September 27, 2012

Information from September 12, 2012 PRB Meeting on NRDC's 2.206 Petition Regarding Indian Point Unit 2's Two Passive Autocatalytic Recombiner Units

Introduction

In the first meeting with the petition review board ("PRB"), Natural Resources Defense Council's ("NRDC") mostly focused on suggesting that Entergy replace Indian Point Unit 2's ("IP-2") two passive autocatalytic recombiner ("PAR") units with two electrically powered thermal hydrogen recombiners. NRDC's point was that if Entergy wants to have two hydrogen recombiner units at IP-2 to handle the quantity of hydrogen that would be produced in a design basis accident, Entergy could replace IP-2's two PARs with two electrically powered thermal hydrogen recombiners. This would be safer in the event of a severe accident, because operators would be able to terminate the operation of electrically powered thermal recombiners in a severe accident. In such an accident, operators would not be able to terminate the operation of PARs to prevent PARs from having ignitions, which could, in turn, cause a detonation.

In the second PRB meeting, Mark Leyse, on behalf of NRDC, responded to the PRB's initial decision to not consider NRDC's 2.206 petition regarding IP-2's PARs.

Part I

Leyse stated that he does not believe that the PRB addressed what NRDC requested in its 2.206 petition: NRDC simply requested that the two PARs be removed from IP-2, because, in the event of a severe accident, the PARs could have unintended ignitions that could cause a detonation.

In different experimental programs, PARs have malfunctioned by having ignitions in elevated hydrogen concentrations—this is documented in NRDC's petition. The petition also has information regarding the fact that a PAR's ignitions could cause a direct detonation in IP-2's containment.

In an e-mail, dated July 30, 2012, that Doug Pickett, the PRB manager, sent to Jordan Weaver of NRDC, there is an explanation of the PRB's initial decision.

The July 30, 2012 e-mail, discussing Regulatory Guide 1.7, “Control of Combustible Gas Concentrations in Containment,” pointed out that Regulatory Guide 1.7 states:

> The staff considers that the combustible gas control systems installed and approved by the NRC as of October 3, 2003, are acceptable without modification.

This was cited as one of the PRB’s justifications for rejecting NRDC’s petition. In the PRB meeting, Leyse asked: “Is it really true that after October 2003, if any defects are discovered in any of the combustible gas control systems installed and approved by the NRC, that the NRC will not do anything about it—even after Fukushima? Is it true that the NRC would ignore experimental data, indicting that PARs have malfunctioned by having ignitions in elevated hydrogen concentrations?”

The July 30, 2012 e-mail, regarding the PRB’s initial decision, says that NRDC raised “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 the July 30, 2012 e-mail states that the NRC had evaluated and resolved these issues in the NRC’s resolution of Generic Safety Issue 121, SECY-00-0198, and in the revision to section 10 C.F.R. 50.44.

The July 30, 2012 e-mail also points out that “[t]he revision to [section] 10 C.F.R. 50.44 “Combustible Gas Control for Nuclear Power Reactors”…led to the removal of technical specification requirements for hydrogen recombiners in large dry PWR containments.”

The fact that the NRC has revised section 10 C.F.R. 50.44 and done some evaluations does not mean that the NRC has evaluated and resolved the issues of NRDC’s 2.206 petition.

In different experimental programs, PARs have malfunctioned by having ignitions in elevated hydrogen concentrations. And a PAR’s ignitions could cause a direct detonation in IP-2’s containment. Those are the issues of NRDC’s 2.206 petition.

In the July 30, 2012 e-mail, regarding the PRB's initial decision, *there is not a reference to any document that states that the NRC has resolved the safety issue of PARs malfunctioning by having ignitions in elevated hydrogen concentrations*.

In fact, NRDC's petition (on page 17) has two quotes from a 2011 International Atomic Energy Agency ("IAEA") report[1] stating that as of 2011, the PAR ignition problem had not been resolved.

Leyse asked the PRB to please consider that the NRC has not resolved the PAR ignition problem; and said that, because the NRC has not evaluated and resolved the issues raised in NRDC's 2.206 petition, the PRB should accept the petition.

The NRDC petition is not about whether or not a large dry PWR containment would withstand a detonation or not. It's about the fact that PARs have had unintended ignitions in elevated hydrogen concentrations, which could cause a detonation.

Leyse asked the PRB to consider the question: "Does either the NRC or Entergy want a detonation to occur in IP-2's containment during a severe accident?"

The PRB's explanation of its initial decision ignored the fact that PARs have had ignitions in elevated hydrogen concentrations in different experimental programs. The PRB did not address that important safety issue; in fact, the PRB avoided the *very* issue that NRDC raised—which is still unresolved.

Leyse would urge the PRB to study the data regarding the ignitions that PARs have incurred in elevated hydrogen concentrations in different experimental programs.

If there is no way to guarantee that the PARs at IP-2 would not have ignitions in the elevated hydrogen concentrations of a severe accident then, the PRB should accept NRDC's 2.206 petition as a step toward ordering Entergy to remove the two PARs from IP-2.

In the PRB's explanation of its initial decision, it refers to SECY-00-0198. And Attachment II of SECY-00-0198 states that:

> A number of combustible gas control systems, along with their pros and cons, are discussed in NUREG/CR-2726... More recently an experimental program was conducted at the Surtsey facility at Sandia National

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

> Laboratories to evaluate a PAR design developed by the NIS Ingenieurgesellschaft Mbh of Hanau, Germany.[2]

And the experimental program is referenced; the reference is:

> T.K. Blanchat and A. Malliakos, "Performance Testing of Passive Autocatalytic Recombiners," NUREG/CR-6580, SAND 97-2632, Sandia National Laboratories, 1998

NRDC's 2.206 petition also refers to the Surtsey facility PAR experiments with the NIS PARs—the same type of PARs that IP-2 has.

On page 15 of NRDC's petition is a quote which states that in the Surtsey facility's PAR experiments: "unexpected ignitions from a NIS recombiner were observed in 3 out of 12 experiments."[3]

Leyse believes that the PRB should have discussed such data in its review of NRDC's petition.

IP-2 should not operate with equipment that has been proven to malfunction in elevated hydrogen concentrations; in a severe accident, a PAR's ignition could cause a detonation in IP-2's containment.

The NRC is a regulator with the duty to protect the public; the NRC should pay attention to experimental data (from an experimental program mentioned in SECY-00-0198) indicating that the PARs in IP-2's containment could have ignitions in the event of a severe accident. Furthermore, this is an unresolved safety issue.

Part II

The second part of the presentation covers information, indicating that IP-2's large dry PWR containment could be vulnerable to failure from hydrogen combustion.

Fukushima demonstrated that the NRC's hydrogen experiments—many of which were conducted at Sandia National Laboratories ("SNL")—did not replicate what would occur in a severe accident.

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[2] NRC, "Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 C.F.R. Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 C.F.R. 50.44 (Combustible Gas Control)," SECY-00-0198, 2000, Attachment II.

[3] Fischer, *et al*., "Hydrogen Removal from LWR Containments by Catalytic-Coated Thermal Insulation Elements (THINCAT)," Nuclear Engineering and Design, 221, 2003, p. 146.

In a September 8, 2011 Advisory Committee on Reactor Safeguards ("ACRS") meeting, Dana Powers of SNL said that it's "extraordinarily hard to get" detonations in experiments, because of ignition problems; and Powers pointed out that detonations occurred in the Fukushima accident.[4]

Perhaps hydrogen combustion experiments have not been realistic enough and perhaps the conclusions from such experiments are non-conservative.

SECY-00-0198, one of the documents cited in the July 30, 2012 e-mail regarding the PRB's initial decision, states that:

> A detonation would impose a dynamic pressure load on the containment structure that could be more severe than the static load from an equivalent deflagration.[5]

The point made in SECY-00-0198 is that a dynamic pressure load on the containment structure could be more severe than a static load.

This is significant, because the calculations mentioned in NRDC's petition on page 13, for hydrogen combustion at Turkey Point Units 3 and 4, PWRs with large dry containments, were for the pressure from an adiabatic and complete hydrogen burn. The NRC's Turkey Point calculations do not take into consideration flame acceleration—resulting in dynamic loads on the containment walls and dome. The calculations are for adiabatic isochoric complete combustion ("AICC")—sometimes termed "constant volume explosion pressure."

A 2011 IAEA report, "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants," states:

> Hydrogen deflagration can pose various risks to the containment and other plants systems. Combustion can give large pressure spikes, varying from relatively low pressure loads, bound by the AICC loads, up to large loads from accelerated flames and detonations. Such acceleration can already occur above about 8% H_2, so that above that value the AICC load may not always be the bounding value.[6]

[4] ACRS, 586th Meeting, September 8, 2011, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML11256A117, p. 95.
[5] NRC, "Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 C.F.R. Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 C.F.R. 50.44 (Combustible Gas Control)," SECY-00-0198, Attachment II, p. 4-2.
[6] IAEA, "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants," p. 58.

And the same IAEA report states:

> In the USA, the hydrogen risk during a severe accident is not considered an area for which further research is warranted: it has been analysed that containments of USA plants can either withstand the induced hydrogen combustion loads with enough safety margins (for the large dry PWR containments, for instance)... The USA analysis [do] not include advanced methods such as the use of CFD [computational fluid dynamics] codes to find a more refined hydrogen containment distribution, or loads from flame acceleration, as it was assessed that the safety margins were large enough to cover such uncertainties.[7]

So the NRC may have determined that Generic Safety Issue 121, "Hydrogen Control for Large, Dry PWR Containments" has been resolved; however, there are calculations—besides the ones for hydrogen combustion at Turkey Point—that indicate that hydrogen combustion could cause a large dry PWR containment to fail.

For example, there were calculations done in "Indian Point Probabilistic Safety Study" by Power Authority of the State of New York, Con Edison, in 1982.[8]

"Indian Point Probabilistic Safety Study" has a table (Table 4.3.5-1) that has the results of calculations in which the peak pressure resulting from combustion exceeds the estimated failure pressure of Indian Point's containments, which is about 141 pounds per square inch absolute ("psia").[9] In the table there are calculations for certain scenarios in which the peak pressure was found to be 160, 169, about 157, and 180 psia or greater.[10] Those calculations were reported in 1982 and their results indicate that hydrogen combustion could cause IP-2's containment to fail. (It is doubtful that these calculations modeled dynamic pressure loads.)

Regarding different types of containment failure, the 2011 IAEA report states:

> The failure mechanism can be of [a] different nature. As the containment exists of a main structure plus a number of penetrations (hatches, pipe and cable penetrations), failure may either be a gross failure of the containment or a failure of one or more of the penetrations. Concrete containments often show initiation of cracks as the first indication of

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[7] *Id*., pp. 105-106.
[8] Power Authority of the State of New York, Consolidated Edison Company of New York, "Indian Point Probabilistic Safety Study," Vol. 8, 1982, available at: www.nrc.gov, NRC Library, ADAMS Documents, Accession Number: ML102520201.
[9] *Id*., p. 4.3-10.
[10] *Id*., pp. 4.3-22, 4.3-23.

> failure. If the cracks are large enough, they will prevent gross containment failure.[11]

Interestingly, "Indian Point Probabilistic Safety Study" discusses a case in which there would be a total of more than 6000 pounds of hydrogen generated; that occurs in a case in which there is molten core concrete interaction.[12]

There is information in SECY-00-0198 Appendix II that relates to this; it states:

> Analyses performed…since TMI-2 have shown that accidents in which the core melts through the reactor pressure vessel (RPV) can pose a more severe threat to containment integrity (and thus are more risk-significant) than if the damaged core is retained within the vessel. *This implies that the proposed option should address full-core meltdown accidents* in which significantly more hydrogen (*i.e.*, perhaps more than a 100% metal water reaction) and also CO may be generated. In addition, the combustible gases and steam flow rates to containment have to reflect the rapid blow-down rates associated with reactor pressure vessel…failure if it occurs at high pressure[13] [emphasis added].

Therefore, SECY-00-0198 states that more hydrogen could be produced in a severe accident than would be produced from a metal-water reaction of 100% of the active fuel cladding.

Hydrogen combustion could perhaps compromise a large dry PWR containment. However, NRDC's petition is not about whether or not a large dry PWR containment would withstand a detonation or not. The petition is about the fact that PARs have ignitions in elevated hydrogen concentrations, which, in a severe accident, could cause a detonation. That is why NRDC has requested that the two PARs be removed from IP-2's containment.

CONCLUSION

NRDC's 2.206 petition is plant-specific. To the best of Leyse's knowledge, Indian Point is the only plant licensed by the NRC that has PARs. IP-2 is the only unit

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[11] IAEA, "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants," pp. 60-61.

[12] Power Authority of the State of New York, Consolidated Edison Company of New York, "Indian Point Probabilistic Safety Study," Vol. 8, 1982, p. 4.3-10.

[13] NRC, "Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 C.F.R. Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 C.F.R. 50.44 (Combustible Gas Control)," SECY-00-0198, Attachment II, p. 6-6.

that, in the event of a severe accident, has the possibility of a PAR malfunctioning by having an ignition; and such an ignition could cause a direct detonation.

It is significant that Resolution of GSI 121 states:

> [I]t was believed that plant-specific vulnerabilities may exist mainly due to the effects of local H_2 detonation. Activities for estimating the likelihood of local H_2 detonation and assessing the consequences would require plant-specific information…

Also, NRDC's petition discusses information from documents that were published after the NRC published its resolution of Generic Safety Issue 121 and SECY-00-0198; and after the NRC revised 10 C.F.R. 50.44, in 2003.

As mentioned above, a 2011 IAEA report, quoted on page 17 of NRDC's petition states that the safety issue of PARs incurring ignitions in elevated hydrogen concentrations has not been resolved.

Furthermore, as Dana Powers pointed out in an ACRS meeting, detonations are "extraordinarily hard to get" in experiments, because of ignition problems; however, detonations occurred in the Fukushima accident.

Respectfully submitted,

/s/

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