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August 5, 1980

Mr. Robert Bernero
Probabilistic Analysis Staff
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Washington, D.C. 20555

Dear Mr. Bernero:

At your request, we have reviewed an evaluation that was made by EPRI of the potential conservatisms and ranges of uncertainty in the WASH-1400 analysis of the iodine release for the TMLB'δ sequence. Our comments follow.

The representation of attenuation factors for the WASH-1400 Scenario and Models (Case A) is somewhat over-simplified and does not quite represent what was actually done. Although only 88% of the iodine inventory was assumed to be released during core melting in the vessel, the other 12% was released during the gap and vaporization periods. The attenuation factor should therefore be unity. Similarly, the fraction of the containment inventory released rapidly at the time of rupture was 0.85. However, more iodine was released from containment during the following hours as the result of gas production from attack of the concrete. In fact, RCB plateout and RCB rupture mode attenuation factors cannot be separated. In WASH-1400, 0.7 of the core inventory of iodine was estimated to be eventually released to the environment. The total attenuation factor was therefore 1.4. In our reanalysis of TMLB'δ using MARCH and CORRAL, the total release obtained was 0.31 for a total attenuation of 3.2. The reduction in the predicted release of iodine relative to WASH-1400 is due to the improved treatment of containment thermal-hydraulics afforded by MARCH, leading to increased plateout in the containment.

Case B, which is intended to be more realistic about attenuation factors, raises some interesting questions that will require more effort to resolve than is possible in this limited review. Some of the most significant issues relate to the details of the thermal-hydraulic behavior in the primary system during core melting, though clearly there are substantial uncertainties regarding the chemistry and transport behavior of iodine. We will provide you with our current views on these issues. Some of the other apsects of fission products attenuation have been addressed in the uncertainty analyses that have been performed for MARCH/CORRAL[1] and TRAP[2].

We see no reason to be as optimistic about the core melt release fraction as indicated by EPRI in Case B. The SASCHA release experiments[3] show 100% release for iodine at the temperatures of interest. Although the S/V ratios in these experiments are not completely representative of reactor situations, we see no reason to assume enhanced retention; though the chemical form of the iodine could obviously have an influence on its release. It has been speculated that some peripheral low power bundles may not actually melt in an accident of this type because of reduced self absorption of nuclear radiation and because of high thermal radiation to surrounding structures. Even if these were the case, it would only represent a small fraction of the core inventory of iodine. We would estimate the range of the core melt release attenuation factor as 1-1.2.

Surface/volume

We have investigated primary system plateout for the TMLB'δ sequence in an uncertainty analysis associated with the development of the TRAP code.[2] Under the assumption that iodine is released as a vapor, the attenuation factor is predicted to be in the range of 1-1.02 with a best estimate of 1.007. If the iodine is actually released in the CsI, as Malinauskas postulated[4], and behaves as a particle, the attenuation factor is predicted to be 1.1. These values are obviously well below the EPRI range of 1-100.

As implied earlier, water trapping of the released iodine is the most difficult mode of attenuation to assess because of many uncertainties regarding the details of thermal-hydraulic conditions during meltdown as well as uncertainties regarding iodine chemistry and transport. The first question is whether or not there will be water in the pressurizer during the time of iodine release from the fuel. Following dryout of the steam generators, the flow through the primary system loops would stagnate. Heat removal from the primary system would then be accomplished by steam generated in the core region passing to the upper plenum, to the pressurizer surge line in one of the hot legs, through the pressurizer and out the relief and/or safety valves to the pressurizer quench tank. As the steam passes through the water in the pressurizer, both would be saturated. Except for some amount of carryover, the water in the pressurizer would not be released out the safety valve or boiled away. Prior to core uncovery, this water would not be able to flow down against the countercurrent flow of steam from the core. At 2 hr following shutdown, the steam flow rate would be approximately 2.3×10^5 lb/hr and the steam velocity in the surge line would be 7.8 ft/sec. According to the correlation by Kutateladze[5] for countercurrent flow in pipes, the critical velocity above which no flooding (countercurrent flow of water) can occur is 1.8 ft/sec under these conditions. Thus, until significant core uncovery occurs, water would be expected to remain in the pressurizer. LOFT experiments also confirm this behavior.[6] As core uncovery takes place, however, two important things happen: The flow rate of steam decreases and the exit temperature of gases from the core becomes superheated relative to the water in the pressurizer. With no countercurrent flow of steam, the pressurizer could empty into the primary system in approximately one minute. Thus, we would expect the water in the pressurizer to flow back into the reactor vessel as the core was being uncovered and heated up. This would tend to extend the period of heatup. It would also, however, lead to reevolution of iodine trapped in the water in the pressurizer earlier in the accident since this water would be subsequently evaporated. Consequently, our current feeling is that water in the pressurizer does not have a significant potential for retaining iodine in an accident of this type.

The other region in which water could trap iodine is the pressurizer quench tank. During the time period prior to core uncovery, the steam leaving the pressurizer is saturated at the pressure corresponding to the set point of the relief and/or safety valves. In depressurizing down to the containment back pressure, the steam remains saturated and actually gains in water fraction (assuming a containment pressure of 2 bars the quality would be approximately 0.925). Thus, the saturated water in the relief tank may not be heated and boiled away by the hydrogen released from the primary system. After core uncovery, the steam released from the primary system would be superheated, but the flow rate would be significantly reduced. If all of the decay heat at this time were transferred to the quench tank, it would take about 40 minutes to boil-away the 900 ft^3 of water in the tank. Since only a fraction of the decay heat would be transferred to the quench tank, it is unlikely that all the water would be boiled off prior to meltthrough of the pressure vessel.

If the water in the quench tank were subcooled, condensation of the steam would be very effective in scrubbing iodine from the flow. Since the water is expected to be saturated, however, the amount of iodine scrubbed depends on the ability of the iodine to diffuse out of the bubbles before the bubbles escape the surface of the water. Assuming a water-steam partition coefficient of 200, a submergency of 5 feet, and a bubble size of 2 cm, the fraction of iodine retained in the water in the pressurizer quench tank can be estimated using mass transfer calculations for stagnant spherical bubble.(7) Under these assumptions, approximately 50 percent of the released iodine would be retained in the water. Variations in the above assumptions do not appear to markedly affect the above results. However, not all of the iodine released from the fuel would flow out of the pressurizer and through the quench tank. Some of the iodine would still be in the primary system at the time of vessel failure and would flow into the reactor cavity following vessel head failure without passing through water in the quench tank. Based on the above estimates of iodine diffusion out of the bubbles and observations of MARCH results regarding gases retained in the vessel, we would estimate the upper bound on the potential for water trapping to be an attenuation factor of 10.

The amount of plateout in the containment has been studied in the uncertainty analyses of the MARCH and CORRAL codes(1) for this accident sequence. At a 90% probability level, the range of attenuation factors was found to be from 2.3 to 20. This range includes uncertainties related to the magnitude of leak rate following containment failure as well as several other factors but does not include attenuation in the leak path. Although it is possible that a benign containment failure mode could involve tortuous leak paths through the concrete which would result in significant attenuation; such a failure mode would not be consistent with pressure levels that challenge the gross structural integrity of the containment, as have been considered in WASH-1400 and related studies. Given the other accident assumptions, we see little basis for taking credit for significant attenuation in the leak path.

Table 1 summarizes our estimates for potential iodine attenuation factors. As you can see, our total range is much smaller than the EPRI evaluation and our best estimate is actually below the EPRI lower value.

We will not comment in detail on Case C since a wide variety of assumptions can be made about partial core melt accidents. The consequences will be obviously influenced by the degree of core melting and, perhaps make importantly, by the effectiveness of containment sprays. Further, if containment integrity is maintained, the consequences to the public health would be minor regardless of other assumptions.

We believe that the exercise performed by EPRI has been useful in showing the magnitude of uncertainty associated with many of the phenomena in the TMLB'δ accident, one of the dominant sequences for the WASH-1400 PWR. The evaluation provides good evidence that more research is required to enable accurate predictions to be made of the consequences of core meltdown accidents. It cannot be concluded, however, that the consequences of the TMLB'δ accident seqeunces are being grossly overestimated under our current assumptions.

Sincerely,

Richard S. Denning/erc

Richard S. Denning
Research Leader
Nuclear and Flow Systems Section

RSD:erc

xc: M. Cunningham, NRC

TABLE 1. ESTIMATED ATTENUATION FACTORS FOR TMLB'δ

	Low	High	B.E.
Core Melt	1	1.2	1
PCS plateout	1	1.1	1
Water trapping	1	10	2
RCB plateout	2.3	20	3.2
	2.3	260	6.4

(1) P. Baybutt, et al., "Results of Uncertainty Studies for the MARCH/CORRAL Code Package", to be published September, 1980.

(2) P. Baybutt, et al., "An Assessment of LWR Primary System Radio-Nuclide Retention in Meltdown Accidents Using the TRAP Computer Code", CONF-800403/V-II, pp 1322-1327 (April, 1980).

(3) H. Albrecht, V. Matschoss, and H. Wild, "Experimental Investigation of LWR Core Material Release at Temperatures Ranging from 1500 - 2800 C", unpublished.

(4) R. A. Lorenz, J. L. Collins, and A. P. Malinauskas, "Fission Product Source Terms for the Light Water Reactor Loss-of-Coolant Accident", Nuclear Technology, Mid-December, 1979.

(5) G. B. Wallis, One-Dimensional Two-Phase Flow, McGraw-Hill Book Company, New York, 1979.

(6) L. P. Leach, "Results and Evaluation of the Nuclear Tests", GRS-16, April, 1980.

(7) Crank, J., The Mathematics of Diffusion, Oxford University Press, Oxford, 1967.

Appendix II

Resume of Dr. Jan Beyea

Resume for Jan Beyea
February 1981

EDUCATION:

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B. A., Amherst College, 1962

EMPLOYMENT HISTORY:

1980 to date, Senior Energy Scientist, National Audubon Society, 950 Third Avenue, New York, New York 10022.
1976 to 1980, Research Staff, Center for Energy and Environmental Studies, Princeton University.
1970 to 1976, Assistant Professor of Physics, Holy Cross College.
1968 to 1970, Research Associate, Columbia University Physics Department.

CONSULTING WORK:

Consultant on nuclear energy to the New Jersey Department of Environmental Protection, the Office of the Attorney General, Commonwealth of Massachusetts, the state of lower Saxony in West Germany and the Swedish Energy Commission, and various citizens' groups in the United States.

PUBLICATIONS CONCERNING ENERGY CONSERVATION AND ENERGY POLICY:

"Details of the The Audubon Energy Plan," Peterson, Beyea, Paulson and Cutler, National Audubon Society, March 1981.

"Indoor Air Pollution," Commentary in the Bulletin of the Atomic Scientists, 37, Page 63, February 1981.

"Locating and Eliminating Obscure but Major Energy Losses in Residential Housing", Harrje, Dutt and Beyea, ASHRAE Transactions, 85, Part II (1979). (Winner of ASHRAE outstanding paper award.)

"Attic Heat Loss and Conservation Policy", Dutt, Beyea, Sinden. ASME Technology and Society Division paper 78-TS-5, Houston, Texas, 1978.

"Comments on the proposed FTC trade regulation rule on labeling and advertising of thermal insulation", Jan Beyea and Gautam Dutt, testimony before the Federal Trade Commission, January 1978.

"Critical Significance of Attics and Basements in the Energy Balance of Twin Rivers Townhouses", Beyea, Dutt, Woteki, Energy and Buildings, Volume I (1977), Page 261. Also Chapter 3 of Saving Energy in the Home, Ballinger, 1978.

"The Two-Resistance Model for Attic Heat Flow: Implications for Conservation Policy", Woteki, Dutt, Beyea, Energy--the International Journal, 3, 657 (1978).

PUBLICATIONS CONCERNING ENERGY CONSERVATION AND ENERGY POLICY (CONT'D.):

"Energy Conservation in an Old 3-Story Apartment Complex," Beyea, Harrje, Sinden, Energy Use Management, Fazzolare and Smith, Pergamon 1977, Volume 1, Page 373.

"Load Shifting Techniques Using Home Appliances," Jan Beyea, Robert Weatherwax, Energy Use Management, Fazzolare and Smith, Pergamon 1978, Volume III/IV, Page 121.

PUBLICATIONS CONCERNING NUCLEAR POWER SAFETY

Articles:

"Emergency Planning for Reactor Accidents," Bulletin of the Atomic Scientists, 36, Page 40, December 1980. (An earlier version of this article appeared in German as Chapter 3 in Im Ernstfall hilflos?, E. R. Koch, Fritz Vahrenholt, editors, Kiepenheuer & Witsch, Cologne, 1980.)

"Dispute at Indian Point," Bulletin of the Atomic Scientists, 36, Page 63, May 1980.

Published Debates:

The Crisis of Nuclear Energy, Subject No. 367 on William Buckley's Firing Line, P.B.S. Television. Transcript printed by Southern Educational Communications Association, 928 Woodrow Street, P. O. Box 5966, Columbia, South Carolina, 1979.

Nuclear Reactors: How Safe Are They?, panel discussion sponsored by the Academy Forum of The National Academy of Sciences, 2101 Constitution Avenue, Washington, D. C. 20418, May 5, 1980, to be published.

Reports:

"Some Long-Term Consequences of Hypothetical Major Releases of Radioactivity to the Atmosphere from Three Mile Island," Report to the President's Council on Environmental Quality, December 1980.

PUBLICATIONS CONCERNING NUCLEAR POWER SAFETY (CONT'D.)

"Decontamination of Krypton 85 from Three Mile Island Nuclear Plant", (with Kendall, et.al.), Report of the Union of Concerned Scientists to the Governor of Pennsylvania, May 15, 1980.

"Some Comments on Consequences of Hypothetical Reactor Accidents at the Philippines Nuclear Power Plant" (with Gordon Thompson), National Audubon Society, Environmental Policy Department Report No. 3, April, 1980.

"Nuclear Reactor Accidents: The Value of Improved Containment", (with Frank von Hippel), Center for Energy and Environmental Studies Report PU/CEES 94, Princeton University, January 1980.

"The Effects of Releases to the Atmosphere of Radioactivity from Hypothetical Large-Scale Accidents at the Proposed Gorleben Waste Treatment Facility", report to the Government of lower Saxony, Federal Republic of Germany, as part of the "Gorleben International Review", February, 1979.

"Reactor Safety Research at the Large Consequence End of the Risk Spectrum", presented to the Experts' Meeting on Reactor Safety Research in the Federal Republic of Germany, Bonn, September 1, 1978.

A Study of Some of the Consequences of Hypothetical Reactor Accidents at Barseback, report to the Swedish Energy Commission, Stockholm, DS I 1978:5, January, 1978.

Testimony:

"Advice and Recommendations Concerning Changes in Reactor Design and Safety Analysis which Should Be Required in Light of the Accident at Three Mile Island," Statement to the Nuclear Regulatory Commission concerning the proposed rulemaking hearing on degraded cores, Dec. 29, 1980.

"Testimony on Behalf of the Anti-Nuclear Group Representing York Regarding A.N.G.R.Y. Contention No. V(d)," submitted Sept. 30, 1980. (This testimony concerned filtered venting retrofits at TMI Unit No. 1 as a condition of restart.)

"Alternatives to the Indian Point Nuclear Reactors", Statement before the Environmental Protection Committee of the New York City Council, December 14, 1979. Also before the Committee, "The Impact on New York City of Reactor Accidents at Indian Point", June 11, 1979. Also "Consequences of a Catastrophic Reactor Accident", statement to the New York City Board of Health, August 12, 1976 (with Frank von Hippel).

PUBLICATIONS CONCERNING NUCLEAR POWER SAFETY (CONT'D)

"Emergency Planning for a Catastrophic Reactor Accident", Testimony before the California Energy Resources and Development Commission, Emergency Response and Evacuation Plans Hearings, November 4, 1978, Page 171.

"Short-term Effects of Catastrophic Accidents on Communities Surrounding the Sundesert Nuclear Installation", testimony before the California Energy Resources and Development Commission, December 3, 1976.

"Consequences of Catastrophic Accidents at Jamesport". Written testimony before the New York State Board on Electric Generation Siting and the Environment in the matter of Long Island Lighting Company (Jamesport Nuclear Power Station, Units 1 and 2), May, 1977.

Miscellaneous:

"Comments on WASH-1400", Statement to the Subcommittee on Energy and the Environment, Oversight Hearings on Reactor Safety, June 11, 1976, Serial No. 94-61, Page 210.

"Upper Limit Calculations of Deaths from Nuclear Reactors", Bull. Am. Phys. Soc. 21, III (1976).

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

RELATED CORRESPONDENCE

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of METROPOLITAN EDISON COMPANY, *et al.*, (Three Mile Island Nuclear Station, Unit No. 1)	Docket No. 50-289

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CERTIFICATE OF SERVICE

I hereby certify that copies of the "Direct Testimony of Dr. Jan Beyea on Behalf of the Anti-Nuclear Group Representing York Regarding A.N.G.R.Y. Contention No.IIIB(D)" have been mailed postage pre-paid this 27th day Of February, 1981, to the following parties:

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