YANKEE ATOMIC ELECTRIC COMPANY

Telephone 617 872-8100

YANKEE

1671 Worcester Road, Framingham, Massachusetts 01701

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FYR 81-118

July 31, 1981

United States Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Mr. Darrell G. Eisenhut, Director
Office of Nuclear Reactor Regulation

References:
(a) Lice ıse No. DPR-3 (Docket No. 50-29)
(b) USNRC Letter to YAEC dated June 8, 1981
(c) USNRC 1980 ACRS Hearing on "Extreme External Phenomena", June 4, 1980
(d) USNRC Letter to YAEC dated August 4, 1980
(e) YAEC Letter to USNRC dated June 26, 1981 (FYR 81-102) with attached Report YAEC 1263

Subject: Consideration of Seismic Design

This letter is in response to your recent letter (Reference (b)) and concerns the selection of an appropriate seismic design basis for the Yankee Nuclear Power Station.

As you are aware, the Yankee Nuclear Power Station was designed and constructed in the 1950's which was before the promulgation of NRC seismic design regulations. Even though these regulations did not exist at that time, the Yankee plant in its present condition has been shown to possess inherent seismic resistance capability. The fundamental issue to be considered is the degree of added seismic capability which could reasonably be required for an older plant such as Yankee.

Current regulations and guidelines dictate a set of stringent seismic criteria for new plants. Meeting these criteria is relatively easy and inexpensive for a new plant because they are incorporated into the original design and construction. Furthermore, a new plant has a 40-year operating lifetime over which to amortize this relatively small marginal cost. The general perception of the risks and benefits for a new plant is that the small additional cost of the added seismic capability is offset by the associated safety gain or risk reduction.

For an existing plant like Yankee, a different situation exists and must be clearly recognized in policy decisions regarding application of seismic criteria:

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1. An existing plant usually is a smaller plant with a relatively small fission product inventory and, therefore, poses less risk.

2. The older plants are usually located in areas of low population where evacuation would be much more practical than in a more heavily populated area. This is particularly important and it is especially true for the Yankee plant.

3. The remaining operating lifetime of an existing plant is less than that of a new plant. In the case of Yankee, the remaining licensed life is less than half that of a new plant and consequently, the period of risk is less by more than a factor of two.

4. An existing plant faces much higher seismic upgrading cost per kilowatt than a plant under construction.

Both the NRC and the ACRS have recognized these marked differences that exist between older, small plants in remote locations and large, new plants in more populated areas. In NUREG-0739 the NRC states that:

"The decision rules proposed herein are for new plants, and may be more stringent, possibly by a factor of two or more, than is deemed appropriate for existing plants."

In a dialogue on the topic of seismic design between the ACRS and the NRC Staff, the following specific reference to Yankee was made (Reference (c)):

ACRS (DR. OKRENT): "At some point the Commission is going to have to decide what it thinks should be backfit and what need not, and I would assume that we are getting to a point where it is not based on the assumption all reactors are equal, because I think the Commission is departing from that currently in connection with three large reactors at highly populated sites."

"It may be, for example, that if what you are proposing based on some of these considerations is adequate for Millstone and Oyster Creek, for example, you could decide you could accept something less for Yankee Rowe and LaCrosse for example."

NRC (MR. KNIGHT): "Along those lines, management has been directed to start factoring those considerations into our priorities, so that very definitely, a large plant, if you will, in a population center or some places of denser population would be given priority both in terms of attention and backfit, as compared to some of the smaller plants or plants in lower population areas."

NRC practice in recent licensing decisions has been to require seismic design levels for new plants in the range of 1,000 (10^{-3} annual probability) to 10,000 (10^{-4} annual probability) year return periods (Reference (d)). As discussed below, with respect to the Yankee plant, even the lower limit (10^{-3}) of these seismic design levels is conservative in the context of public risk and associated benefit.

Specifically, to illustrate the conservative nature of a 10^{-3} seismic design level for the Yankee plant, a simplistic but conservative assessment of the probabilistic risk was made (See Appendix). Under the assumption that the Yankee plant is upgraded to the 10^{-3} seismic design level, the risk, as measured by early and latent public health consequences, is much lower than the typical WASH-1400 plant. If evacuation is assumed, no early fatalities would be expected even in a core meltdown.

This analysis demonstrates that with the 10^{-3} seismic level, the risk of plant operation for Yankee is well below the typical new plant risk as presented in the WASH-1400. This conclusion should not be surprising due to Yankee's lower power level and lower than average near site populations. Thus, a seismic design level that has a probability of occurrence of 10^{-3} per year exceeds the safety goal objective of acceptable risk as defined by new plant licensing standards.

A technical report documenting the development of a Composite Spectrum for Yankee has been submitted for review (Reference (e)). This spectrum was based on both of the following criteria:

1) A conservative estimate of the 10^{-3} Probabilistic Spectra, and

2) A peak ground acceleration (PGA) of 0.1g, and median spectral amplification factors applied to the PGA from NUREG/CR-0098 to determine the constant acceleration portion of the spectrum.

Criterion (1) governs in the low frequency range and criterion (2) governs in the high frequency range. It is noteworthy that the peak ground acceleration of 0.1g is more than three times the maximum calculated historical value at the Yankee site, based on 250 years of record.

Three 10^{-3} reference probabilistic spectra were developed using the attenuation models of Nuttli, Weston Geophysical Corporation and Bollinger. The Composite Spectrum envelopes the 10^{-3} estimates of the peak ground acceleration, spectral acceleration and spectral velocity for all three reference spectra.

The Composite Spectrum was confirmed by comparison with other spectra in a sensitivity analysis. The comparison spectra were developed from 3 attenuation models, 3 source models, 3 different source area zonations and increase in upper bound earthquake magnitudes of the source regions.

Finally for comparison purposes, the 10^{-4} probabilistic spectra were developed. The 10^{-4} spectrum is found to be generally consistent with the LLL/TERA Spectrum identified for the Yankee site (Reference (b)).

From these studies, it is concluded that the Composite Spectrum meets the criteria established above. Therefore, the Composite Spectrum lies within the 10^{-3} to 10^{-4} range of probabilities which is consistent with current NRC policy as expressed by Mr. Eisenhut in Reference (d).

In summary, a probabilistic risk analysis of the plant upgraded to the 10^{-3} Composite Spectrum shows that the risk, as measured by early and latent public health consequences, is much lower than the typical WASH-1400 plant. If evacuation is assumed, no early fatalities are expected. This result, in conjunction with consideration of the plant size, location, retrofit costs and remaining operational life, leads to the conclusion that the 10^{-3} seismic design level is more than necessary for the Yankee plant.

Current NRC policy for new plants implies seismic design levels in the range of 10^{-3} to 10^{-4}. This is conservative for the Yankee plant; nevertheless, the Composite Spectrum is within this range. Moreover, the Composite Spectrum is shown to be a conservative estimate of the 10^{-3} seismic probability level for the site. It is, therefore, concluded that the Composite Spectrum is more than adequate and reasonable for the Yankee Nuclear Power Station.

Very truly yours,

YANKEE ATOMIC ELECTRIC COMPANY

Andrew C. Kadak

Andrew C. Kadak
Yankee Project Manager

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Attachment

APPENDIX

PROBABILISTIC SEISMIC RISK ASSESSMENT OF THE 10^{-3} SPECTRUM

The preliminary probabilistic risk assessment of the Yankee plant performed in accordance with the methodology of the Reactor Safety Study (WASH-1400) for random failure events indicates that the risk to the public from continued operation of Yankee is orders of magnitude lower than the typical plant analyzed in WASH-1400.

In an attempt to provide the decision-maker with some guidance as to the level of additional risk a seismic event poses to the public health and safety, the following simple illustrative analysis is presented.

Hypothesis:

1. The plant is upgraded to withstand the 10^{-3} event without exceeding design code allowables for structures and systems. This assumption would lead to the deterministic conclusion that seismic failure would not occur for this 10^{-3} event.

2. The annual probability of experiencing a seismic event centered about a Peak Ground Acceleration (PGA) g is given by Table 1, which is based on the data found in Reference (e).

3. The probability of seismically induced failure of systems leading to a core melt is shown in Table 2. These probabilities are considered to be realistically conservative since the plant is upgraded to withstand the .1g event, and structures and systems designed to codes have demonstrated inherent seismic margins as shown by example on Figure 1.

From these curves and other similar results[1] we can estimate a minimum factor of 4 in acceleration above the design value for certain failure in typical structures and systems even in older plants.

The NRC also supports this finding in that it has concluded[2] that for a seismic event two to three times higher than the design basis, a serious accident would be unlikely since "loss of function is not expected to be sufficient to prevent plant shutdown when all plant systems and available corrective actions are considered." However, we have in effect, assumed for conservatism that the core does melt at accelerations of .25g and above.

Each of the core melt probabilities assumed at lower accelerations can be increased at least an order of magnitude without affecting the conclusions.

4. The probability of a containment failure given the event and core melt is shown in Table 3. Analysis has shown that the present containment fully meets the requirements of a Regulatory Guide 1.60 spectrum anchored at .1g. Furthermore, it has been shown that the containment will not fail when subjected to the LLL/TERA spectrum anchored at .2g. From the sample fragility curve for a containment structure shown on

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(1) Kennedy, Cornell, Campbell, Kaplan, Perla, "Probabilistic Seismic Safety Study of An Existing Nuclear Power Plant", Nuclear Engineering and Design, August 1980, Volume 59, #2.

(2) NRC letter to Yankee Atomic Electric Company, May 24, 1979, Docket 50-309, "Discussion of Conservatisms in Maine Yankee's Seismic Design".

Figure 1, it can be estimated that for a doubling of the design acceleration value, the conditional failure probability is about 10^{-1}. For larger accelerations, even though typical fragility curves show additional margin, we have assumed certain containment failure in Table 3.

The probability of containment failure for smaller seismic events is dominated by the probability of containment failure given a core melt. The failure probabilities are those associated with WASH-1400 failure modes for the key core melt accident sequences. Namely, core melts causing Yankee specific containment failure due to:

Reactor Vessel Steam Explosion	-	10^{-3}
Failure to Isolate	-	10^{-3}
Hydrogen Burn	-	10^{-2}
Overpressure	-	10^{-3}
Vessel Melt-Through	-	10^{-1}

The major public health concern is the relatively rapid release of fission products. This consideration excludes the vessel melt-through phenomenon which takes on the order of 50 hours for Yankee. Thus, we are then left with a containment failure probability of 10^{-2} to 10^{-3}. Let us assume 10^{-2} for core melt-dominated failures.

Each of the containment failure probabilities assumed at lower accelerations can be increased by at least an order of magnitude without affecting the conclusions.

With these four assumptions, a simple cumulative core melt and release probability for seismic events can be determined by combining the probabilities of Tables 1 - 3. Shown on Table 4 is a summary of the seismic risk results.

Within the limits of this illustrative and conservative analysis, one can see that the seismic failure probability is approximately an order of magnitude above the random failure probability previously calculated in "The Preliminary Risk Assessment", dated December 5, 1980. This is due primarily to the conservative core melt and containment failure assumptions made at higher than design value accelerations (i.e., .30g and .40g). These higher acceleration results dominate the total failure probability since the probability of experiencing an acceleration greater than .35g is on the order of 10^{-5} which is about an order of magnitude above the random failure probability. When the seismic failure probability is added to the random failure probability, the total annual failure probability for Yankee may be a factor of ten higher than what the random failure analysis would indicate. In fact, it is probably lower due to the conservative failure assumptions made.

If one were to apply this factor of 10 to the results presented in the "Preliminary Probabilistic Risk Assessment", dated December 5, 1980, the resulting public health consequences, as shown in Figure 2, would still be lower than the "average" WASH-1400 plant. If evacuation is assumed, no early fatalities are expected. A similar scaling of the latent health consequences is shown in Figure 3 with similar conclusions.

If one were to make more realistic assumptions which reflect actual experience on the ability of structures and systems to withstand seismic events, especially the short duration, low effective acceleration events that characterize the Rowe site, in conjunction with a more sophisticated probabilistic analysis, these results could be reasonably reduced. In any case, these conclusions should not be surprising due to Yankee's lower power level and lower than average near-site population. Thus, the seismic design level associated with an event having a probability of occurrence of 10^{-3}/yr clearly meets the safety goal objective of acceptable risk as defined in WASH-1400 and typically considered in new plant licensing decisions.

TABLE 1

Assumed Probability of Peak Ground Acceleration Per Year for the Yankee Site

Incremental Ground Acceleration*	Assumed Probability
.03g	9.98×10^{-1}
.10g	2.4×10^{-3}
.20g	$1.1 \times 10^{-}$[illegible]
.30g	1.9×10^{-5}
.40g**	1.2×10^{-5}

* The increment includes a band of accelerations around that specified, e.g., the probability at .10g equals the probability of an acceleration in the range from .05g to .15g.

** This probability includes all accelerations above .35g.

TABLE 2

Assumed Probability of System Failure Leading to Core Melt for Seismic Events

Incremental Ground Acceleration	Assumed Probability Of Core Melt
.03g	10^{-5}
.10g	10^{-4}
.20g	10^{-2}
.30g	1.0
.40g	1.0

TABLE 3

Assumed Probability of a Containment Failure

Given a Seismic Event and Core Melt

Incremental Ground Acceleration	Assumed Probability of Containment Failure	
.03g	10^{-2}	(1)
.10g	10^{-2}	(1)
.20g	10^{-1}	(2)
.30g	1.0	(2)
.40g	1.0	(2)

Notes:

(1) Containment failure modes determined by core melt (e.g., steam explosion, hydrogen burn, etc.).

(2) Containment failure mode dominated by seismic event.

TABLE 4

Assumed Probability of Producing a Core Melt and Release for Yankee Designed to a .1g Seismic Event

Ground Acceleration	Probability of Ground Acceleration	Probability of Core Melt	Probability of Containment Failure	Probability Of Release
.03g	9.98×10^{-1}	10^{-5}	10^{-2}	9.98×10^{-8}
.10g	2.4×10^{-3}	10^{-4}	10^{-2}	2.4×10^{-9}
.20g	1.1×10^{-4}	10^{-2}	10^{-1}	1.1×10^{-7}
.30g	1.9×10^{-5}	1.0	1.0	1.9×10^{-5}
.40g	1.2×10^{-5}	1.0	1.0	1.2×10^{-5}
		TOTAL		3.1×10^{-5}

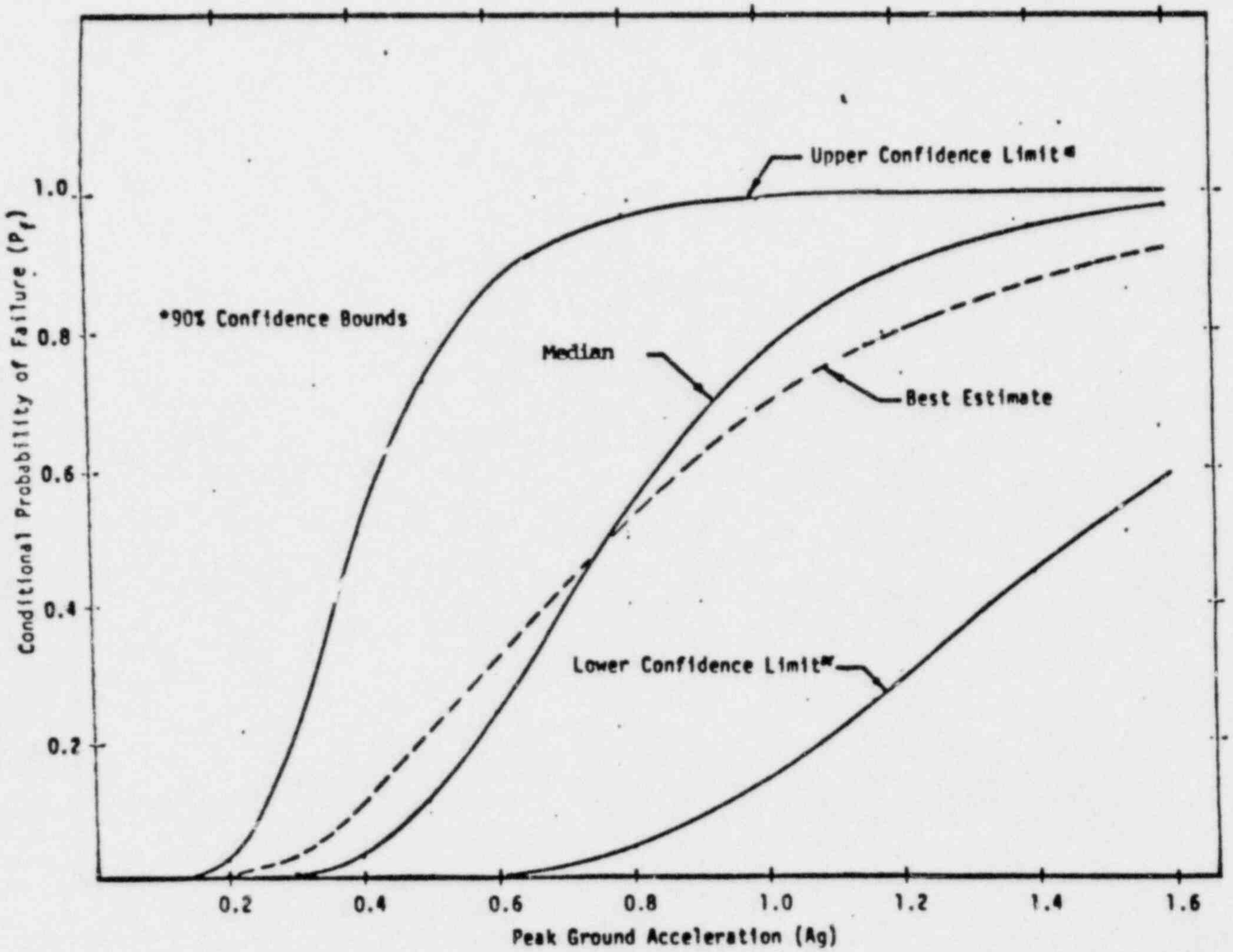

FIGURE 1 CONDITIONAL PROBABILITY OF CLASS I STRUCTURAL FAILURE (OPERABILITY LIMITS) VERSUS PEAK GROUND ACCELERATION FOR A STRUCTURE DESIGNED TO 0.11g/0.22g (OBE/SSE)

FIGURE 2

PRELIMINARY PROBABILISTIC RISK ASSESSMENT FOR EARLY FATALITIES
(PLANT SPECIFIC FAILURE RATES USED FOR YANKEE)

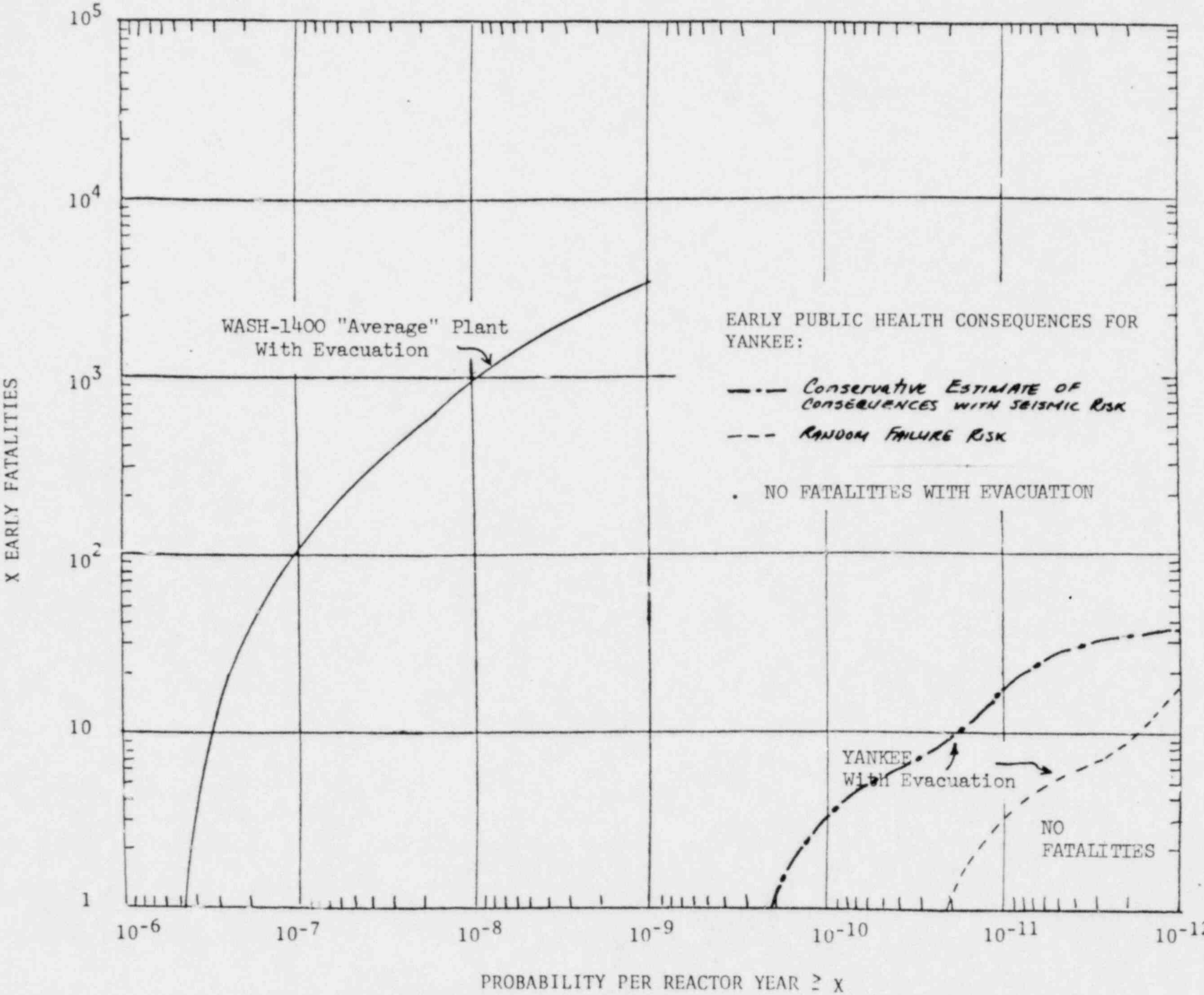

FIGURE 3

PRELIMINARY PROBABILISTIC RISK ASSESSMENT

FOR LATENT FATALITIES

(Plant Specific Failure Rates used for Yankee)