UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION

Eric J. Leeds, Director

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| In the Matter of | ) | |
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| ENTERGY NUCLEAR OPERATIONS, INC. | ) | |
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| ENTERGY NUCLEAR INDIAN POINT 2, LLC | ) | |
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| Indian Point Nuclear Generating Unit No. 2 | ) | Docket No. 50-247 |
| | ) | License No. DPR-26 |

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DIRECTOR'S DECISION UNDER 10 CFR 2.206

I. Introduction

By electronic transmission dated April 16, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12108A052), Mr. C. Jordan Weaver of the Natural Resources Defense Council, Inc. (NRDC), the Petitioner, submitted a petition under Title 10 of the *Code of Federal Regulations* (10 CFR) 2.206, "Requests for Action under This Subpart," to Mr. R.W. Borchardt, Executive Director for Operations, U.S. Nuclear Regulatory Commission (NRC, or Commission). The Petitioner requested that the NRC take enforcement action by ordering Entergy Nuclear Operations, Inc. (Entergy), the licensee for Indian Point Nuclear Generating Unit No. 2 (Indian Point 2), to remove the passive autocatalytic recombiners (PARs) from the Indian Point 2 containment. The Petitioner subsequently supplemented the

petition by requesting that the PARs be replaced with electrically powered thermal hydrogen recombiners.

Actions Requested

In the petition dated April 16, 2012, the Petitioner requested that the NRC order the licensee for Indian Point 2 to remove the PARs from the Indian Point 2 containment because the PAR system could have unintended ignitions in the event of a severe reactor accident, which, in turn, could cause a hydrogen detonation (i.e., a combustion wave traveling at a supersonic speed, relative to the unburned gas). The Petitioner stated that experimental data demonstrates that Indian Point 2's two PAR units could have at least one unintended ignition on their catalytic surfaces following a severe reactor accident.

As the basis for the request, the Petitioner stated, in part, the following:

- The PAR systems are simple devices consisting of catalyst surfaces where spontaneous catalytic reactions occur in the presence of hydrogen and oxygen to form water vapor. PARs are passive systems and do not need external power supplies or operator action to function. As a consequence, control room operators cannot deactivate them or remove them from service.
- The PARs at Indian Point 2 are capable of controlling hydrogen generated from the NRC's design basis accident as described in the Indian Point 2 Updated Final Safety Analysis Report. The focus of the petition regards the behavior of PARs following a severe reactor accident.
- Following a severe reactor accident, hydrogen generation rates could overwhelm the PARs at Indian Point 2. As a result, the containment atmosphere could have elevated concentrations of hydrogen gas approaching 8-10 percent or greater.

- The petition references test data, including work sponsored by the NRC at the Sandia National Laboratory Surtsey test facility, where PARs were observed to have unintended ignitions in environments containing elevated levels of hydrogen gas (i.e., 8-10 percent). According to the Petitioner, ignitions could lead to detonations.
- The NRC has not published any documentation indicating that the issue of PAR ignitions have been studied and resolved.
- Removal of the PARs at Indian Point 2 will lead to a safer post-accident condition because a potential source of ignition would be removed. Furthermore, if the PARs are replaced by electrically powered hydrogen thermal recombiners, control room operators would have the option of deactivating them because electrically powered hydrogen thermal recombiners can also have unintended ignitions.

Representatives of the Petitioner made a presentation before the NRC's Petition Review Board (PRB) on June 14, 2012, to clarify the bases for the petition. The Petitioner acknowledged that the PARs at Indian Point 2 could adequately control hydrogen generated from the NRC's design basis accident. The Petitioner focused on severe reactor accidents where significant quantities of hydrogen gas can be generated very quickly. Test results demonstrate that PARs can have ignitions in environments containing high concentrations of combustible gases which could lead to a detonation. During the presentation, the Petitioner supplemented the petition by requesting that the licensee replace the PARs with electrically powered thermal hydrogen recombiners because control room operators would have the option of deactivating electrically powered recombiners during a severe reactor accident. The transcript of this meeting (ADAMS Accession No. ML12300A412) has been added as a supplement to the petition.

By electronic transmission dated July 30, 2012 (ADAMS Accession No. ML122550089), the Petitioner was informed that the initial recommendation of the PRB was to reject the petition from the 10 CFR 2.206 review process based on the finding that (1) the petitioner raises issues that have already been the subject of NRC staff review and evaluation either on that facility, other similar facilities, or on a generic basis, for which a resolution has been achieved, the issues have been resolved, and the resolution is applicable to the facility in question and (2) the request addresses deficiencies within existing NRC rules.

Representatives of the Petitioner made a second presentation before the PRB on September 12, 2012. The Petitioner objected to the PRB's initial recommendation because the PRB did not address the petition's research regarding PARs malfunctioning by having ignitions in environments containing elevated hydrogen concentration. The Petitioner questioned whether detonations would be acceptable to the NRC following a severe reactor accident and noted that the PRB did not reference any document indicating that the NRC had reviewed and resolved this possibility. The Petitioner also referenced a 2011 International Atomic Energy Agency report indicating that the PAR ignition problem has not been resolved. In the concluding remarks, the Petitioner stressed that the petition was not about whether a large dry containment could withstand a detonation, but rather that PARs can initiate ignitions following a severe reactor accident which could lead to a detonation. The transcript of this meeting (ADAMS Accession No. ML12300A428) has been added as a supplement to the petition.

By letter dated November 16, 2012 (ADAMS Accession No. ML12305A436), the Petitioner was informed that, based on the additional information provided in the second presentation before the PRB, the PRB reconsidered its initial recommendation and accepted the petition for review under 10 CFR 2.206. Furthermore, the Petitioner was informed that while

evaluating the petition, the NRC staff would take into consideration long-term actions taken or planned by the NRC's task force responding to the events of March 2011 at the Fukushima Dai-chi nuclear power plant in Japan.

All documents referenced in this Director's Decision are available for inspection at the NRC's Public Document Room (PDR), located at One White Flint North, Room O1-F21, 11555 Rockville Pike (first floor), Rockville, Maryland 20852. Publicly available documents created or received at the NRC are accessible electronically through ADAMS in the NRC Library at *http://www.nrc.gov/reading-rm/adams.html*. Persons who do not have access to ADAMS or who encounter problems in accessing the documents located in ADAMS should contact the NRC's PDR reference staff by telephone at 1-800-397-4209 or 301-415-4737, or by sending an e-mail to *PDR.Resource@nrc.gov*.

II. Discussion

Indian Point 2 is a pressurized water reactor characterized as having a large dry containment. The containment building is a reinforced concrete axisymmetric right vertical cylindrical structure with a hemispherical dome lined with a steel plate on the inside. Two PARs are located on the operating deck outside the missile shield wall at the 95 foot elevation. This location is away from the reactor coolant piping and possible impingement from high-energy line breaks. There are five safety related fan coolers that cool and mix the post-accident containment atmosphere. Two seismic class 1 hydrogen/oxygen analyzers are available to monitor hydrogen and oxygen concentrations and provide sampling capability required by NUREG-0737, "Clarification of TMI Action Plan Requirements," Item II.B.3.

In the NRC's design basis accident, the amount of hydrogen gas generated is limited to the amount produced by an oxidation reaction of 5 percent of the cladding metal with steam

over a 2 minute period. The Petitioner does not question the ability of the PARs to adequately control hydrogen following NRC's design basis accident. The Petitioner states that hydrogen generation during a design basis accident is estimated at 0.001 to 0.05 kilograms per second and the hydrogen removal capacity per PAR unit is several grams per second of hydrogen. Therefore, the PARs would be sufficient to maintain hydrogen concentrations below 4 volume percent such that there would not be any reasonable expectation of deflagrations (i.e., a combustion wave traveling at a subsonic speed, relative to the unburned gas) within containment.

Following a severe reactor accident, the zirconium alloy fuel cladding used in U.S. light water reactors begins reacting with steam at a significant rate, producing zirconium oxide, hydrogen gas, and heat. The mass of zirconium present in a typical commercial light water reactor core is sufficient to produce hundreds of kilograms of hydrogen. The Petitioner cites reports of hydrogen generation of 0.1 to 10 kg per second during a severe reactor accident. The Petitioner further states that pressurized-water reactors, similar to Indian Point 2, would need 30 to 60 hydrogen recombiners in containment to mitigate these levels of hydrogen production. As a matter of reference, it has been estimated that the 1979 accident at Three Mile Island produced 400 kg of hydrogen.

PARs are characterized as simple devices without moving parts and do not need power supplies to operate. They consist of multiple cartridges with catalytic surfaces that are exposed to the containment atmosphere. When exposed to free hydrogen, a catalytic reaction combines the hydrogen and available oxygen to form water vapor. While PARs do not require a power supply to operate, they also cannot be stopped or deactivated by control room operators. For this reason, the Petitioner requests the NRC to order the removal of PARs from the Indian

Point 2 containment and replace them with electrically powered thermal hydrogen recombiners that can be started or deactivated by control room operators.

The Petitioner states that PARs would be overwhelmed by the production of hydrogen following a severe reactor accident resulting in elevated concentrations of hydrogen which would lead to combustion. Combustion, in turn, could lead to a detonation. The NRC has acknowledged that electrically powered hydrogen recombiners would be overwhelmed by the production of hydrogen following a severe reactor accident and does not question the Petitioner's assertion that PARs would be similarly overwhelmed.

The Petitioner also references test results where PARs have unintended ignitions in environments containing elevated levels of hydrogen concentration. The Petitioner made numerous references to the NRC-sponsored tests conducted by Sandia National Laboratory at the Surtsey test vessel in 1998. The results of this work were published in NUREG/CR-6580, "Performance Testing of Passive Autocatalytic Recombiners." The Surtsey tests, which were conducted to evaluate and understand the behavior of PARs under varying conditions, documented that PARs can have ignitions. As a result of ignitions, the PARs would effectively become igniters. The petition cites a number of studies describing the risks and difficulties of modeling igniters for hydrogen control.

In summary, the Petitioner believes that following a severe reactor accident, the PARs at Indian Point 2 would be overwhelmed by the production of hydrogen, combustible levels of hydrogen would be created, the PARs would have unintended ignitions, and the ignitions could be followed by a detonation. While the petition does not focus on whether the Indian Point 2 containment could withstand a detonation, this is clearly inferred as the ultimate safety consideration. The Petitioner believes that ordering the removal of the PARs and replacing

them with electrically powered thermal hydrogen recombiners would result in a safer configuration because control room operators would be able to deactivate conventional recombiners if necessary. In support of the petition, the Petitioner references a number of research papers and testing that has taken place subsequent to 2003 when the NRC revised 10 CFR 50.44, "Combustible gas control for nuclear power plants," resulting in the current staff position on hydrogen control.

In its evaluation of the NRDC petition, the NRC staff notes that when hydrogen concentration reaches the lower flammability limit of 5 volume percent at room temperature and 1-atmosphere pressure, it can be ignited (i.e., burned via deflagration) and will generate a slowly rising pressure spike (on the order of several seconds). For hydrogen concentrations greater than 10 volume percent, experimental results have shown that flame acceleration could occur and reach sonic velocity. If the hydrogen concentration exceeds 19 volume percent in a confined volume or becomes stratified, it will detonate rather than burn. As a matter of reference, the 1979 accident at Three Mile Island, which included a hydrogen deflagration and a resultant pressure spike of 28 pounds per square inch, was attributed to a hydrogen concentration of 8.5 volume percent (NUREG/CR-2569, "Response of the Zion and Indian Point Containment Buildings to Severe Accident Pressures").

The following discussion provides the NRC staff's belief that (a) a detonation caused by hydrogen combustion during a degraded core accident at Indian Point 2 is considered unlikely, and (b) there are benefits for maintaining the PARs and, therefore, they should not be removed from the Indian Point 2 containment:

1. Hydrogen deflagrations are the most likely mode of combustion in degraded core accidents. The likelihood and nature of deflagrations inside containment are influenced

by gas mixture composition and availability of ignition sources. Due to the small amount of energy needed to ignite combustible mixtures, there are numerous potential ignition sources, such as, sparks from electrical equipment, electrostatic discharges, hot jets/gases, hot surfaces (including PARs), core melt particles, etc. Most of these sources tend to be random and/or occurring for a short duration. What makes PARs beneficial from these selected ignition sources is that hydrogen is continually being removed from the atmosphere prior to hydrogen concentrations reaching the lower flammability limit. If the unit exceeds its recombination range resulting in locally high surface temperatures, then the PAR will act as a reliable igniter thereby initiating combustion at "lean" hydrogen concentrations resulting in "milder" deflagrations.

2. The Indian Point 2 large dry containment exhibits extremely favorable design characteristics: (1) a large free volume in order to dilute the reactor coolant system releases; (2) hydrogen generation will tend to be in the lower containment region promoting gas mixing; and (3) high containment pressure capacity. During a degraded core accident, the containment could withstand the consequences of a global deflagration without loss of function.
3. In SECY 00-0198, “Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.44 (Combustible Gas Control),” the NRC staff concluded that combustible gases are not a significant challenge to containment integrity for approximately 24 hours after the onset of core damage for large dry containments. However, hydrogen concentration could increase over a long period of time (on the order of days). SECY 00-0198 recommended that licensees have severe accident

management strategies for control of combustible gases as they may challenge the containment integrity in the long term (more than 24 hours). Indian Point 2 has Severe Accident Management Guidelines (SAMGs) that provide options to control room operators to manage long-term accumulation of combustible gases. Entry into the SAMGs will only occur after it has been determined that the Emergency Operating Procedures are no longer effective in controlling a severe reactor accident. Options within the SAMGs include (a) preventing undue hydrogen accumulation by intentionally igniting hydrogen when concentrations are still relatively low when deflagration induced pressures would be relatively benign and (b) preventing hydrogen from igniting by maintaining the containment steam inert. The Indian Point 2 SAMGs, combined with the hydrogen/oxygen analyzers, are designed to control the long term threat to containment integrity from a combustion event late in a core meltdown accident sequence. It should be noted that development of the SAMGs is an industry initiative that is neither required nor reviewed by the NRC.

4. The staff believes that the presence of PARS at Indian Point 2 would make it safer and would outweigh the benefits of replacing them. In the event of an extended station blackout condition, similar to that which occurred at Fukushima, the PARs would be an effective means of controlling long-term accumulation of hydrogen gas. If the PARs were removed and replaced by electrically powered hydrogen thermal recombiners as recommended by the Petitioner, this means of controlling hydrogen gas accumulation during station blackout conditions would not be available.

III Conclusion

The Petitioner sought enforcement action to improve public and plant worker safety at Indian Point 2. The Petitioner requested that the NRC order the licensee for Indian Point 2 to remove the PARs from the Indian Point 2 containment and replace them with electrically powered thermal hydrogen recombiners. The Petitioner believes that the PAR system could have unintended ignitions on their catalytic surfaces in the event of a severe reactor accident, which, in turn, could cause a hydrogen detonation.

The NRC staff has reviewed the NRDC petition and does not agree that the presence of PARs represent a sufficient risk to warrant their removal by order. Multiple ignition sources, besides PARs, would be present in containment to initiate combustion at lower flammability limits which would be expected to maintain hydrogen concentrations below detonable levels. Furthermore, the NRC staff believes that the presence of PARs could prove beneficial in the event of an extended station blackout. Therefore, the petitioner's request to order the removal of PARs at Indian Point 2 is denied.

As provided in 10 CFR 2.206(c), the NRC will file a copy of this Director's Decision with the Secretary of the Commission for the Commission to review. As provided for by this regulation, the decision will constitute the final action of the Commission 25 days after the date of the decision unless the Commission, on its own motion, institutes a review of the decision within that time.

Dated at Rockville, Maryland, this day of 2013.

FOR THE NUCLEAR REGULATORY COMMISSION

Eric J. Leeds, Director
Officer of Nuclear Reactor Regulation

PROPOSED