234

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May 16, 1984

DOCKETED
USNRC

'84 MAY 18 A10:30

Honorable Lawrence Brenner
Administrative Law Judge
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U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Honorable Peter A. Morris
Administrative Law Judge
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U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Honorable Richard F. Cole
Administrative Law Judge
Atomic Safety and Licensing Board
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

RE: IN THE MATTER OF PHILADELPHIA ELECTRIC COMPANY (LIMERICK GENERATING STATION, UNITS 1 & 2) DOCKET NOS. 50-352 & 50-353

Dear Board Members:

Enclosed herewith please find a copy of the study commissioned by the City of Philadelphia. This study was delivered to Mr. Wetterhahn on Tuesday, May 15, 1984. I am conveying it herewith by express delivery to the Board and the NRC Staff. Delivery to all other parties by regular mail.

Sincerely,

Martha W. Bush

MARTHA W. BUSH,
Deputy City Solicitor

MWB:ddb

Enclosure

cc: ALL PARTIES

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POTENTIAL CONSEQUENCES OF SEVERE ACCIDENTS AT THE LIMERICK NUCLEAR POWER PLANT

Fred C. Finlayson

May 14, 1984

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POTENTIAL CONSEQUENCES OF SEVERE ACCIDENTS AT THE LIMERICK NUCLEAR POWER PLANT

1.0 INTRODUCTION

If a severe accident involving a core meltdown and a substantial release of radiation were to occur at the Limerick nuclear power plant, state, local, and regional planners might consider taking several protective action options in an effort to reduce the potential radiological hazards to the public. Recommendations for evacuation might be made to the people living within the ten mile radius, Plume Exposure Pathway Emergency Planning Zone (EPZ). Even outside the Plume Exposure EPZ, people might voluntarily evacuate their homes if an order to evacuate were given. Another important option for reducing the radiological hazards of a core melt accident is the concept of sheltering. If sheltering were recommended as a protective measure, people would be encouraged to stay inside their houses -- in their basements, if they were available -- until the radioactive cloud had passed by or had dissipated within their neighborhoods. This report analyzes the probable radioactive exposures and resulting consequences associated with protective action recommendations for evacuation and for sheltering within the vicinity of the City of Philadelphia and the Limerick plant. For comparison, the exposures associated with conditions where no protective actions would be taken are also reviewed.

Site specific results are presented in this report for the geographical area about the Limerick site and for the Philadelphia area in particular. The results have been based upon radiological source term descriptions for severe accidents at the Limerick plant as they have been derived by the Nuclear Regulatory Commission (NRC) in their Draft Environmental Statement (NUREG-0974) for the facility (Ref. 1). The individual source term categories considered in the descriptions of the accidents are presented in Table 1 (Reproduced from Ref. 1). The corresponding probabilities of the contributing source term categories are presented in Table 2 (Reproduced from Ref. 1). Consequences have been calculated using the CRAC2 statistical analysis code -- a state of the art computer code developed by the NRC for estimating the potential effects of postulated severe core melt accidents at nuclear power plants. Meteorological conditions for the site were furnished by the Philadelphia Electric Company. (Ref. 2).

2.0 CONSEQUENCE ANALYSIS RESULTS

Calculational results are shown in Figure 1 for a model of public response where the people are assumed to take no special protective actions for an entire day in response to the accident conditions. The model characterizes the public as going about their daily lives as though conditions were normal for a 24 hour period of exposure to the radioactive fission products released in the event. The concept of the model is based upon the results originally presented by the NRC in their basic planning document, NUREG-0396 (Ref. 3). Shielding factors for the calculations are presented in Table 3.

In analyzing the results of Figure 1, a substantial fraction of the population of Philadelphia is located at distances of between 20 and 30 miles from the Limerick plant. The city boundaries are generally east-southeast (ESE) to southeast (SE) of the facility. At this distance and direction, assuming no protective actions are taken by the public, the mean doses projected are between 2.0 and 3.0 rems. The mean doses presented in these results represent the probabilistically weighted arithmetic mean (or "average") values of over 1300 to 2600 individual calculations of the magnitudes of doses and/or health effects for each analytical case considered. Peak doses and health effects values have also been presented in the text below. The peak values cited represent the largest single values of the conditions calculated from the 1300 to 2600 individual results calculated for each case and location in the analyses.

2.1 Health Impacts of Ionizing Radiation

Exposure to the ionizing radiation resulting from a severe nuclear power plant accident may cause health effects as a result of biological changes induced in the cellular structure of the body. However, the health effects induced by radiation can only be projected on a stastical basis. That is, within a group of people that have all been exposed to the same average dose, individual members of the group will not necessarily experience the same symptoms -- especially at relatively low doses. Thus not everyone exposed to radioactive doses sufficiently large to induce some early deaths or injuries may be victims of such effects. However, survivors of early effects may subsequently succumb to the delayed effects of latent cancers. These delayed effects would also be probabilistically distributed among individual survivors and would ordinarily begin to appear after latency periods of ten years or more.

In order to minimize the probability that the public will be exposed to health threatening radiological doses, the Environmental Protection Agency (EPA) has established Protective Action Guidelines (PAG's). The PAGs require responsible government agencies to initiate protective actions whenever projected doses to the public from an

accident are expected to exceed 1 to 5 rems to the whole body and/or 5 to 25 rems to the thyroid. The EPA did not propose that the PAGs represented acceptable doses to the public. The PAGs simply represent triggering dose levels at which protective actions must be initiated, if projected doses exceed the established limits (Ref. 4).

However, if PAG level doses were received by the public, the probability of health effects to individuals would be quite low. The probability of early deaths or injuries - occurring within 30 to 60 days after exposure - would be negligible. Moreover, the probability of delayed cancer deaths (or incidence) would be less than 1/1000.

Threshold doses for induction of early fatalities are commonly considered to be about 200 rems. If doses of this magnitude were received, a ten percent probability exists that early deaths would occur - assuming that the recipients received little of no immediate medical treatment for their radiological exposures. If the people receiving 200 rem doses survived the early fatality threat, there would be a 60 percent chance that they would experience early injuries -- primarily respiratory ailments, nausea, etc. After recovery from the effects of the early injuries, there would still be a 3 to 8 percent probability that their exposure to such a large dose would ultimately result in death from latent cancers.

The commonly accepted threshold doses for early injuries are about 30 rems. At a 30 rem exposure, a one percent probability exists of incurring early injuries. On the other hand, the individual probability of latent cancer deaths occurring as a result of receiving a dose of 30 rems is about 0.5 to 1.2 percent. In this study, latent cancers have been assumed to be linearly related to the magnitudes of radioactive doses received with a probabilistic frequency of about 150 cancer deaths per million person-rems. Recent evidence suggests that the probabilistic frequency of cancer deaths from radioactive exposure could be as large as 400 deaths per million person-rems. Therefore, the latent cancer death estimates presented in this report are believed to be conservatively low.

2.2 Dose-Distance-Probability Results

Thus the mean calculated dose levels of 2 to 3 rem within the Philadelphia city limits, for the sum total of all probable accidents at the Limerick plant, fall within the PAG limits. Peak values for the projected doses within the city limits for the same set of accidents range between 194 and 424 rem. The results of the calculations show that the probability of exceeding PAG levels within the city limits is about 40 to 45 percent at 1 rem and from 8 to 14 percent at 5 rems, if no protective actions were to be taken by the public. As indicated in Figure 1,

the probability of receiving life threatening or injury inducing doses is quite low at distances as far away from the Limerick site as Philadelphia. Though as noted above, the peak doses calculated for the city were quite high, the probability of exceeding doses as high as 200 rems was calculated to be about 1/10,000 (or 0.01%). The probability of exceeding doses of 30 rems was calculated to be about the order of 1 percent at distances between 20 to 30 miles downwind from the plant.

In Figure 2, the results are shown of calculations of the potential doses to individuals who were modeled as evacuating through the City of Philadelphia with an average velocity of one mile per hour. For purposes of this study, it was assumed that the residents of Philadelphia were also evacuating, even though they may not have been included in the evacuation order. The calculated mean doses to such evacuees at distances of 20 to 30 miles from the plant range from 1.7 to 2.3 rems. Under corresponding accident conditions, the peak calculated doses to evacuees within the city ranged between 110 and 151 rem. consequently, the probability of life threatening doses was calculated to be negligible. The probability of receiving doses in excess of 30 rems was calculated to be less than 1 percent (ranging from .62 to .34 percent). The probability of exceeding 1 rem was calculated to be about 40 percent (ranging from 37 to 43 percent).

An estimate was made of the potential effects of overloading the traffic carrying capacity of the city streets. To estimate these effects, calculations were made of the doses received by people who were caught in gridlock conditions in their automobiles while evacuating within the city. Doses received under these conditions would, of course, be very time dependent relative to the time during which gridlock conditions existed. Calculations were performed for parametric gridlocked periods ranging from 2 to 12 hours. For the unlikely case where gridlock existed within the city limits for the longest times of twelve hours, the doses received under such conditions were calculated to be very similar to those for the no protective action case. The calculated mean doses ranged from 2.2 to 3.4 rems. Though the peak calculated doses ranged between 213 and 458 rems, the probability of receiving life threatening doses even under these extreme gridlocked conditions was essentially negligible. However, the probability of receiving doses in excess of 30 rems was of the order of 1 percent. Doses in excess of 5 rems were calculated to have a probability of from 8.9 to 16 percent. The probability of exceeding 1 rem was estimated to range from 41 to 50 percent. For gridlocked periods of about two hours, the probability of exceeding either 200 or 30 rems becomes negligible. The probability of exceeding 5 rems is reduced to a range of from about 2 to 6 percent; and the probability of

exceeding 1 rem is reduced to from 25 to 35 percent.

In Figure 3, the results are shown of calculations of the potential doses that might be received by individuals if they took shelter in brick houses with basements -- like those that are typical of the Philadelphia area. The mean calculated doses for people who take shelter in this fashion for a period of 12 hours range from 1.0 to 1.6 rems at distances of from 20 to 30 miles from the Limerick plant. The probability of life threatening doses was calculated to be negligible under these circumstances. The probability of exceeding doses of 30 rems was of the order of 0.1 percent (ranging from .064 to .261 percent depending upon distance from the plant within the city limits). The probability of exceeding 5 rems ranged from 3.8 to 5.5 percent; while the probability of exceeding 1 rem ranged from 28 to 35 percent.

2.3 Health Effects

Analyses were made of the health effects associated with the accident sequences and associated doses of radioactivity incurred by exposed individuals as discussed above. In particular, early fatalities, early injuries, and latent cancer fatalities were projected for the severe accident sequences analyzed. In all the cases reported on below, the health effects included the combined summation of all the source term elements defined for the NRC's Draft Environmental Statement (DES) as described in Tables 1 and 2. The calculations were conducted for the population associated with the two sectors ESE and SE of the Limerick facility within which the city of Philadelphia is located. The health effects were analyzed parametrically for three evacuation conditions and for three sheltering conditions. The evacuation analyses were conducted on the basis of the assumption that an evacuation had been recommended for the city of Philadelphia and that evacuees were moving through the city at three different average velocities: 2.5, 1.0, and 0.5 miles per hour (mph). A two hour delay period prior to initiation of evacuation was assumed for all cases -- in accordance with the DES assumptions (Ref. 1, p.5-22). The sheltering calculations were performed under the assumption that the majority of the population of Philadelphia took shelter in brick houses with basements. The effects of exposure periods of 6, 12, and 24 hours were investigated parametrically.

As expected, the highest velocity evacuation case was the most effective protective action analyzed. For the 2.5 mile per hour average velocity case, there were 1.05 mean early fatalities (relative to the peak value of 4860 fatalities for all calculated cases with this average velocity). By comparison, there were mean and peak values of early fatalities of 4.15 (9120 peak) and 24.9 (54,900 peak) for the 1 mph and 0.5 mph cases respectively. In

most cases, early fatalities occurred outside the city limits, within the close-in regions nearer the Limerick facility.

Early injuries were also found to be of limited significance to the city planners. Only for the lowest velocity case (0.5 mph) was there any substantial likelihood of early injuries occurring within the city boundaries. In this case, where a mean value of 449 early injuries was projected for the population distributed over all distances from the reactor, 131 of the early injuries (or 29.2 percent) were calculated to occur within the city boundaries. For all the other velocity cases investigated, the probability of early injuries occurring within the city boundaries was found to be essentially negligible.

Latent cancer fatalities were only calculated for the one mile per hour evacuation case. A mean calculated value of 613 fatalities was projected for this case (compared to a peak calculated value of 62,000 fatalities). Of the 613 mean total fatalities for the ESE and SE sectors and all distances from the facility, 320 (or 52.2 percent) were calculated to occur within the city boundaries.

For the sheltering cases examined, the overall early fatalities were smaller in number than they were for the 1 mph evacuation case. When all distances from the plant were included, mean values ranged from 2.42 fatalities for the 6 hour exposure period case to 3.98 for the 24 hour exposure period conditions. Peak values of early fatalities associated with these exposure conditions were 7610 and 5560 respectively. However, like the evacuation cases examined, the impact of early fatalities on the city was essentially negligible. In only a few relatively rare cases were fatalities incurred as far from the plant as the city limits. Even in these rare cases, it appears that few, if any, deaths would be expected to occur within the city limits.

Early injuries were projected for the sheltering cases that were examined. The results indicated that early injuries under these conditions have a limited impact on the city. The mean early injury values at all distances from the reactor were found to range from 27.8 to 36.3 for all the exposure periods investigated. For the mean values calculated, the city's contribution to the whole was found to be less than one-half of one percent (0.5%). The peak values observed for all distances from the plant ranged from about 90,000 to 100,000. For these cases, the city's contribution to the overall total is unknown. However, it is likely to be larger than the fractional contribution calculated above. In any case, however, the probability of the peak values of early injuries occurring in an accident is very remote

(approximately 1/10,000,000 -- assuming that a severe core melt accident has occurred).

Latent ' cancer fatalities were calculated for conditions where the population was sheltered for the 12 hour exposure case. A mean calculated value of 581 deaths was projected for the entire area considered in the calculation (compared to the peak value of 59,300 deaths for the same area). Of the total mean value of 581 deaths, 274 were projected to occur within the city limits (about 47.2 percent of the total).

3.0 CONCLUSIONS

The results of the calculations performed for this report were dominated by the effects of only a small number of the 27 listed Release Categories presented in Table 1. The relative probability of a severe coremelt accident is dominated by the release categories I-T/DW, the two I-T/WW cases, and the two I-T/LGT cases. Together, these five cases represent over 92 percent of the relative probability of a severe accident occurring. However, the projected doses for these release categories (when considered in terms of their individual contributions) are quite low. For example, the mean dose associated with the I-T/WW series is about 0.5 rem at the city limits.

On the other hand, a few release categories with large fission product releases contribute most of the rest of the impact on doses and health effects. For example, the II-T/WW, III-T/WW and the IV-T/WW series dominate the impacts of the high dose categories. Though these three categories contribute less than five percent to the overall relative probability of a severe accident at Limerick, they contribute 25 percent of the overall mean value of the dose for all integrated contributions of the release categories. The calculated mean dose for the individual contribution of the IV-T/WW category at the city limits is about 37 rems -- a rather large mean dose, slightly in excess of the early injury threshold. Thus, these few, relatively large, release categories have a disproportionate influence on the consequences of severe accidents. An accident in any of these categories, if it were to occur, could cause unfortunate consequences for the city. A significant question to ask is whether the approximately five percent relative contribution to the probability of an accident associated with these combined categories is sufficiently small to be negligible for city emergency planning purposes.

As a result of the influence of the relatively high probability of the Limerick release categories associated with low doses, the projected mean doses were rather low within the city limits for all cases considered in this report. Mean values ranged from about 1 rem with

sheltering to about 3 rems for cases where no protective action was taken. On the other hand, peak dose values for these same identical cases ranged from from about 100 rems to about 425 rems. The peak values show the influence of the relatively high consequence release categories combined with bad weather conditions. Peak doses are almost always associated with rainfall conditions occurring simultaneously with the arrival of the radioactive cloud from the accident over the city limits. However, as noted above and as shown in Figures 1 to 3, the meteorological conditions leading to peak doses are relatively rare occurrences.

Though the calculated one to three rem mean dose values are relatively low, the probability of incurring more substantial dose levels within the city limits is relatively high. The probability of incurring doses in excess of 30 rems - the early injury threshold - is about one percent assuming that a core melt accident has occurred. Moreover, the probability of incurring a 10 rem dose is about 5 percent. Though doses of 10 to 30 rems have a negligible probability of being associated with early fatatities, they do increase the individuals incremental probability of incurring latent cancers by about one to two percent.

The calculated consequence results indicate that early fatalities and early injuries will probably not have a major impact on the city, unless very low evacuation velocities are expected to occur within the city. For most practical purposes, the effects of early deaths and injuries are confined to areas outside the city limits. Except for those cases where evacuation velocities were substantially less than 1 mph, when early deaths and injuries occurred within the city limits the consequences were essentially negligible. The effects of latent cancers are so pervasive however, that they are calculated to impact the city. As noted, in the cases considered, about 50 percent of the overall mean latent cancers induced by the accidents occurred within the city limits. It should be noted, however, that the individual risks of incurring cancer as a result of the radioactive doses received in an accident are relatively low within the city limits. On the basis of the potentially exposed population of about 1,767,000 included in the zones of the calculation for the city, the mean values of the individual risk of death from latent cancer induction from the accidents are about 1/10,000.

It should also be noted that the latent cancer deaths associated with such accidents would be distributed over a relatively long period of time. No deaths are likely to occur in the first ten years after exposure to the ionizing radiation. Thereafter, the probability of cancer induced death is distributed essentially uniformly throughout the remainder of an individual's lifetime.

Thus, the indicated mean values of latent cancer deaths projected for the city in the calculations (approximately 300 in both the evacuation and sheltering cases considered) would probably be spread out over many decades of time after the accident. For comparative purposes, the cancer induced natural deaths over a similar period of time for the population of a city the size of Philadelphia would be about 300,000. If an accident with doses more severe than the mean values were to occur (e.g., 10 to 30 rems as discussed above) then the number of latent cancer deaths might reach values of the order of 10,000 for the city. Though these deaths would also be distributed over decades of time, their impact on the city would clearly be substantially greater than the impact of the mean value cases (300 latent cancer fatalities) as discussed above.

Since the number of latent cancer deaths could be much larger than the mean values cited above in the event of an especially severe accident, it will be important for the city planners to consider the necessary protective action options that might be exercised to limit the potential hazards of nuclear power reactor accidents. The results of the calculations suggest that sheltering can offer as much effectiveness as practically any other option considered. In addition, sheltering probably offers an easier planning option than preparing for complex evacuation procedures. Thus, sheltering appears to be a relatively effective protective action for the city of Philadelphia. It should probably be given serious consideration in the mix of protective options available to the city planners.

REFERENCES

1. U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, "Draft Environmental Statement - Related to the Operation of Limerick Generating Station, Units 1 and 2", (Docket Nos. 50-352 and 50-353, Philadelphia Electric Company), NUREG-0974, Supplement No. 1, December 1983.

2. Private Communications, Philadelphia Electric Company, 13 April 1984.

3. Collins, H.E.; Grimes, B.K.; Galpin, F., "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants", NUREG-0396, EPA 520/1-78-016, December 1978.

4. Environmental Protection Agency, "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents", EPA-520/1-75-001, September 1975.

TABLE 1.

Table 5.11c Summary of the atmospheric release specifications used in consequence analysis for Limerick Units 1 and 2[a]

Release category[b]	Release time (hr)	Release duration (hr)	Warning time for evacuation (hr)	Energy release (10^6 Btu/hr)	Release height (m)	Fractions of Core Inventory Released							
						Xe-Kr	Organic I[c]	Inorganic I	Cs-Rb	Te-Sb	Ba-Sr	Ru[d]	La[e]
I-T/DW(22)*	5.17	0.5	3.67	100	25	1.0	6.99(-3)**	1.78(-3)	1.88(-2)	8.41(-2)	9.94(-4)	4.95(-3)	9.89
I-T/WW(25)	5.17	0.5	3.67	100	25	1.0	6.99(-3)	1.48(-4)	3.11(-4)	1.24(-3)	1.91(-5)	7.39(-5)	1.46
I-T/$\overline{WW}$(24)	5.17	0.5	3.67	100	25	1.0	6.99(-3)	2.09(-4)	9.19(-4)	2.16(-3)	8.22(-5)	1.39(-4)	2.61
I-T/SE(14)	2.4	0.5	1.0	130	25	1.0	--	9.6(-2)	1.0(-1)	4.0(-1)	1.0(-2)	4.0(-1)	2.0(
I-T/HB(20)	2.4	0.5	1.0	100	25	1.0	--	2.0(-1)	6.0(-2)	1.0(-1)	7.0(-3)	8.0(-2)	1.0(
I-T/LGI(26)***	1.5	3.4	0	1.0	25	0.73	--	2.7(-3)	9.8(-5)	4.6(-4)	1.6(-5)	3.2(-5)	5.8(
I-T/$\overline{LGI}$(18)	1.5	3.4	0	1.0	25	0.73	--	1.9(-2)	9.8(-2)	4.6(-2)	1.6(-3)	3.2(-3)	5.8(
II-T/WW(8)	24.92	3.91	5.32	1.0	25	0.98	6.86(-3)	6.73(-1)	3.36(-1)	2.31(-1)	4.1(-2)	4.0(-2)	3.28
II-T/SE(14)	27	0.5	7	130	25	1.0	--	9.6(-2)	1.0(-1)	4.0(-1)	1.0(-2)	4.0(-1)	2.0(
III-T/WW(10)	2.67	1.38	2.17	100	25	1.0	6.99(-3)	7.81(-2)	2.24(-1)	5.74(-1)	1.95(-2)	3.65(-2)	6.92
[illegible]T/SE(5)	2.0	0.5	1.0	130	25	1.0	--	4.0(-1)	5.0(-1)	5.0(-1)	5.0(-2)	5.0(-1)	3.0(
[illegible]-T/HB(20)	2.0	0.5	1.0	100	25	1.0	--	2.0(-1)	6.0(-2)	1.0(-1)	7.0(-3)	8.0(-2)	1.0(
III-T/LGI(26)	0.5	3.5	0	1.0	25	0.73	--	2.7(-3)	9.8(-5)	4.6(-4)	1.6(-5)	3.2(-5)	5.8(
III-T/$\overline{LGI}$(18)	0.5	3.5	0	1.0	25	0.73	--	1.9(-2)	9.8(-2)	4.6(-2)	1.6(-3)	3.2(-3)	5.8(
IV-T/DW(2)	1.13	3.34	0.5	1.0	25	1.0	6.99(-3)	9.39(-1)	8.61(-1)	8.62(-1)	9.39(-2)	1.49(-1)	1.15
IV-T/WW(4)	1.13	3.34	0.5	1.0	25	1.0	6.99(-3)	9.39(-1)	7.72(-1)	6.88(-1)	9.0(-2)	1.19(-1)	9.38
IV-T/$\overline{WW}$(3)	1.13	3.34	0.5	1.0	25	1.0	6.99(-3)	8.74(-1)	8.04(-1)	5.82(-1)	9.55(-2)	1.38(-1)	7.89
IV-T/SE(5)	2.0	0.5	1.5	130	25	1.0	--	4.0(-1)	4.0(-1)	5.0(-1)	5.0(-2)	5.0(-1)	3.0(
I-S/DW(23)	5.11	0.5	3.76	100	25	9.99(-1)	6.99(-3)	3.31(-3)	4.89(-3)	2.80(-3)	6.01(-4)	2.87(-4)	4.01
IV-A/DW(1)	1.17	3	0.5	1.0	25	9.99(-1)	6.99(-3)	9.65(-1)	8.7(-1)	8.74(-1)	9.9(-2)	1.51(-1)	1.2(
IS-C/DW(13)	0.37	3.16	0.37	1.0	25	1.0	6.99(-3)	7.61(-2)	1.37(-1)	5.68(-1)	7.42(-3)	8.17(-2)	7.05
IS-C/SE(14)	1.3	0.5	1.3	130	25	1.0	--	9.6(-2)	1.0(-1)	4.0(-1)	1.0(-2)	4.0(-1)	2.0(
IS-$\overline{C}$/DW(12)	1.47	2.9	1.47	1.0	25	1.0	6.99(-3)	8.22(-2)	1.43(-1)	6.06(-1)	7.78(-3)	1.07(-1)	7.37
IS-$\overline{C}$/SE(14)	2.3	0.5	2.3	130	25	1.0	--	9.6(-2)	1.0(-1)	4.0(-1)	1.0(-2)	4.0(-1)	2.0(
S-H2O/$\overline{WW}$(11)	2.67	4.56	2.67	1.0	25	9.87(-1)	6.99(-3)	1.09(-1)	1.62(-1)	2.89(-1)	1.23(-2)	4.9(-2)	3.64
S-H2O/SE(5)	3.5	0.5	3.5	130	25	1.0	--	4(-1)	4(-1)	5(-1)	5(-2)	5(-1)	3.0(
S-$\overline{H2O}$/$\overline{WW}$(9)	2.83	3.55	2.83	1.0	25	9.68(-1)	6.98(-3)	2.56(-1)	2.74(-1)	3.86(-1)	2.57(-2)	6.18(-2)	4.99

[a]See Section 5.9.4.5(7) for discussion of uncertainties.

[b]See Appendix H for designations and descriptions of the release categories.

[c]Organic iodine is added to inorganic iodine for consequence calculations because organic iodine is likely to be converted to inorganic or partic forms during environmental transport.

[d]Includes Ru, Rh, Co, Mo, Tc.

[e]Includes Y, La, Zr, Nb, Ce, Pr, Nd, NP, Pu, Am, Cm.

*Number in parentheses indicates relative ranking of the release category according to cesium fraction.

**6.99(-3) = 6.99×10^{-3}.

***This release category is combined with III-T/LGI in consequence analysis.

TABLE 2

Table 5.11d Summary of the calculated mean (point estimate) probabilities of atmospheric release categories

Release category	Probability of the release category initiated by internal causes, fires, and low to moderately severe earthquakes (per reactor-year)	Probability of the release category initiated by severe earthquakes (per reactor-year)
I-T/DW	2.41(-5)*	5.6(-7)
I-T/WW	2.18(-5)	5.1(-7)
I-T/$\overline{WW}$	2.44(-6)	5.7(-8)
I-T/SE	9.77(-9)	2.3(-10)***
I-T/HB	9.77(-7)	2.3(-8)
I-T/LGT**	2.17(-5)	5.0(-7)
I-T/$\overline{LGT}$	2.67(-5)	6.2(-7)
II-T/WW	2.04(-6)	2.0(-8)
II-T/SE	4.0(-12)***	4.06(-10)***
III-T/WW	1.66(-6)	3.7(-7)
III-T/SE	3.4(-10)***	7.4(-11)***
III-T/HB	3.4(-8)	7.4(-9)
III-T/LGT	7.5(-7)	1.6(-7)
III-T/$\overline{LGT}$	9.2(-7)	2.0(-7)
IV-T/DW	1.63(-7)	4.7(-8)
IV-T/WW	1.46(-7)	4.27(-8)
IV-T/$\overline{WW}$	1.63(-8)	4.75(-9)
IV-T/SE	3.25(-11)***	9.5(-12)***
I-S/DW	3.76(-8)	0.0
IV-A/DW	5.0(-9)	0.0
IS-C/DW	1.4(-8)	1.3(-7)
IS-C/SE	1.4(-12)***	1.3(-11)***
IS-$\overline{C}$/DW	1.0(-7)	9.0(-7)
IS-$\overline{C}$/SE	1.0(-11)***	9.0(-11)***
S-H2O/$\overline{WW}$	1.35(-8)	4.1(-8)
S-H2O/SE	1.35(-12)***	4.1(-12)***
S-$\overline{H2O}$/$\overline{WW}$	1.35(-8)	3.69(-7)
Total probability per reactor-year	1.04(-4)	4.56(-6)

*2.41(-5) = 2.41×10^{-5}

**This release category is combined with III-T/LGT

***Any release category with probability less than 10^{-9} per reactor-year is omitted from consequence analysis because of its low probability and insignificant contribution to risks.

NOTE: Please see Section 5.9.4.5(7) for discussion of uncertainties.

Table 3 Shielding Factor Projections

Population Status	Shielding Factors	
	Cloud	Ground
Preparing for Evacuation 1/	0.75	0.33
During Evacuation 2/	1.0	0.7
During Sheltering 3/	0.4	0.05
Normal Activity -- No Protective Actions 4/	0.75	0.33

1/ Data from NUREG 0396

2/ Data from PRA Procedures Guide NUREG/CR 2300 Vol. II

3/ TYPICAL SHIELDING FACTORS FOR BRICK HOUSES WITH BASEMENTS.

4/ Data from NUREG 0396

Figure 1

DOSP1 - NO PROTECTIVE ACTIONS

SUMMARY

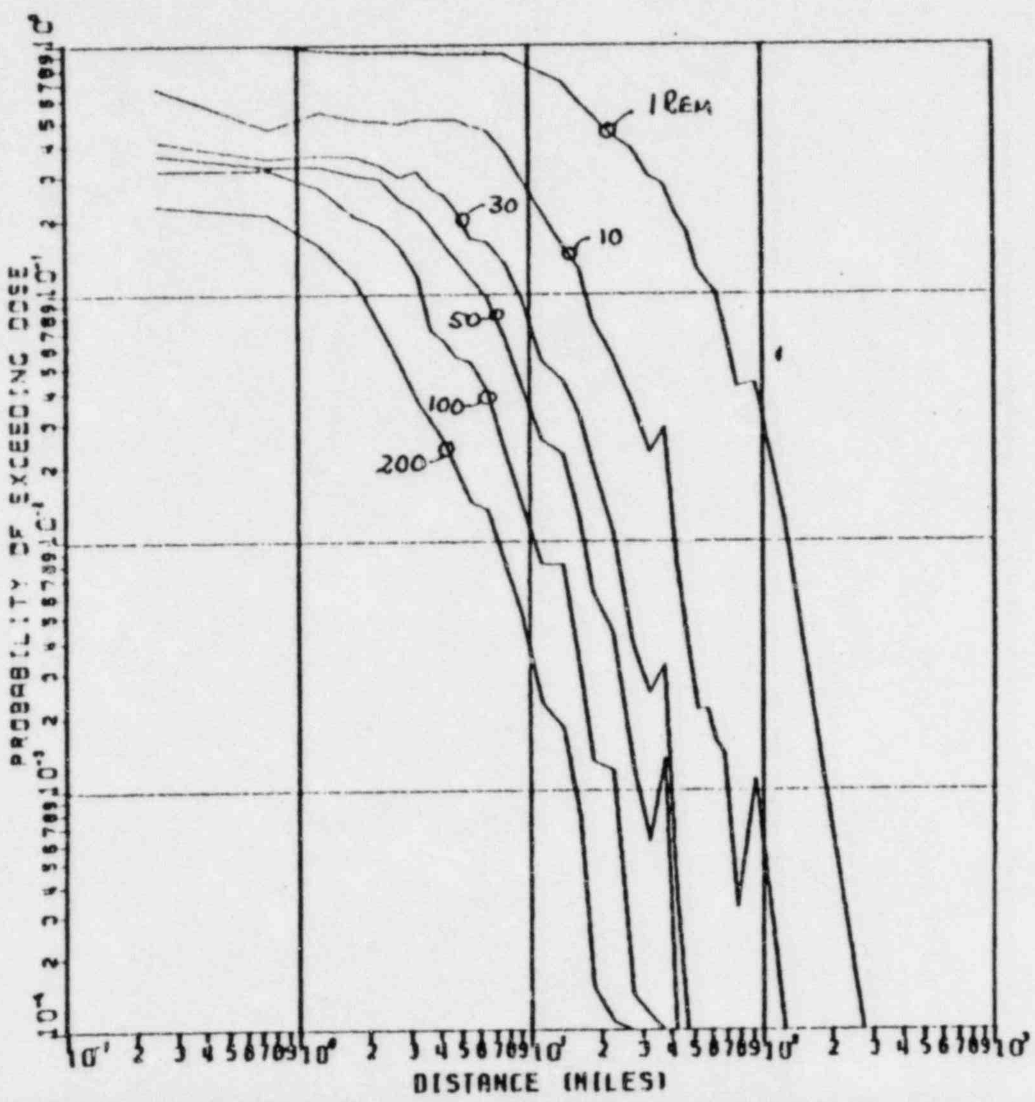

Figure 2

DOSP2A - EVACUATION ANALYSIS

SUMMARY

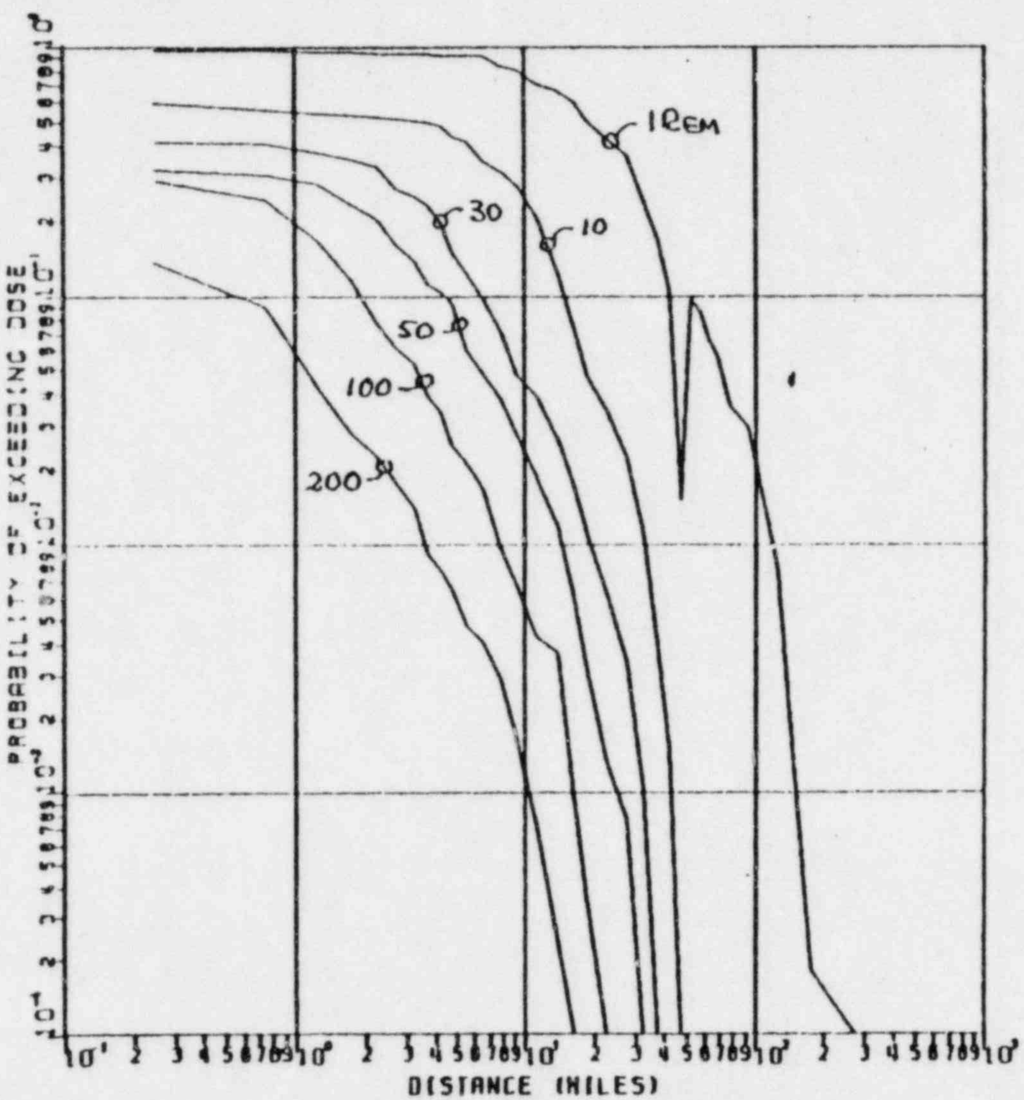

Figure 3

DOSP2C - SHELTERING EFFECTIVENESS ANALYSIS

SUMMARY