March 6, 2017

Mark Leyse's Written Testimony Regarding the "Zero-Emissions Credit" Program Established by the Public Service Commission

A Fukushima-Type Accident Could Occur at FitzPatrick or Nine Mile Point

The FitzPatrick and Nine Mile Point nuclear plants each have a reactor like the three that melted down in the Fukushima accident, in March 2011. The design is called the boiling water reactor (BWR) Mark I. (Nine Mile Point, which has two reactors, also has a BWR Mark II, which is similar to the BWR Mark I design.) The primary containment of a BWR Mark I is intended to protect the public from large releases of radioactive material in the event of a meltdown. In the Fukushima accident, three such primary containments failed to protect the Japanese public.

In the event of a meltdown, there is **no guarantee** that the primary Mark I containments at either FitzPatrick or Nine Mile Point would prevent the harmful release of large amounts of radioactive material into the environment, as occurred in the Fukushima accident.

U.S. Nuclear Regulatory Commission (NRC) reports from 1975[1] and 1990[2] both concluded that in the event of a meltdown, a BWR Mark I primary containment has "a relatively high containment failure probability," because it has a relatively small volume for a commercial reactor.[3] (It has a volume of approximately 0.28×10^6 ft^3.[4])

A BWR Mark I primary containment is comprised of a drywell, shaped like an inverted light bulb, and a wetwell (also termed "torus"), shaped like a doughnut. The wetwell is half filled with water (typically about 790,000 gallons[5]). This water is called the suppression pool.

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[1] NRC, "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," NUREG-75-014, WASH-1400, October 1975.

[2] NRC, "Severe Accident Risks: An Assessment or Five U.S. Nuclear Power Plants," NUREG-1150, December 1990.

[3] Charles Miller, *et al.*, NRC, "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," SECY-11-0093, July 12, 2011, (available at ADAMS No: ML111861807), p. 39.

[4] M. F. Hessheimer, *et al.*, Sandia National Laboratories, "Containment Integrity Research at Sandia National Laboratories: An Overview," NUREG/CR-6906, July 2006, (available at ADAMS No: ML062440075), p. 24.

[5] NRC, "NRC Information Notice 2006-01: Torus Cracking in a BWR Mark I Containment," January 12, 2006, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML053060311, Attachment 1, p. 1.

In 1989, the NRC recommended[6] that plant owners install hardened vents in BWR Mark I primary containments.[7] Such vents are intended to help BWR Mark Is cope with meltdowns (by depressurizing and removing excessive heat from primary containments). Such vents (which are essentially mere bandages placed onto defective BWR Mark I primary containments) did not save the day in the Fukushima accident.

The defective, antiquated BWR Mark I design performed poorly in the Fukushima Daiichi accident. In the accident, three BWR Mark I reactors melted down, each generating hundreds of kilograms of explosive hydrogen gas. Hydrogen leaked from the primary containments into the reactor buildings, where it accumulated and detonated at different times, destroying three reactor buildings, which released large quantities of harmful radioactive material into the environment. There are **many reasons to believe** that in the event of a meltdown at either FitzPatrick or Nine Mile Point that the BWR Mark I design would perform poorly, **not preventing the release of large quantities of harmful radioactive material into the environment**.

Hydrogen Generation in a BWR Mark I Meltdown: Rates and Quantities

In a BWR meltdown, if an overheated reactor core were re-flooded with water (a typical procedure in order to attempt to cope with a meltdown), hydrogen could be generated at rates as high as from 5.0 to 10.0 kilograms per second.[8] The total quantity of hydrogen that could be generated in a meltdown at a BWR Mark I is extremely large. It could easily **exceed 3,000 kilograms**.[9] In the Fukushima accident (which resulted in the meltdowns of three BWR Mark Is), there was likely more than 3,000 kilograms of hydrogen generated at each affected unit. This is **more hydrogen** than either FitzPatrick or Nine Mile Point's BWR Mark I primary containments would likely be able to handle.

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[6] Generic Letter 89-16 states that "the Commission has directed the [NRC] staff to approve installation of a hardened vent under the provisions of 10 CFR 50.59 ["Changes, Tests, and Experiments"] for licensees, who on their own initiative, elect to incorporate this plant improvement;" see NRC, "Installation of a Hardened Wetwell Vent," Generic Letter 89-16, September 1, 1989, p. 1.

[7] NRC, "Installation of a Hardened Wetwell Vent," Generic Letter 89-16, September 1, 1989, p. 1.

[8] E. Bachellerie *et al*., "Generic approach for designing and implementing a passive autocatalytic recombiner PAR-system in nuclear power plant containments," Nuclear Engineering and Design, Volume 221, Nos. 1-3, April 2003, p. 158; and J. Starflinger, "Assessment of In-Vessel Hydrogen Sources," in *Projekt Nukleare Sicherheitsforschung: Jahresbericht 1999*, (Karlsruhe: Forschungszentrum Karlsruhe, FZKA-6480, 2000).

[9] International Atomic Energy Agency (IAEA), "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants," IAEA-TECDOC-1661, July 2011, p. 10.

FitzPatrick's Outdated Meltdown Evaluation Analyses

In the case of FitzPatrick: an **outdated** safety evaluation report (from September 1992) has been used to argue that FitzPatrick would not release large amounts of radioactive material in the event of a meltdown.[10] (Those who argue that Nine Mile Point would not release large amounts of radioactive material in the event of a meltdown also rely on outdated safety evaluation reports.)

It has **not** been demonstrated that in the event at a meltdown at any of Nine Mile Point and FitzPatrick's reactors that a hydrogen explosion would be prevented; one that could destroy the reactor building. There is no reason to believe that a meltdown at any of these three reactors would turn out any differently than it did at in the Fukushima accident, in which hydrogen **leaked** from primary containments into reactor buildings and **detonated**, which **released large quantities of harmful radioactive material into the environment**.

Currently, FitzPatrick has a decades-old primary containment (wetwell) vent. There is **no reason** to believe that FitzPatrick's vent (essentially a mere bandage placed onto its defective BWR Mark I primary containment) would be effective in a meltdown. Such vents did not save the day in the Fukushima accident. Nine Mile Point's BWR Mark I primary containment has newer vent; however, there is **no guarantee** that it would perform adequately in a meltdown scenario in which there were rapid containment-pressure increases. It is pertinent that a 1983 Sandia National Laboratories manual cautions that "it may be difficult to design vents that can handle the rapid transients involved [in a meltdown]."[11] The scenario in which there would be the reflooding of an overheated reactor core, with the possible generation of between 5.0 and 10.0 kilograms of hydrogen per second,[12] would be a rapid transient.

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[10] Entergy, "Request for Extension to Comply with NRC Order EA-13-109 at James A. FitzPatrick Nuclear Power Plant: Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions," License No. DPR-059, JAFP-16-0148, September 8, 2016, Attachment, p. 2; and NRC, "Safety Evaluation Report: Hardened Wetwell Vent Capability at the James A. FitzPatrick Nuclear Power Plant," (ADAMS Accession No. ML13015A634), September 28, 1992.

[11] Allen L. Camp, *et al*., Sandia National Laboratories, "Light Water Reactor Hydrogen Manual," NUREG/CR-2726, August 1983, p. 2-66.

[12] J. Starflinger, "Assessment of In-Vessel Hydrogen Sources," in *Projekt Nukleare Sicherheitsforschung: Jahresbericht 1999*, (Karlsruhe: Forschungszentrum Karlsruhe, FZKA-6480, 2000).

Current Computer Safety Models Under-Predict Meltdown Hydrogen Generation Rates

A 2001 OECD Nuclear Energy Agency report advises that high hydrogen generation rates "must be taken into account in risk analysis and in the design of hydrogen mitigation systems." However, the same report notes that computer safety models used by regulators under-predicted the actual rates of hydrogen generation that occurred in important experiments simulating meltdowns (severe accidents).[13] A 1997 Oak Ridge National Laboratory report discusses additional experiments for which hydrogen generation rates failed to be predicted by models.[14] This indicates that **computer safety models under-predict the hydrogen generation rates that would occur in meltdowns**.

A 2011 International Atomic Energy Agency (IAEA) report states that computer safety models under-predict the rates of hydrogen generation that would occur during a reflooding of an overheated reactor core (a typical procedure in order to attempt to cope with a meltdown).[15]

Contemporary computer simulations of meltdowns under-predict hydrogen generation rates. Evidence indicates that the computer simulations that have been conducted of the hydrogen generation rates that would occur in the event of a meltdown at either FitzPatrick or Nine Mile Point are **inadequate**.

Computer Safety Models have Limitations in Predicting the Hydrogen Distribution and Steam Condensation that Would Occur in the BWR Mark I Reactor Buildings in a Meltdown

In a September 2011 meeting of the Advisory Committee on Reactor Safeguards, Dana Powers (then a senior scientist at Sandia National Laboratories) expressed concern over the fact that hydrogen detonations occurred in the Fukushima accident and stated that in experiments, "detonations are…extraordinarily hard to get."[16] Consequently, computer safety models derived from these same experiments have limitations in predicting the hydrogen distribution and steam

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[13] Report by Nuclear Energy Agency Groups of Experts, OECD Nuclear Energy Agency, "In-Vessel and Ex-Vessel Hydrogen Sources," NEA/ CSNI/R(2001)15, October 1, 2001, Part I: B. Clément (IPSN), K. Trambauer (GRS), and W. Scholtyssek (FZK), Working Group on the Analysis and Management of Accidents, "GAMA Perspective Statement on In-Vessel Hydrogen Sources," p. 9.

[14] L.J. Ott, Oak Ridge National Laboratory, "Advanced BWR Core Component Designs and the Implications for SFD Analysis," 1997, p. 4.

[15] IAEA, "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants," IAEA-TECDOC-1661, July 2011, p. 14.

[16] Advisory Committee on Reactor Safeguards, 586th Meeting, September 8, 2011, (ADAMS Accession No. ML11256A117), p. 95.

condensation that would occur in the containment and elsewhere in different severe accident scenarios.

A 2007 OECD Nuclear Energy Agency report states that computer safety models have limitations in predicting "[steam] condensation, gas density stratification, and jet injection."[17] This pertains to containments but it is also pertinent to other areas of a nuclear plant (like the reactor building) where hydrogen could enter in the event of a meltdown. Models also have limitations in predicting the phenomenon of hydrogen deflagrations transitioning into detonations; as well as the maximum pressure loads the containment (or other structures) would incur from detonations, in different scenarios.

Evidence indicates that the computer simulations that have been conducted of the hydrogen distribution and steam condensation that could occur in the BWR Mark I reactor building in the event of a meltdown at either FitzPatrick or Nine Mile Point are **inadequate**.

Upstate Nuclear Plants Should Be Promptly Shuttered and Replaced with Wind Farms

There is **no reason** to subsidize dangerous upstate New York nuclear plants with a multibillion-dollar bailout, particularly when **safety analyses for FitzPatrick and Nine Mile Point are outdated and inadequate**.

Mark Z. Jacobson, director of Stanford University's Atmosphere/Energy program, has criticized the upstate nuclear bailout for being a form of energy blight. He argues that instead of bailing out the troubled reactors with $7.6 billion over a period of 12 years, the four upstate reactors should be promptly shuttered and replaced with onshore wind farms. New York will end up replacing the reactors with wind anyway, in order to satisfy its Clean Energy Standard—a commitment to produce 50 percent of the state's electricity from non-CO_2-emitting sources by 2030. Jacobson recommends installing wind farms as soon as possible because they could provide the same amount of electricity as the reactors, while costing less and creating more jobs. He maintains that "if we replace nuclear with wind now, then spend the $7.6 billion on additional onshore wind (rather than on nuclear), thereby replacing coal or gas, we would reduce CO_2 emissions 60 percent more compared with keeping the nuclear open, but at the same cost."[18]

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[17] OECD Nuclear Energy Agency, "International Standard Problem ISP-47 on Containment Thermal Hydraulics: Final Report," NEA/CSNI/R(2007)10, September 2007, p. 7.

[18] Mark Z. Jacobson, "Invest in clean energy, not nukes," *Times Union*, July 29, 2016.