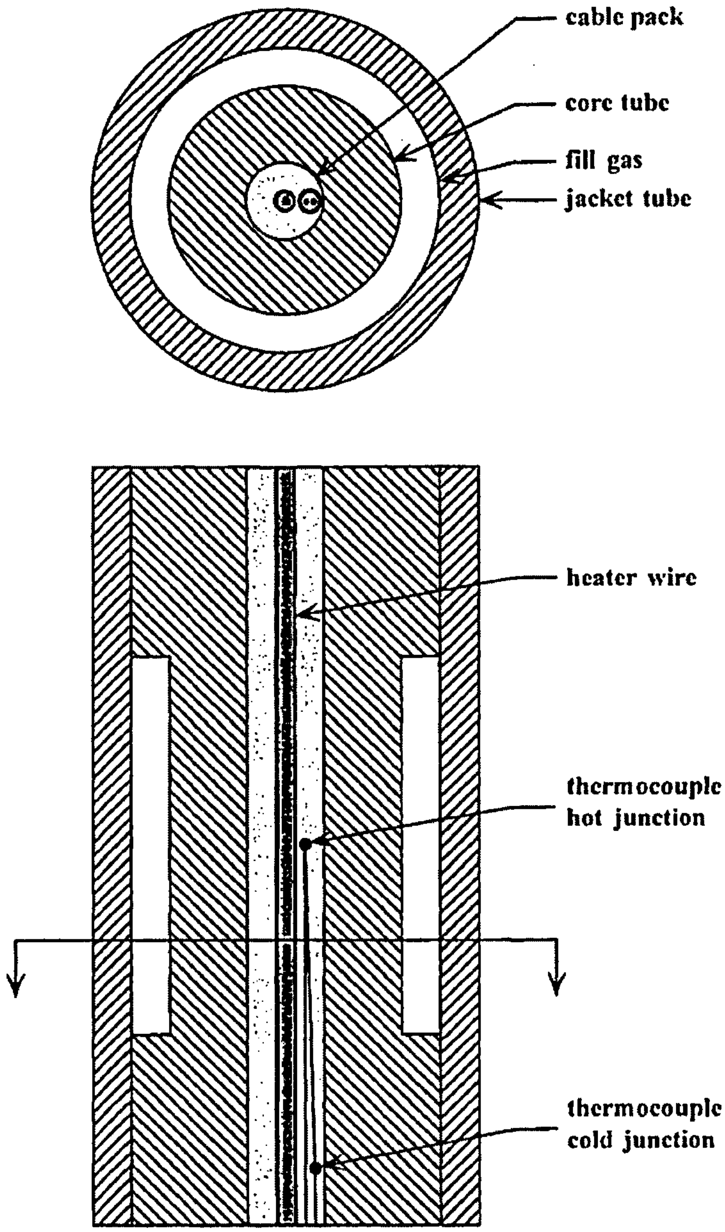


Figure 1-1, Cross Section of a Gamma Thermometer

Appendix B Table 7A-2, Worldwide Experience with Gamma Thermometers[2]

[2] GE Nuclear Energy, "ESBWR Design Control Document," Tier 2, Chapter 7, "Instrumentation and Control Systems," 26A6642AW, Revision 1, January 2006, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML060520260, pp. 7A-18, 7A-19.

Table 7A-2

Worldwide Experience with Gamma Thermometers

Utility or Company	Unit or Plant	Type GT System	No. Sensors per rod	No. of rods	Year	Comments/Status
DuPont	Savannah River	RPM	N/A	N/A	1950-80	Tritium reactor; GT used for heat flux monitoring. Single point thermocouples used.
OECD Norway	Dodewaard	RPM	1	4	1980	BWR: 10% drift in first two cycles. 1 unit had bad connector failed. Response not stable.
EdF	Bugey-5	RPM	9	2	1979	PWR; no heater this design. 7 of 18 sensors failed. Response not stable.
EdF	Tricastin-3	RPM	9	4	1980	PWR; all sensors working after 4 cycles. Some drift and parasitic noise.
EdF	Tricastin-2	RPM	9	4	1980	PWR: 1 heater failure. heaters not hot enough. 3 sensors failed.
Duke Power Co.	Experimental Unit	N/A	7	1	1982	Irradiated sample tests performed by TEC/ORNL.
EdF	Cruas-2	RPM	9	8	1983	PWR; 18 m long. replaced TIP. after two cycles: within 6% of TIP data. and all sensors working.
SSPB	Forsmark-1	RPM	6	2	1983	BWR: 15 m long. 3 sensor failures during installation only. Operational since 1983.
AP&L	Experimental Unit	RVLMS	9, 14	2	1984	Tested in ORNL loop. 2 GT rods for qualification as RVLMS system.

Table 7A-2

Worldwide Experience with Gamma Thermometers

Utility or Company	Unit or Plant	Type GT System	No. Sensors per rod	No. of rods	Year	Comments/Status
SSPB	Ringhals-2	RPM	9	4	1984	PWR: 35 m long with 9 sensors and 1 heater each. 1 heater failure after 2 cycles.
AP&L	ANO-2	RVLMS	14	2	1985	PWR; operational since 1985; 2 sensors failed.
DuPont	Savannah River	RPM	7	2	1985	Tritium reactor: evaluation units successfully tested.
AP&L	ANO-1	RVLMS	9	2	1986	PWR; in operation since 1986.
General Atomic	Fort St. Vrain	RPM	7	1	1986	GCR: status not known.
SSPB	Ringhals-2	RPM	9	4	1987	PWR: 35 m long with 9 sensors and 1 heater each. No failures in operation.
Consumers Power Co.	Palisades	RVLMS	8	4	1988	PWR: 2 in reactor, 2 spares. 1 sensor failure in 1. 1 sensor & heater in 2nd. Replaced 2nd in 1990. All OK.
Westing-house	Savannah River 1-3	RPM	7	36	1988-89	Tritium reactor: 9 GTs operating OK. 18 more installed & checked out OK. 9 spares.
AP&L	ANO-1	RVLMS	9	4	1990	PWR: 4 spares rods delivered 1990
AP&L	ANO-2	RVLMS	14	4	1990	PWR: 4 spares rods delivered 1991
			———	——		
		Total:	723 sensors	90 rods		

Appendix C Figure 7.2-8, Axial Distribution of LPRM Detectors[3]

[3] GE Nuclear Energy, "ESBWR Design Control Document," Tier 2, Chapter 7, "Instrumentation and Control Systems," 26A6642AW, p. 7.2-60.

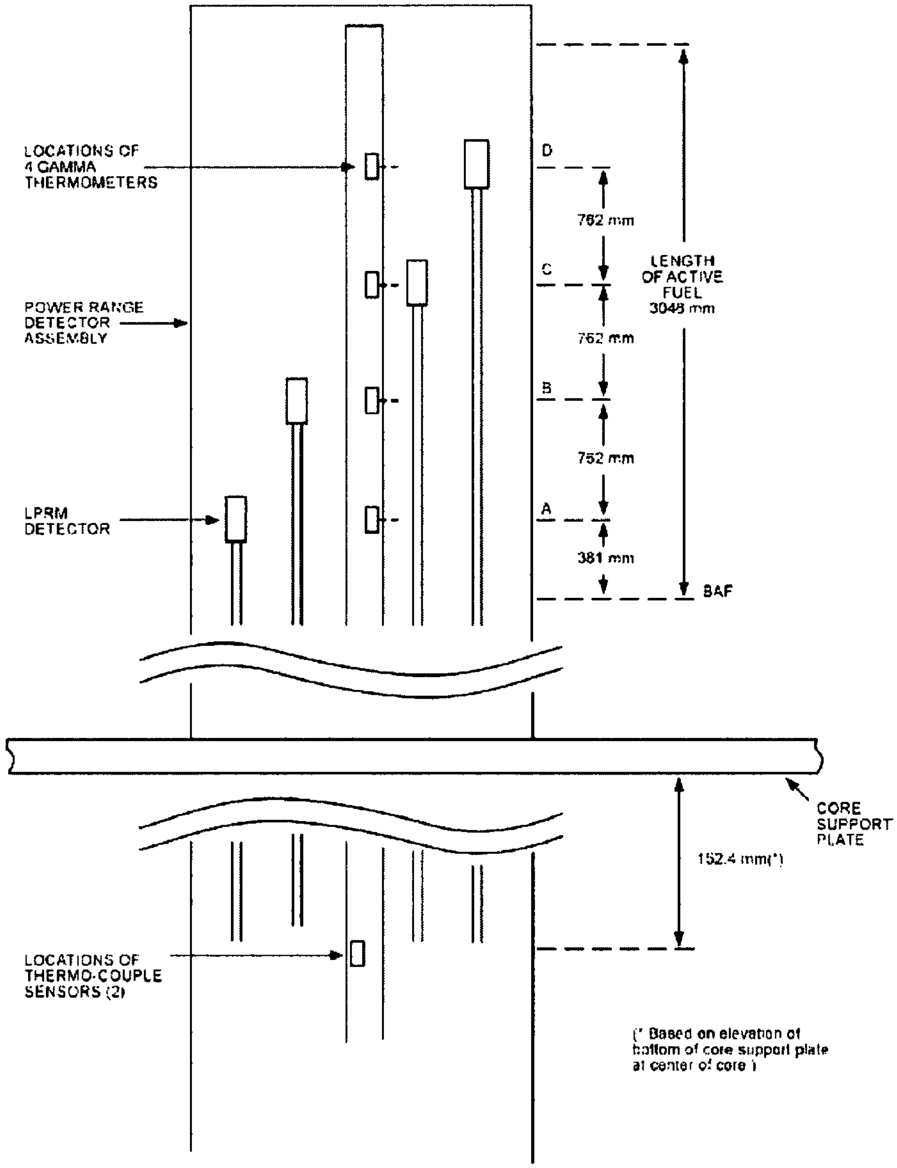
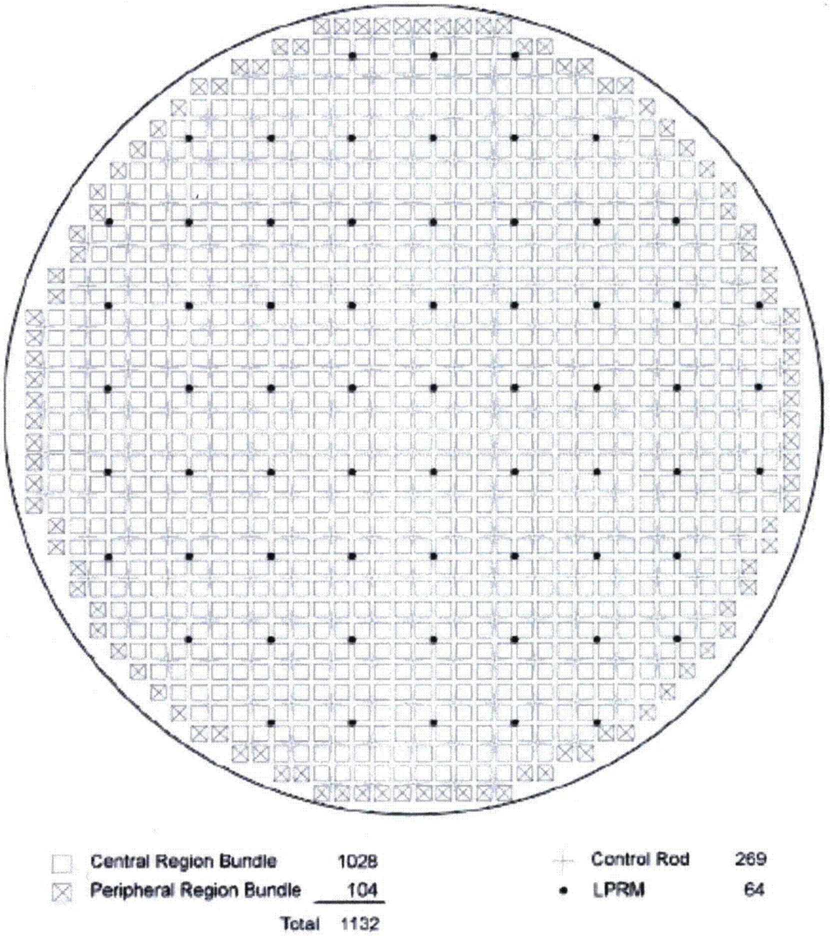


Figure 7.2-8. Axial Distribution of LPRM Detectors

Appendix D Figure 7.2-7, LPRM Locations in the Core[4]

[4] GE Nuclear Energy, "ESBWR Design Control Document," Tier 2, Chapter 7, "Instrumentation and Control Systems," 26A6642AW, p. 7.2-59.



ESBWR Core Map

Figure 7.2-7. LPRM Locations in the Core

Rulemaking Comments

From: Mark Leyse [markleyse@gmail.com]
Sent: Wednesday, August 22, 2012 6:33 PM
To: Rulemaking Comments
Cc: PDR Resource; Bladey, Cindy; Inverso, Tara
Subject: NRC-2012-0056 (Second)
Attachments: PRM-50-105 Comments (Second); Response to NEI.pdf

Dear Ms. Vietti-Cook:

Attached to this e-mail is Mark Leyse's, Petitioner's, second response, dated August 22, 2012, to the NRC's notice of solicitation of public comments on PRM-50-105, NRC-2012-0056, published in the Federal Register on May 23, 2012. In these comments on PRM-50-105, Petitioner responds to the Nuclear Energy Institute's ("NEI") comments on PRM-50-105, dated August 2, 2012.

Petitioner has responded to NEI's comments on PRM-50-105 promptly: Petitioner notes that although NEI's comments are dated August 2, 2012, NEI's comments were placed into the docket folder for PRM-50-105 on August 13, 2012.

Sincerely,

Mark Leyse