Science and Global Security, 12:251–254, 2004

ISSN: 0892-9882 print
DOI: 10.1080/08929880490518027

LETTERS

The following exchange refers to two articles in the last two issues of the Journal: "Reducing the hazards from stored spent power-reactor fuel in the United States" by Robert Alvarez, Jan Beyea, Klaus Janberg, Jungmin Kang, Ed Lyman, Allison Macfarlane, Gordon Thompson, and Frank von Hippel, *Science & Global Security* 11 (2003)—referred to as "Reducing the hazards;" and "Damages from a major release of ^{137}Cs into the atmosphere of the United States" by Jan Beyea, Ed Lyman and Frank von Hippel, *Science & Global Security* 12 (2004)—referred to as "Damages from a major release."

To the Editor:

The addendum, "Damages from a major release," is a valuable response to criticisms about the population density used in previous postulated consequences of Cs releases. Revised health and economic consequences are significantly smaller, with postulated latent fatalities 44 times smaller than the earlier 100% release case. Additional criticisms not covered in this addendum were responded to by coauthor Professor Frank von Hippel at National Academy of Sciences meetings. He correctly stated that "partial unloading of the pool may not be enough." Forces large enough to penetrate the bottom of a massive spent fuel structure would likely crush nearby spent fuel, preventing adequate air cooling. As mentioned by von Hippel, "water sprays" may be needed to overcome crushed fuel or other debris. He also identified that "recovery strategies must be developed" to cope with lethal radiation levels above the pool. Additionally, a rapid recovery strategy may be needed to prevent oxidation of the zirconium* at the top of the fuel. The calculated fuel air exit temperature is 900 degrees C and nearby zirconium would be hotter. At 920 degrees C, complete zirconium oxidation would only take 15 minutes. See footnote 55 in final version of "Reducing the hazards."

Unless these vulnerabilities are overcome in a revised design, the addendum's benefit portion of the cost/benefit analysis is questionable. Von Hippel did not offer a recovery strategy; however refilling the pool with water is an obvious choice. Water systems have cost, heat transfer, source term reduction, vulnerability, and recovery advantages over air systems. Von Hippel also noted that it may "not be necessary to go all the way back to open racking." If heat transfer analyses show that removing only 20% of the cesium inventory (see Figure 2 of "Damages from a major release") is acceptable, costs would be lower than the originally proposed 75% removal. Lowering costs in this manner, however, tends to eliminate the authors' original claimed benefit of reduced cesium inventory. An acceptable heat transfer analysis outcome seems likely if MELCOR, an advanced heat transfer code, is used. NRC analyses based on MELCOR concluded that, "There are other measures than removal of the fuel and lower density racking." This implies that 0% cesium removal is acceptable, i.e., no enlarged dry cask program is necessary to assure adequate safety. Independent nuclear industry MELCOR analyses support this conclusion. The issues of crushed fuel and recovery would still have to be addressed.

With consequences markedly down, with the need to use water systems to overcome shortcomings in air cooling schemes, and with no need to rely on an enlarged dry cask program, there is little left of the original air cooling proposal to recommend it. One benefit, though, of the authors' effort is that it supports a conclusion that postulated effects from nuclear power events are largely dominated by economic consequences, not health consequences.

Herschel Specter
President, RBR Consultants, Inc

Response by the authors:

To the Editor:

Mr. Specter is correct that the number of cancer deaths from a spent-fuel pool fire estimated in a Brookhaven National Laboratory report and in a footnote of "Reducing the hazards"[1] were much higher than calculated in our article, "Damages from a major release."[2] This resulted from substituting real radial population densities for average values, which dramatically reduced the population beyond the decontamination area. As we noted in "Damages from a major release," however, the relatively limited success of decontamination efforts after the Chernobyl accident puts in doubt the feasibility of achieving in practice the theoretical decontamination factors of up to a factor of eight that we used. Thus, either the EPA's threshold annual dose for long-term evacuation would have to be raised—increasing the population radiation dose and number of cancer deaths considerably—and/or a much larger area would have to be condemned—raising the economic consequences considerably above the already high numbers calculated in "Damages from a major release."

Mr. Specter is *not* correct that quick post-attack water cooling may be necessary in all scenarios because of high air temperatures. We used an assembly cooling air exit temperature of 900°C to obtain an upper bound on the velocity of the convectively driven air. If convective air cooling is not blocked, however, even recently discharged open-racked fuel or dense-racked fuel cooled for more than about a year would not raise the air temperature above 565°C. Below this temperature, oxidation of the fuel would be slow enough to allow a prolonged period of air cooling.[3] Since there are many scenarios in which air cooling might be obstructed, however, "Reducing the hazards" recommended additional measures, such as installation of the water sprays that Mr. Specter advocates.

Mr. Specter prefers measures that would be less costly than moving to dry storage four fifths of the spent fuel in dense-packed pools, as would be required to restore open racking. We are not opposed to reducing costs, if future analyses demonstrate that less costly measures are effective in preventing spent-fuel fires in a large number of scenarios. In our paper, we proposed examination of partial measures, such as facilitating convective air cooling by removal of every fifth fuel assembly. Another even less costly possibility that should be analyzed is rearrangement of the spent fuel so that, to the extent possible, each recently discharged hot spent fuel assembly would be surrounded by older cooler fuel assemblies to which heat could be radiated and then removed by convective air cooling.

For more than 25 years, the NRC did not respond to reports done for it by the national labs and by its own staff warning of the possibility of spent-fuel fires. We therefore look forward to independent reviews of the assumptions that have gone into the Nuclear Regulatory Commission (NRC) and industry calculations that Mr. Specter cites in support of low-cost measures that supposedly obviate the need for a return to open-rack storage. We are pleased that Congress responded to "Reducing the hazards" by commissioning the National Academy of Sciences to carry out an independent review of the risks and how to mitigate them.[4] As of the time of this writing (July 2004), the National Academy has submitted a classified report to Congress and is negotiating a declassified version with the Nuclear Regulatory Commission.

Jan Beyea,[a] Ed Lyman,[b] and Frank N. von Hippel[c]
a. Consulting in the Public Interest, 53 Clinton St., Lambertville, NJ 08530. E-mail: jbeyea@cipi.com
b. Union of Concerned Scientists, 6th floor, 1707 H St., NW, Washington, DC 20006. E-mail: elyman@ucsusa.org
c. Program on Science and Global Security, Princeton University, 221 Nassau St., 2nd Floor, Princeton, NJ 08542-4601. E-mail: fvhippel@princeton.edu

NOTES AND REFERENCES

1. *A Safety and regulatory assessment of generic BWR and PWR permanently shutdown nuclear power plants*" by R. J. Travis, R. E. Davis, E. J. Grove and M. A. Azarm (Brookhaven National Laboratory NUREG/CR-6451, 1997); "Reducing the hazards," p. 1 (see footnote 29).

2. "Damages from a major release," p. 125.

3. See *Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plant*s, pp. 3–4 for the basis for the choice of 565°C and "Reducing the hazards," p. 19 and endnote 62 for the methods that we used for calculation of convective cooling. We note here an omission in endnote 62 that led us to underestimate the full benefits to convective cooling of returning to open-rack storage, which removes the partitions used for criticality control in dense-pack storage and provides space around each fuel assembly. We accounted for the factor of seven higher convective air velocity due to reduced air friction but we failed to account for the seven times higher heat capacity of the air in the open rack per fuel assembly. As a result, for a given temperature rise, the convective air cooling per fuel assembly is about *50 times higher* for an open-rack than for a dense-packed configuration.

4. Conference Report, *Making appropriations for energy and water development for the fiscal year ending September 30, 2004, and for other purposes*, House Report 108-357, Nov. 7, 2003, p. 191; see also the follow up instructions to the Nuclear Regulatory Commission in *Energy and water development appropriations bill, 2005*, House Report 108-554, June 24, 2004, p. 163.