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November 29, 1982

Director of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

ATTN: Mr. Steven A. Varga, Chief
Operating Reactors Branch No. 1
Division of Licensing

SUBJECT: Indian Point Unit 2
Docket No. 50-247

Indian Point Unit 3
Docket No. 50-286

Indian Point Probabilistic Safety Study

Dear Mr. Varga:

In response to your letter of October 27, 1982 regarding the DRAFT Battelle Analysis of Liquid Pathways Consequences due to Basemat Penetration as presented in the Indian Point Probabilistic Safety Study please find enclosed our comments.

We wish to emphasize that the risk to public health and safety from such an event is conservatively bounded in the IPPSS since we made the radioactive release from a liquid pathway release into an airborne release to maximize health effects. Also, the probability of basemat penetration is much lower than other scenarios which have a substantial contribution to risk.

Very truly yours,

J. P. Bayne
Executive Vice President
Power Authority of the State
of New York

John D. O'Toole
Vice President
Consolidated Edison Company
of New York, Inc.

A001

attach.

RESPONSE TO DRAFT BATTELLE ANALYSIS OF INDIAN POINT PROBABILISTIC SAFETY STUDY
APPENDIX 6.7 - ANALYSIS OF LIQUID PATHWAYS CONSEQUENCES DUE TO BASEMAT PENETRATION

These responses follow the order of the comments themselves, that is:

1. Summary;
2. Clarification; and
3. Technical Issues.

SUMMARY

While a part of the overall Indian Point Probabilistic Safety Study (IPPSS), the Analysis of Liquid Pathways Consequences was never represented to be a probabilistic risk assesment. Where appropriate, information was developed and subsequently presented in a statistical manner. However, the results are presented as a point estimate which is associated with the best estimate of the ground water travel time. This was judged to be a proper and sufficiently rigorous approach given (1) the exceedingly low probability of a liquid pathways type of accident, and (2) the ability to interdict as warranted.

The first summary comment concerns site-specific data. It is clearly stated in Section 6.7.3.2.5 what ground-water data were available for the site. These data consisted of detailed geology (from boring logs and surface mapping) and water-level data (from borings). This amount of ground-water data is not uncommon in field programs for which the primary interest is foundation stability.

The liquid pathways sequence is highly unlikely because the basemat would probably not be penetrated if there is water in the containment. If the containment were to become dry during an overpressure failure, and the basemat thereby be penetrated, there would no longer be contaminated water available to be dispersed through a liquid pathway. Thus, the conditions leading to basemat penetration and significant releases through a liquid pathway may be mutually exclusive.

The liquid pathways sequence was conservatively modeled in the IPPSS as an atmospheric release and thus overstates the health risk. Because it is a minor contributor to overall risk, the level of data was considered sufficient for the analysis presented. Moreover, the liquid pathways analysis contained in IPPSS is at least as rigorous as any site-specific liquid pathways analysis which has been performed for any site to date.

The analysis was designed to make use of all available data and to evaluate the uncertainty in important hydraulic parameters. Recharge was estimated and a steady-state flow analysis was used to obtain an estimate of hydraulic conductivity (p. 6.7-9) using the water-level data for model calibration. The effect of uncertainty in the resulting hydraulic conductivity was evaluated using Monte Carlo simulation techniques to obtain a range of travel times to the Hudson River. The effect of uncertainty in the porosity estimate was also evaluated in this manner, whereas the effect of uncertainty in the distribution coefficient was evaluated using sensitivity analysis (Section 6.7.3.4.3).

Such an approach is common in ground-water studies. Indeed, even if data are available for hydraulic conductivity, the values used for modeling are usually changed during the course of the study. Often in ground-water studies, estimates of hydraulic conductivity obtained from aquifer tests are modified during the model calibration portion of the study. This is because aquifer-test results represent local or point estimates of hydraulic conductivity, whereas the model calibration analysis yields an estimate for hydraulic conductivity that is averaged over a larger region.

In all ground-water studies some parameters have to be estimated based on professional judgment and experience developed by analyzing similar problems. Many of the references cited in this response are such examples. The effects of the uncertainty in these estimates must also be evaluated. This approach was used at Indian Point. Given the lower significance of liquid pathways, the analysis was considered adequate and no additional data were collected.

The second summary comment deals with the equivalent porous media approach. The use of an equivalent porous media approach is appropriate for the Indian Point site because the scale of the fracturing or jointing (inches) is much less than the scale of the flow path (475 feet). Consultants to the utilities, who have actually examined the site, found that the metamorphosed limestone is brittle and intensely fractured. Examination of outcrops at the site (or of the cores that are available on site) shows the scale of fracturing to be quite small. Indeed, a quote from Thomas W. Fluhr (ref. 6.7-6) which was included in page 6.7-7 describes the degree of fracturing as "The jointing has an intensity which might almost be described as brecciation." The above quote conveys a picture of a highly fractured rock.

CLARIFICATIONS

1. The statement referred to on page 6.7-1 is included to establish a proper perspective between the relative importance of liquid and atmospheric pathways to human health effects. Because the IPPSS models liquid pathways as an atmospheric release, human health effects are conservatively bounded.

2. The code SWIFT is a United States NRC sponsored code capable of simluating flow, solute transport with decay, and heat transport in porous media. The code's capabilities are described in the attached table.

3. The assumed operating conditions are conservative in that they allow for build up of all fission products to the end of cycle equilibrium conditions and furthermore are consistent with assumptions for the atmospheric consequence analysis.

4. Wide ranges of k_d values appear in the literature. Values from the lower, more conservative end of these ranges were used in this analysis. Surface area based k_d values are inappropriate for this system, but would lead to the same lesser retardation effects as were simulated in this analysis by using low end k_d values.

5. The reports referred to are publications of national laboratories.

Use has been made of J. Serne's experience with the k_d values as he suggested in the letter attached to the comments. The limestone in the Indian Point area is definitely not oolitic. Thus, values from Table 2 in Serne's letter are appropriate for comparison with the values given in Table 6.7-2 of this report as shown in the following table.

	Table 6.7-2		Serne's letter of 15-Sept-82 Table 2	
Element	k_d	Retardation Factor*	k_d	Retardation Factor*
Co	3.0	1.6×10^3	--	--
Sr	0.5	2.7×10^2	13.	7.0×10^3
Ru	0.0	1	--	--
I	0.0	1	--	--
Cs	3.0	1.6×10^3	6500	3.5×10^6
Pu	13.0	7.0×10^3	90	4.9×10^4

* Retardation factor = $(1 + \frac{2.7}{0.005} k_d)$: see p. 6.7-12

The third and fifth columns of this table are the factors by which the nuclide velocity is retarded relative to the water velocity for the various k_d values given. As this shows, retardation factors calculated using the values suggested by Serne are from 7 to 2000 times larger than the factors derived using k_d values chosen. Using Serne's proposed k_d values would clearly lead to much smaller doses from strontium, cesium, and plutonium.

It should be noted that since August 1980 when this report was prepared, a field measured value for ruthenium retardation has been published (Coles and Ramspott, 1982).[1] This study reports that in an oxidizing tuff environment, ruthenium apparently migrated at the same rate as did tritium. Oxidizing conditions are likely to prevail in the Indian Point ground water. Tritium, as part of the water molecule, is generally considered not to be retarded. Tuff is a much more sorptive rock than limestone so that if retardation of an element was to occur, it would be more strong on tuff than on limestone. Thus, the lack of retardation reported by Coles and Ramspott supports the choice of a zero value for the k_d of ruthenium in this system.

6. The order of data presentation does not need to be changed.

7. It is stated on p. 6.7-8 that we are using an equivalent porous medium approach. This assumption plus the use of the term effective porosity (p. 6.7-14) are adequate to explain the definition we use for porosity. We are unclear as to what the reviewer means by "static porous medium porosity" or "dynamic effective value." These terms are not defined in standard textbooks on ground-water hydrology such as Freeze and Cherry (1979). The value of 0.005 was estimated using Reference 6.7-15 and is thought to be representative of a fractured limestone. The value of 0.005 for porosity also gives a conservative estimate for travel time. That is, because the Darcy velocity is

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1. Coles, David G. and Ramspott, Lawrence D., 1982. "Migration of Ruthenium - 106 in a Nevada Test Site Aquifer: Discrepancy Between Field and Laboratory Results." Science, v. 215, p. 1235-37.

divided by porosity in the travel time calculation, a small value of porosity gives a faster travel time.

8. The sump water entry rate was calculated using the 2-D SWIFT simulation of the Indian Point ground-water system. The sump water was assumed to be driven into the natural aquifer system by a head of 13.3 feet. This is the elevation of the basemat floor of IP3 (46 ft. above mean sea level) plus the retaining wall height of 4 feet minus the elevation of the undisturbed water level at the location (36.7 feet) from the system model.

The SWIFT code showed that a head of 13.3 feet would give a steady-state injection rate of 320 ft^3/day.

9. The reviewers are correct that the figures could have been more clearly identified.

10. Based on the discussion in 6.7.3.4.5.2 and Figure 6.7-12, there is no reason to select a higher leach rate.

11. The estimating procedure is discussed in the text on page 6.7-12. An additional footnote to Table 6.7-2 could be added which indicates that the ruthenium isotopes are either uncharged or negatively charged and are therefore assigned to a k_d of 0. as was iodine, and that cobalt is likely to have a low positive charge similar to cesium and is, therefore, given a k_d of 3.0 as was cesium. The other k_d values are based on measurements as noted.

TECHNICAL ISSUES

Available Data Versus Sophistication of SWIFT

HYDRAULIC GRADIENT: The match of the hydraulic head data in Figure 6.7-5 was performed to obtain an estimate of the hydraulic conductivity. The match is reasonably good and was not improved for the reasons given on p. 6.7-10, that is, limited data did not warrant it. The observed hydraulic gradient from IP3 to the h=0 contour in Figure 6.7-3 is approximately 40'/350' or 0.114. Note, as pointed out on p. 6.7-10, that this corresponds to the site with no buildings. The computed match gave a gradient of 0.062 (p. 6.7-14). The computed hydraulic gradient is therefore less than the observed, which would produce slower travel times. It is interesting to note, however, that both gradients, computed and observed, represent pre-building recharge. As pointed out on p. 6.7-10, when the recharge was reduced for the area covered by buildings and pavement, the gradient was reduced by 40 percent. Therefore, the present gradient is probably reduced due to decreased recharge, and if the 40 percent factor is used, the observed pre-building gradient becomes (60%) (0.114) or 0.68, which is very close to the value of 0.062 used in the Monte Carlo simlulations. The sensitivity of the travel time to the hydraulic gradient was not considered since the relationship is linear.

In summary, given the uncertainty in the data, both the match on hydraulic head and the values used for the hydraulic gradient are reasonable.

TWO-DIMENSIONAL SIMULATION: The two-dimensional simulation was appropriate for the amount of data and the questions to be addressed. The two-dimensional simulation (1) took advantage of the water-level data, (2) was planned initially to examine remedial action (this part of the simulation was later deemed unnecessary), and (3) was necessary to simulate the sump water release scenario.

Travel Times and Uncertainty Analysis

While some of the calculations could have been made, as the reviewer suggests, by taking the logarithm of Equation 6.7-3 directly, the Monte Carlo simulations were necessary for case 2 where hydraulic conductivity and porosity are assumed to be correlated. Indeed, comparison of the Monte Carlo simulations with the analytical solutions (where applicable) provided a check on the computational procedure. The 190-day water travel time was calculated using our best estimates of hydraulic parameters. The distance to the river was measured, the hydraulic gradient and hydraulic conductivity were obtained from the areal simulations, and the remaining parameters were estimated from reports dealing with similar geology and hydrology. It should also be noted that the uncertainty in the distribution coefficient was evaluated, in part, by a sensitivity analysis.

Probabilistic Consequence Analysis

See response to Summary for a response to the comments regarding the probabilistic nature of this analysis.

With regard to the comment on travel time estimates for Pu-

239 (page 6.7-19), the field observation discussed in the response to the second SUMMARY comment suggests that major fracture flow of the type proposed in this comment is not an appropriate conceptual model for this site. Furthermore, if such flow did occur the treatment of the hydrologic data discussed in the response to the first summary comment indicates that its volume could only be a small fraction of the total water flow in the system. Any such postulated fracture would not be of sufficient size to prevent significant retardation by adsorption nor would it permit rapid flow of more than a very small fraction of the sump water in the system.

Release Rate for the Sump Water Release Scenario

The derivation of the sump water release rate is discussed in the response to Clarification Comment 8 above.

Leach Rate for the Core Melt Leaching Scenario

In a system as tightly fractured as is this one (see response to Summary comment, above) no real distinction between the influence of porous or fracture flow on the leaching mechanism seems appropriate. If, as the reviewer suggests, less flow intercepted the core than would be predicted from surface area considerations alone, the leach rate would, in fact, be lower than that calculated. Finally, it is not clear what additional factors the reviewer had in mind which might contribute to uncertainty in the leach rate.

SWIFT

THE SANDIA SIMULATOR FOR WASTE ISOLATION,

FLOW AND TRANSPORT MODEL[1]

PURPOSE: The SWIFT model is applicable for modeling the porous media flow and transport of energy and both dominant and trace constituents. The model may be used to analyze both high and low-level radionuclide accidental release and migration in the subsurface environment.

PRIMARY EQUATIONS:

- Fluid-flow material balance
- Energy balance
- Brine (solute) transport
- Radionuclide (chains) transport

ASSUMPTIONS:

- Fluid flow in the aquifer may be described by Darcy's Law for flow through a porous medium.
- Fluid density may be a function of pressure, temperature and contaminant concentration. Fluid viscosity may be a function of temperature and concentration.
- Hydrodynamic dispersion may be described as a tensor function of fluid velocity.
- The energy equation may be described as

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1. Dillon, R.T., Lance, R.B., and Pahwa, S.B., "Risk Methodology for Geologic Disposal of Radioactive Waste: The Sandia Waste Isolation, Flow and Transport (SWIFT) Model," USNRC, NUREG/CR-0424, 1978.

"enthalpy in - enthalpy out = change in internal energy of the system." This is rigorous except for kinetic and potential energy which have been neglected.

- Water table conditions in an unconfined aquifer may be approximated by no capillarity and no residual water saturation (specific retention).
- Contaminant reaction may be described by a first order reaction - similar to radioactive decay.
- Contaminant adsorption on rock surface may be described by linear adsorption isotherms.
- The following aquifer properties vary with position-porosity, permeability, thickness, depth, specific heat and adsorption distribution coefficient.

APPROXIMATION METHOD:

- Finite-difference using variable grid spacing

SOLUTION TECHNIQUES:

- Direct, ordered Gaussian elimination
- Iterative two-line successive over-relaxation (L2SOR)

GEOMETRY:

- 1-, 2, or 3-dimensional cartesian
- 2-dimensional cylindrical

OPTIONS:

- Steady-state or transient (flow and/or brine)
- Solute transport
- Heat transport
- Well-bore submodel
- Restart capability
- Contour mapping
- Heterogeneous and/or anisotropic media

- Confined or water-table conditions
- Recharge and/or wells
- Radioactive waste-leach submodel (source generation)
- Central/backward differencing in space
- Crank Nicholson/backward differencing in time

BOUNDARY CONDITIONS:

- Specified value
- Specified flux
- Aquifer influence functions

DEVELOPED BY: INTERA