EDO Principal Correspondence Control

FROM: DUE: 03/30/12 EDO CONTROL: G20120142
DOC DT: 02/28/12
FINAL REPLY:

Mark Leyse
New York, NY

TO:

Borchardt, EDO

FOR SIGNATURE OF : ** GRN ** CRC NO:

Johnson, NRO

DESC:

2.206 Vogtle Electric Generating Plant Units 3 and 4 (EDATS: OEDO-2012-0120)

ROUTING:

Borchardt
Weber
Virgilio
Ash
Mamish
OGC/GC
McCree, RII
Burns, OGC
Mensah, NRR
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Russell, NRR
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Kotzalas, OEDO

DATE: 02/29/12

ASSIGNED TO: NRO

CONTACT: Johnson

SPECIAL INSTRUCTIONS OR REMARKS:

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E-RIDS: EDO-01

EDATS

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General Information

Assigned To: NRO — **OEDO Due Date:** 3/30/2012 11:00 PM

Other Assignees: — **SECY Due Date:** NONE

Subject: 2.206 - Vogtle Electric Generating Plant Units 3 and 4

Description:

CC Routing: RegionII; OGC; Tanya.Mensah@nrc.gov; Merrilee.Scott@nrc.gov; Andrea.Russell@nrc.gov; Catherine.Scott@nrc.gov

ADAMS Accession Numbers - Incoming: NONE — **Response/Package:** NONE

Other Information

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OCA Concurrence: NO

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Document Information

Originator Name: Mark Leyse — **Date of Incoming:** 2/28/2012

Originating Organization: Citizens — **Document Received by OEDO Date:** 2/29/2012

Addressee: R. W. Borchardt, EDO — **Date Response Requested by Originator:** NONE

Incoming Task Received: E-mail

Jaegers, Cathy

From: Mark Leyse [markleyse@gmail.com]
Sent: Tuesday, February 28, 2012 8:30 PM
To: Borchardt, Bill; Mensah, Tanya; PDR Resource; PDR Resource
Cc: Christopher Paine; Thomas B. Cochran; Weaver, Jordan; Matthew G. McKinzie; Dave Lochbaum; Ed Lyman; Nuclear
Subject: 10 C.F.R. § 2.206 Enforcement Petition Regarding Vogtle Electric Generating Plant Units 3 and 4
Attachments: 10 C.F.R. § 2.206 Enforcement Petition Regarding Vogtle Electric Generating Plant Units 3 and 4.pdf

Dear Mr. Borchardt:

Attached to this e-mail is a petition for an enforcement action, regarding Vogtle Electric Generating Plant Units 3 and 4, dated February 28, 2012, submitted pursuant to 10 C.F.R. § 2.206.

Sincerely,

Mark Leyse
P.O. Box 1314
New York, NY 10025
markleyse@gmail.com

EDO --G20120142

February 28, 2012

R. William Borchardt
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington D.C. 20555-0001

10 C.F.R. § 2.206 REQUEST TO HAVE THE LICENSEE OF VOGTLE ELECTRIC GENERATING PLANT UNITS 3 AND 4 CONDUCT SAFETY ANALYSES OF SEVERE ACCIDENT SCENARIOS IN WHICH THE AP1000 HYDROGEN IGNITER SYSTEM WOULD BE ACTUATED (EITHER DUE TO FLAWED EMERGENCY RESPONSE GUIDELINES OR PLANT OPERATOR ERROR) AFTER A DETONABLE CONCENTRATION OF HYDROGEN DEVELOPED IN THE CONTAINMENT

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February 28, 2012

UNITED STATES OF AMERICA
U.S. NUCLEAR REGULATORY COMMISSION
BEFORE THE COMMISSION

In the Matter of: SOUTHERN NUCLEAR OPERATING COMPANY, INC. (Vogtle Electric Generating Plant Units 3 and 4; Docket Nos. 52-025-COL and 52-026-COL)	TO: R. WILLIAM BORCHARDT Executive Director for Operations U.S. Nuclear Regulatory Commission Washington D.C. 20555-0001 Docket No. ______

MARK EDWARD LEYSE,
Petitioner

10 C.F.R. § 2.206 REQUEST TO HAVE THE LICENSEE OF VOGTLE ELECTRIC GENERATING PLANT UNITS 3 AND 4 CONDUCT SAFETY ANALYSES OF SEVERE ACCIDENT SCENARIOS IN WHICH THE AP1000 HYDROGEN IGNITER SYSTEM WOULD BE ACTUATED (EITHER DUE TO FLAWED EMERGENCY RESPONSE GUIDELINES OR PLANT OPERATOR ERROR) AFTER A DETONABLE CONCENTRATION OF HYDROGEN DEVELOPED IN THE CONTAINMENT

I. REQUEST FOR ACTION

This petition for an enforcement action is submitted pursuant to 10 C.F.R. § 2.206 by Mark Edward Leyse (hereinafter "Petitioner"). 10 C.F.R. § 2.206(a) states that "[a]ny person may file a request to institute a proceeding pursuant to § 2.202 to modify, suspend, or revoke a license, or for any other action as may be proper."

Petitioner requests that United States Nuclear Regulatory Commission ("NRC") order the licensee of Vogtle Electric Generating Plant Units 3 and 4 ("VEGP-3 and -4") to conduct safety analyses of severe accident scenarios in which the AP1000 hydrogen igniter system would be actuated too late (either due to flawed emergency response

guidelines or plant operator error), after a local hydrogen concentration of eight percent[1] or greater was reached in the containment, which could cause a fast hydrogen deflagration,[2] and after a local detonable concentration of hydrogen developed in the containment, which could cause a hydrogen detonation.[3]

(Westinghouse's probabilistic risk assessment for the AP1000 claims that "[c]ontainment failure from a directly initiated detonation wave is not considered to be a credible event for the AP1000 containment. There are no ignition sources of sufficient energy to directly initiate a detonation in the AP1000 containment."[4] Westinghouse does not consider that the AP1000 containment's hydrogen igniter system could provide an ignition source of sufficient energy to directly initiate a detonation; if the hydrogen igniter system were actuated after a detonable concentration of hydrogen developed in the containment, it could directly initiate a detonation, which could, in turn, compromise the containment.)

Petitioner also requests that NRC order the licensee of VEGP-3 and -4 to demonstrate that actuating hydrogen igniters in a severe accident after the core-exit temperature exceeds a predetermined temperature (1200°F[5]) is a productive and safe emergency response guideline for all severe accident scenarios.

(Westinghouse's probabilistic risk assessment for the AP1000 states that in the event of a severe accident, the AP1000 containment's "hydrogen igniters are actuated by

[1] "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants" states that "[a]bove about 8% H_2 concentration, flames may accelerate and larger loads may result. ... In addition, combustion is more complete, so that loads also increase due to the fact that more hydrogen is burned. Note that flame acceleration is a complex process, and does not depend just on the hydrogen concentration, but also on the amount of blockage, the degree of confinement, the presence of diluent gases (steam, CO_2), etc." See IAEA, "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants," IAEA-TECDOC-1661, July 2011, pp. 58-59.
[2] A deflagration is a combustion wave traveling at a subsonic speed, relative to the unburned gas. A subsonic speed is a speed that is less than the speed of sound.
[3] A detonation is a combustion wave traveling at a supersonic speed, relative to the unburned gas. A supersonic speed is a speed that is greater than the speed of sound.
[4] Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 19, "Probabilistic Risk Assessment," Sections 19.34 to 19.35, June 13, 2011, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML11171A405, p. 19.34-4.
[5] Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 19, "Probabilistic Risk Assessment," Appendix 19D, "Equipment Survivability Assessment," June 13, 2011, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML11171A416, p. 19D-3.

manual action when [the] core-exit temperature exceeds a predetermined temperature as directed by the emergency response guidelines (ERG)."[6] Westinghouse does not consider that experimental data indicates that core-exit temperature measurements would not be an adequate indicator for when to either correctly or safely actuate hydrogen igniters in a severe accident.[7])

II. STATEMENT OF PETITIONER'S INTEREST

On March 15, 2007, 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[8] and commented on and deemed "a well-documented justification for...recommended changes to the [NRC's] regulations"[9] by Union of Concerned Scientists. In 2008, NRC decided to consider the issues raised in PRM-50-84 in its rulemaking process.[10] And in 2009, NRC published "Performance-Based Emergency Core Cooling System Acceptance Criteria," which gave advanced notice of a proposed rulemaking, addressing four objectives: the fourth being the issues raised in PRM-50-84.[11]

PRM-50-84 requests that NRC make new regulations: 1) to require licensees to operate LWRs 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) ECCS acceptance criteria; and 2) to stipulate a maximum allowable percentage of hydrogen content in fuel cladding.

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[6] Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 19, "Probabilistic Risk Assessment," Sections 19.41 to 19.54, June 13, 2011, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML11171A409, p. 19.41-4.

[7] See 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.

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

[9] 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.

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

[11] 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 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."[12]

Petitioner is submitting this 10 C.F.R. § 2.206 petition because Westinghouse's probabilistic risk assessment for the AP1000 does not consider that the AP1000 containment's hydrogen igniter system could provide an ignition source of sufficient energy to directly initiate a detonation; if the hydrogen igniter system were actuated after a detonable concentration of hydrogen developed in the containment, it could directly initiate a detonation, which could, in turn, compromise the containment.

Petitioner is also submitting this 10 C.F.R. § 2.206 petition because Westinghouse's probabilistic risk assessment for the AP1000 does not consider that experimental data indicates that core-exit temperature measurements would not be an adequate indicator for when to either correctly or safely actuate hydrogen igniters in a severe accident.

A. Plant Specific Issues

This 10 C.F.R. § 2.206 petition is plant specific because VEGP-3 and -4 will be AP1000s, which are considered "future water-cooled reactors." NRC Policy Statement, "Combustible Gas Control in Containment," states that "[the] requirements [for 'future water-cooled reactors with the same potential for the production of combustible gas as currently-licensed light-water reactor designs'[13]] reflect the Commission's expectation

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

[13] NRC Policy Statement, "Combustible Gas Control in Containment," Federal Register, Vol. 68, No. 179, September 16, 2003, p. 54128.

that future designs will achieve a higher standard of severe accident performance"[14, 15] than currently operating light water reactors ("LWR").

This 10 C.F.R. § 2.206 petition addresses the fact that Westinghouse's probabilistic risk assessment for the AP1000 does not consider severe accident scenarios in which the hydrogen igniter system would be actuated after a detonable concentration of hydrogen developed in the containment, which could directly initiate a detonation, which could, in turn, compromise the containment. In the event of a severe accident, ice condenser pressurized water reactors ("PWR") and Mark III boiling water reactors ("BWR") would also be susceptible to scenarios in which the hydrogen igniter system would be actuated after a detonable concentration of hydrogen developed in the containment; however, this 10 C.F.R. § 2.206 petition is plant specific because VEGP-3 and -4 will be AP1000s—a different LWR design than ice condenser PWRs and Mark III BWRs.

This 10 C.F.R. § 2.206 petition is plant specific because NRC requires that "future water-cooled reactors," like the AP1000, "achieve a higher standard of severe accident performance" than currently operating LWRs; this would include a higher standard regarding the use of core-exit temperature measurements for accident management.

This 10 C.F.R. § 2.206 petition specifically requests that NRC order the licensee of VEGP-3 and -4 to demonstrate that actuating hydrogen igniters in a severe accident after the core-exit temperature exceeds a predetermined temperature (1200°F) is a productive and safe emergency response guideline for all severe accident scenarios. In the event of a severe accident, operators of many LWRs would use core-exit temperature measurements for accident management; however, use of core-exit temperature measurements for accident management "could also be quite different from plant to plant."[16]

[14] NRC Policy Statement, "Severe Reactor Accidents Regarding Future Designs and Existing Plants," Federal Register, Vol. 50, August 8, 1985.
[15] NRC Policy Statement, "Combustible Gas Control in Containment," Federal Register, Vol. 68, No. 179, p. 54128.
[16] Robert Prior, *et al.*, "Core Exit Temperature (CET) Effectiveness in Accident Management of Nuclear Power Reactor," pp. 7-8.

III. FACTS CONSTITUTING THE BASIS FOR PETITIONER'S REQUEST

A. Westinghouse does Not Consider that the AP1000 Containment's Hydrogen Igniter System would be Capable of Providing Enough Energy to Directly Initiate a Detonation

Westinghouse's probabilistic risk assessment for the AP1000 claims that "[c]ontainment failure from a directly initiated detonation wave is not considered to be a credible event for the AP1000 containment. There are no ignition sources of sufficient energy to directly initiate a detonation in the AP1000 containment."[17] Westinghouse does not consider that the AP1000 containment's hydrogen igniter system could provide an ignition source of sufficient energy to directly initiate a detonation; if the hydrogen igniter system were actuated after a detonable concentration of hydrogen developed in the containment, it could directly initiate a detonation, which could, in turn, compromise the containment.

Westinghouse's probabilistic risk assessment for the AP1000 states that in the event of a severe accident, the AP1000 containment's "hydrogen igniters are actuated by manual action when [the] core-exit temperature exceeds a predetermined temperature as directed by the emergency response guidelines (ERG)."[18] Westinghouse's probabilistic risk assessment for the AP1000 also states that "[a]s the core-exit gas temperature increases above 1200 degrees F...the control room staff initiates actions to mitigate a severe accident [including] turning on the hydrogen igniters for hydrogen control."[19]

Westinghouse's probabilistic risk assessment for the AP1000 does not consider that severe accident scenarios could occur in which the AP1000 hydrogen igniter system would be actuated too late (either due to flawed emergency response guidelines or plant operator error), after hydrogen concentrations of eight volume percent or greater were reached in the containment, which could cause a fast hydrogen deflagration, and after a

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[17] Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 19, "Probabilistic Risk Assessment," Sections 19.34 to 19.35, p. 19.34-4.
[18] Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 19, "Probabilistic Risk Assessment," Sections 19.41 to 19.54, p. 19.41-4.
[19] Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 19, "Probabilistic Risk Assessment," Appendix 19D, "Equipment Survivability Assessment," p. 19D-3.

detonable concentration of hydrogen developed in the containment, which could cause a hydrogen detonation.

Regarding the importance of using igniters at the correct time in a severe accident, "Current Knowledge on Core Degradation Phenomena, a Review" states that "[t]he concentration of hydrogen in the containment may be combustible for only a short time before detonation limits are reached."[20]

B. Westinghouse does Not Consider that the AP1000 Containment's Passive Autocatalytic Hydrogen Recombiner System would be Capable of Providing Enough Energy to Directly Initiate a Detonation

Westinghouse's general description of the AP1000 states that "[t]he AP1000 design includes mechanisms for...controlling hydrogen inside the containment. ... Passive autocatalytic hydrogen recombiners control hydrogen concentration following design basis events."[21]

Passive autocatalytic hydrogen recombiners could also provide an ignition source of sufficient energy to directly initiate a detonation, because "in reality recombiners in a combustible cloud with 8 to 10% hydrogen are likely to become igniters in a rather dry atmosphere with <40% steam."[22] Hydrogen recombiners have malfunctioned by having unintended ignitions in elevated hydrogen concentrations; this occurred "[d]uring experimental investigations at several institutions; *e.g.*, Battelle Model Containment, KALI facility, and SURTSEY facility."[23] In the event of a severe accident, "[i]n a

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[20] Peter Hofmann, "Current Knowledge on Core Degradation Phenomena, a Review," Journal of Nuclear Materials, Vol. 270, 1999, p. 208.

[21] Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 1, "Introduction and General Description of Plant," Section 1.9, June 13, 2011, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML11171A337, p. 1.9-80.

[22] P. Royl, J. R. Travis, W. Breitung, "GASFLOW Analysis of Hydrogen Recombination in a Konvoi Type PWR Containment under Hypothetical Small Break and Large Break LOCA Conditions," Jahrestagung Kerntechnik, Bonn, May 23-25, 2000, pp. 4-5.

[23] Ernst-Arndt Reinecke, Inga Maren Tragsdorf, Kerstin Gierling, "Studies on Innovative Hydrogen Recombiners as Safety Devices in the Containments of Light Water Reactors," Nuclear Engineering and Design, 230, 2004, p. 49.

situation when the hydrogen concentration rises, a delayed ignition [by a hydrogen recombiner] enhances the risk because it may start a detonation."[24]

Plant operators would be able to actuate and shut off electrically powered thermal hydrogen recombiners; however, operators would not be able to control the operation of passive autocatalytic hydrogen recombiners, which "do not need external power or operator action:" "[passive autocatalytic recombiners] are simple devices, consisting of catalyst surfaces arranged in an open-ended enclosure. In the presence of hydrogen (with available oxygen), a catalytic reaction occurs spontaneously at the catalyst surface and the heat of reaction produces natural convection flow through the enclosure."[25]

The licensee of VEGP-3 and -4 also needs to conduct safety analyses of severe accident scenarios in which the AP1000 passive autocatalytic hydrogen recombiner system would malfunction by having unintended ignitions after a local hydrogen concentration of eight percent or greater was reached in the containment, which could cause a fast hydrogen deflagration, and after a local detonable concentration of hydrogen developed in the containment, which could cause a hydrogen detonation.

For example, the licensee of VEGP-3 and -4 needs to conduct safety analyses of severe accident scenarios in which the AP1000 containment's hydrogen igniter system would not be operational. (Westinghouse qualifies that "*if operational during a severe accident*, [the AP1000 containment's hydrogen igniter system] will burn hydrogen as soon as the lean upward flammability limits are met"[26] [emphasis added].) In such severe accident scenarios, a local detonable concentration of hydrogen could develop in the containment and passive autocatalytic hydrogen recombiners could provide an ignition source of sufficient energy to directly initiate a detonation, which could, in turn, compromise the containment.

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[24] K. Fischer, *et al.*, "Hydrogen Removal from LWR Containments by Catalytic-Coated Thermal Insulation Elements (THINCAT)," Nuclear Engineering and Design, 221, 2003, p. 146.
[25] IAEA, "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants," p. 77.
[26] Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 19, "Probabilistic Risk Assessment," Sections 19.41 to 19.54, p. 19.41-4.

C. Recent Reports have Questioned the Safety of Using Igniters to Mitigate Hydrogen at Certain Times in Severe Accidents and/or without having Conducted Thorough Safety Analyses with Computer Codes

Recent reports have questioned the safety of using igniters to mitigate hydrogen at certain times in some severe accident scenarios and/or without having conducted thorough safety analyses with computer codes.

Below are quotes from recent reports that: 1) question the safety of using igniters in a severe accident; 2) emphasize that igniters must be used at precisely the correct time in order for them to not cause detonations in a severe accident; and 3) emphasize that igniters must be only used in cases where the affects of their use is entirely predictable and that "[a] prediction must show, that the integrity of the containment will not be challenged by any turbulent deflagration caused by the...deliberate ignition of a mixture of hydrogen, air and steam."[27]

The quotes from such recent reports pertaining to the use of igniters in severe accidents are as follows:

1) An OECD Nuclear Energy Agency report, "State-of-the-Art Report on Flame Acceleration and Deflagration-to-Detonation Transition in Nuclear Safety," published in August 2000, states:

> The main question in the application of the igniter concept is its safety orientation. The use of igniters should *reduce* the overall risk to the containment and should not create new additional hazards such as a local detonation [emphasis not added].[28]

2) A paper, "Studies on Innovative Hydrogen Recombiners as Safety Devices in the Containments of Light Water Reactors," published in 2004, states:

> The introduction of igniters as discussed in the past still seems to be very questionable as the prediction of hydrogen distribution and combustion in

[27] Helmut Karwat, "Igniters to Mitigate the Risk of Hydrogen Explosions—A Critical Review," Nuclear Engineering and Design, 118, 1990, p. 268.

[28] OECD Nuclear Energy Agency, "State-of-the-Art Report on Flame Acceleration and Deflagration-to-Detonation Transition in Nuclear Safety," NEA/CSNI/R(2000)7, August 2000, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML031340619, p. 1.10.

> the containment is at present not reliable enough to ensure the safe application of this measure.[29]

3) A paper, "Current Knowledge on Core Degradation Phenomena, a Review," published in 1999, states:

> The concentration of hydrogen in the containment may be combustible for only a short time before detonation limits are reached. This limits the period during which igniters can be used.[30]

4) A paper, "Safety Implementation of Hydrogen Igniters and Recombiners for Nuclear Power Plant Severe Accident Management," published in 2006, states:

> For a postulated accident, hydrogen will accumulate in the upper region of the room because of buoyancy. Reasonable location of the igniter system and selection of the initial ignition time are critical to effective hydrogen removal and control of the hydrogen concentration and the high local thermal and pressure loads. Hydrogen can be removed by a slow diffusion flame, with flame acceleration and DDT excluded. With early ignition, the hydrogen will be eliminated by slow combustion without high thermal and temperature loads, but with late ignition, hydrogen detonation transition will quickly occur with high local thermal and pressure loads which will threaten the integrity of the containment.[31]

5) On the importance of predicting the affects of the controlled ignition of hydrogen in a severe accident, "Igniters to Mitigate the Risk of Hydrogen Explosions—A Critical Review," published in 1990, states:

> The application of controlled ignition requires that the combustion process must be predictable for any case of its activation. A prediction must show, that the integrity of the containment will not be challenged by any turbulent deflagration caused by the incidental or deliberate ignition of a mixture of hydrogen, air and steam. Moreover, also highly energetic local deflagrations must not damage internal structures of steel containments leading to the formation of internal missiles.[32]

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[29] Ernst-Arndt Reinecke, Inga Maren Tragsdorf, Kerstin Gierling, "Studies on Innovative Hydrogen Recombiners as Safety Devices in the Containments of Light Water Reactors," p. 59.

[30] Peter Hofmann, "Current Knowledge on Core Degradation Phenomena, a Review," p. 208.

[31] Xiao Jianjun, Zhou Zhiwei, Jing Xingqing, "Safety Implementation of Hydrogen Igniters and Recombiners for Nuclear Power Plant Severe Accident Management," Tsinghua Science and Technology, Vol. 11, Number 5, October 2006, p. 557.

[32] Helmut Karwat, "Igniters to Mitigate the Risk of Hydrogen Explosions—A Critical Review," p. 268.

As "Igniters to Mitigate the Risk of Hydrogen Explosions—A Critical Review" states, "[t]he application of controlled ignition requires that the combustion process *must be predictable for any case of its activation*"[33] [emphasis added]. Clearly, the licensee of VEGP-3 and -4 needs to conduct safety analyses of severe accident scenarios in which the AP1000 hydrogen igniter system would be actuated too late (either due to flawed emergency response guidelines or plant operator error), after hydrogen concentrations of eight volume percent or greater were reached in the containment, which could cause a fast hydrogen deflagration, and after a detonable concentration of hydrogen developed in the containment, which could cause a hydrogen detonation.

D. Westinghouse does Not Consider that Experimental Data Indicates that Core-Exit Temperature Measurements would Not be an Adequate Indicator for When to either Correctly or Safely Actuate Hydrogen Igniters in a Severe Accident

Westinghouse's probabilistic risk assessment for the AP1000 states that in the event of a severe accident, the AP1000 containment's "hydrogen igniters are actuated by manual action when [the] core-exit temperature exceeds a predetermined temperature as directed by the emergency response guidelines (ERG);"[34] the predetermined core-exit temperature is 1200°F.[35] Westinghouse does not consider that experimental data from tests conducted at four facilities indicates that core-exit temperature measurements would not be an adequate indicator for when to either correctly or safely actuate hydrogen igniters in a severe accident.[36]

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[33] *Id.*

[34] Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 19, "Probabilistic Risk Assessment," Sections 19.41 to 19.54, p. 19.41-4.

[35] Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 19, "Probabilistic Risk Assessment," Appendix 19D, "Equipment Survivability Assessment," p. 19D-3.

[36] Robert Prior, *et al.*, "Core Exit Temperature (CET) Effectiveness in Accident Management of Nuclear Power Reactor," pp. 128-129.

Regarding 13 common conclusions made from the evaluation of tests conducted in four facilities (LOFT, PKL, ROSA/LSTF, and PSB-VVER) on core-exit temperature ("CET") measurements, an OECD Nuclear Energy Agency report, "Core Exit Temperature (CET) Effectiveness in Accident Management of Nuclear Power Reactor," published in August 2010, states:

> 1) The use of the CET measurements has limitations in detecting inadequate core cooling and core uncovery.
>
> 2) The CET indication displays in all cases a significant delay (up to several 100 [seconds]).
>
> 3) The CET reading is always significantly lower (up to several 100 [Kelvin]) than the actual maximum cladding temperature.
>
> 4) CET performance strongly depends on the accident scenarios and the flow conditions in the core.
>
> 5) The CET reading depends on water fall-back from the upper plenum (due to; *e.g.*, reflux condensing [steam generator] mode or water injection) and radial core power profiles. During significant water fall-back the heat-up of the CET sensor could even be prevented.
>
> 6) The colder upper part of the core and the cold structures above the core are contributing to the temperature difference between the maximum temperature in the core and the CET reading.
>
> 7) The steam velocity through the bundle is a significant parameter affecting CET performance.
>
> 8) Low steam velocities during core boil-off are typical for [small-break loss-of-coolant accident] transients and can advance 3D flow effects.
>
> 9) In the core as well as above (*i.e.*, at the CET measurement level) a radial temperature profile is always measured (*e.g.*, due to radial core power distribution and additional effects of core barrel and heat losses).
>
> 10) Also at low pressure (*i.e.*, shut down conditions) pronounced delays and temperature differences are measured, which become more important with faster core uncovery and colder upper structures.
>
> 11) Despite the delay and the temperature difference the CET reading in the center reflects the cooling conditions in the core.

12) Any kind of [accident management] procedures using the CET indication should consider the time delay and the temperature difference of the CET behavior.

13) In due time after adequate core cooling is re-established in the core the CET reading corresponds to no more than the saturation temperature.[37]

Clearly, Westinghouse's use of a predetermined CET measurement of 1200°F as the signal for when to actuate the AP1000 containment's hydrogen igniter system is not based on sound science.

(The LOFT facility was an actual nuclear reactor that was 1/50th the volume of a full-size PWR, "designed to represent the major component and system response of a commercial PWR."[38])

Regarding "two general limitations [that] have been identified regarding the ability of core exit fluid [thermocouples] to monitor a core uncovery"[39] in four tests conducted in the LOFT facility, NUREG/CR-3386, "Detection of Inadequate Core Cooling with Core Exit Thermocouples: LOFT PWR Experience" published in November 1983, states:

> First, there was a delay between the core uncovery and the [thermocouple] response. This delay ranged from 28 to 182 [seconds] in the four LOFT LOCA simulations [discussed in this report], and could have been even longer in one case, had the reactor operators not initiated core reflood. The delay is judged to be caused by a film of water that coats the [thermocouple] and must be removed before the [thermocouple] can respond to the vapor superheat. The film of water exists due to slow drainage of liquid from the upper plenum. Although the magnitude of these delays is acceptable under the controlled conditions in the LOFT system, these delay times may differ in commercial systems and should be accounted for in the use of core exit [thermocouple] response to predict or measure [inadequate core cooling ("ICC")]. Since it is expected that ICC will initiate in the hottest core regions, any delay or inadequacy in measuring the temperature of these regions must be considered when analyzing potential methods for ICC detection.

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[37] *Id.*

[38] T. J. Haste, B. Adroguer, N. Aksan, C. M. Allison, S. Hagen, P. Hofmann, V. Noack, Organisation for Economic Co-Operation and Development, "Degraded Core Quench: A Status Report," August 1996, p. 13.

[39] James P. Adams, Glenn E. McCreery, "Detection of Inadequate Core Cooling with Core Exit Thermocouples: LOFT PWR Experience," NUREG/CR-3386, EGG-2260, November 1983, p. 13.

> Second, the measured core exit [thermocouple] response was several hundred Kelvin lower than the maximum cladding temperatures in the core. This temperature difference results from the vapor superheat at the core exit being limited by the cladding temperatures near the core exit. In the LOFT system, these cladding temperatures were up to 360 K (648°F) lower than those in the high-power regions near the core center.
>
> In conclusion, any procedure that relies on the response of core exit fluid [thermocouples] to monitor a core uncovery should take these two limitations into account. There may be accident scenarios in which these [thermocouples] would not detect inadequate core cooling that preceded core damage.[40]

The four tests performed in the LOFT facility discussed in the quote above were the LOFT L2-5, L3-6/L8-1, L5-1, and L8-2 tests, which had maximum fuel cladding temperatures of 1479°F, 687°F, 828°F, and 1317°F, respectively.[41] The maximum fuel cladding temperatures in these four tests were more than 700°F below NRC's maximum fuel cladding temperature limit of 2200°F for design basis accidents.[42] Therefore, when measured CETs were several hundred Fahrenheit lower—648°F in one case—than the maximum fuel cladding temperatures in the LOFT core, maximum fuel cladding temperatures were far below those of a severe accident.

In the severe accident temperature range—when maximum fuel cladding temperatures exceed 2200°F—it is probable that there would be far greater temperature differences between the measured CETs and maximum fuel cladding temperatures than was observed in the four LOFT facility tests discussed above, which simulated design basis accidents. In fact, significant temperature differences—greater than 2000°F—were observed in the final experiment conducted at the LOFT facility, the LOFT LP-FP-2 experiment, a severe accident experiment,. in which maximum fuel cladding temperatures exceeded 3308°F, the melting point of Zircaloy.[43]

(LOFT LP-FP-2 is the only severe accident experiment that was an actual reactor core meltdown; it combined decay heating, severe fuel damage, and the quenching of

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[40] *Id.*
[41] *Id.*, p. 5.
[42] 10 C.F.R. § 50.46(b)(1)
[43] NRC, "Feasibility Study of a Risk-Informed Alternative to 10 CFR 50.46, Appendix K, and GDC 35," June 2001, located at: www.nrc.gov, Electronic Reading Room, ADAMS Documents, Accession Number: ML011800519, p. 3-1.

Zircaloy cladding with water.[44] LOFT LP-FP-2 is considered "particularly important in that it was a large-scale integral experiment that provides a valuable link between the smaller-scale severe [accident] experiments and the TMI-2 accident."[45])

Regarding the significant temperature differences between measured CETs and maximum fuel cladding temperatures that were observed in LOFT LP-FP-2, "Core Exit Temperature (CET) Effectiveness in Accident Management of Nuclear Power Reactor" states:

> When the core temperatures started [thermal] runaway[46] at about 1500 [seconds after the experiment commenced] and quickly exceeded 2100 K [3321°F] with a fission product release, the fluid temperatures in the upper plenum measured over the center fuel module...actually started to decrease. The temperature was typically 700 K [801°F] when quenching of the core occurred. For the peripheral bundles the temperatures were typically around 600 K [621°F] when core quench began.[47] ... The core quench caused a large excursion in the fluid temperature measurements. For a few seconds temperatures near 2000 K [3141°F] were observed followed by indication of saturation temperature.
>
> There was no evidence in the test that the CET indication was very much delayed. It can be concluded though that the core exit temperatures were much lower than typical core temperatures. During the rapid oxidation

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[44] T. J. Haste, *et al.*, "Degraded Core Quench: A Status Report," p. 13.

[45] S. R. Kinnersly, *et al.*, "In-Vessel Core Degradation in LWR Severe Accidents: A State of the Art Report to CSNI," January 1991, p. 3.23.

[46] The initial heat up rate of the fuel cladding in LOFT LP-FP-2 was approximately 1.8°F per second. See T. J. Haste, *et al.*, "Degraded Core Quench: A Status Report," p. 13.

In LOFT LP-FP-2, at fuel cladding temperatures at which the zirconium-steam reaction became rapid, the local heat up rate of the fuel cladding began increasing. For example, at one location on the central fuel bundle (at the 42-inch elevation) when cladding temperatures had reached just below 2200°F, the fuel cladding heat up rate had increased to approximately 21.4°F per second; at the same location, between cladding temperatures of approximately 2200°F and 2780°F, the *average* heat up rate was approximately 36.3°F per second. See NRC, "Draft Interim Review of PRM-50-93/95 Issues Related to the LOFT LP-FP-2 Test," 2011, located at: www.nrc.gov, Electronic Reading Room, ADAMS Documents, Accession Number: ML112650009, pp. 4, 5.

The phenomenon of rapid oxidation causing rapid fuel cladding temperature increases is sometimes termed "runway oxidation," "thermal runway," or "runway conditions." See Robert Prior, *et al.*, "Core Exit Temperature (CET) Effectiveness in Accident Management of Nuclear Power Reactor," p. 130.

[47] The conductors of LOFT LP-FP-2 commenced reflooding the reactor core 1782.6 seconds after the experiment started. See J. P. Adams, *et al.*, "Quick Look Report on OECD LOFT Experiment LP-FP-2," OECD LOFT-T-3804, September 1985, located at: www.nrc.gov, Electronic Reading Room, ADAMS Documents, Accession Number: ML071940358, Appendix E, p. E-17.

> phase the CET appeared essentially to be disconnected from core temperatures. ... The temperature excursion at core quench is probably explained by a violent flow up through the bundle that heated up the thermocouples.[48]

In LOFT LP-FP-2, in a time period when maximum core temperatures were measured to exceed 3300°F, CETs were typically measured at 800°F—more than 2500°F lower than maximum core temperatures. And in LOFT LP-FP-2, "during the rapid oxidation phase the CET appeared essentially to be disconnected from core temperatures."[49]

The results of LOFT LP-FP-2 demonstrate that Westinghouse's emergency operating procedures ("EOP") for the AP1000 are based on false premises. For example, Westinghouse's plan to have EOPs transition to severe accident management guidelines[50] is based on the false premise that it *would not* be possible for CETs to be lower than 1200°F after "the onset of significant core damage [occurred] as evidenced by the rapid zirconium-water reactions in the core."[51]

It is clear that Westinghouse's use of a predetermined CET measurement of 1200°F as the signal for when to actuate the AP1000 containment's hydrogen igniter system is not based on sound science.

IV. CONCLUSION

To uphold its congressional mandate to protect the lives, property, and environment of the people of Georgia and South Carolina living within proximity to VEGP, NRC needs to order the licensee of VEGP-3 and -4 to conduct the analyses and demonstration requested in this 10 C.F.R. § 2.206 petition. If implemented, the

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48 Robert Prior, *et al.*, "Core Exit Temperature (CET) Effectiveness in Accident Management of Nuclear Power Reactor," pp. 49-50.

49 *Id.*, p. 50.

50 Regarding severe accident scenarios for the AP1000, Westinghouse states "[a]s the core-exit gas temperature increases above 1200 degrees F, the EOPs transition to a red path indicating inadequate core cooling..." See Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 19, "Probabilistic Risk Assessment," Appendix 19D, "Equipment Survivability Assessment," p. 19D-3.

51 Westinghouse, "AP1000 Design Control Document," Rev. 19, Tier 2 Material, Chapter 19, "Probabilistic Risk Assessment," Appendix 19D, "Equipment Survivability Assessment," p. 19D-3.

enforcement actions requested in this petition would help improve public and plant worker safety.

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Respectfully submitted,

/s/

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