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Advisory Committee on Reactor Safeguards
1717 H Street
Washington, D.C. 20555

Dear Sirs:

Attached is a brief review of NUREG/CR-2497, "Precursors to Potential Severe Core Damage...". Because my schedule restricted my review and report to ~ 2 days, I have concentrated on two items: 1) an overview of what the findings mean vis-a-vis existing PRAs and actual severe core damage experience (i.e. TMI-2); and 2) items in the report's methodology that might have caused differences between report findings and the findings of existing PRAs. Since my review was performed prior to my receiving the INPO review, some of my comments overlap INPO's. However, nothing INPO related in their report appeared to affect my opinions as related herein.

Before beginning a review, it seems appropriate to question how the report findings are to be interpreted. Per Dr. Cottrell, the severe core damage frequencies calculated by the report are to be interpreted to depict what a representative core damage frequency estimate should have been in the years 1969-1979. However, the report effectively added the "actual occurrence" frequency of one (TMI) per 432 reactor years (U.S. operating experience 1969-1979) to a predicted frequency based on all other "potential precursors". Conceptually, this seems to be summing "true events" and probabilistically weighted "what if" events. One might question what the predicted number of automobile deaths per year would be with this approach. Although factoring actual precursors into predicted risk is appealing, some way of reducing "true events" by a probabilistic weight of their not occurring would have to be incorporated for this estimation technique not to overpredict risk a priori.

Several plausible severe core damage (SCD) frequency estimates are shown on Table 1 of this memo for comparison with PRA-predicted core melt frequencies. If, as implied in Dr. Cottrell's presentation at the 2/9/83 PRA Subcommittee Meeting, core melt is 2 to 20 times less likely than severe core damage, the "2497" report's estimated range of 1.7-3 to 4.5-3 for SCD frequency would correspond to the high side of current PRA predictions for similar events. However, as related in the same meeting, the distinction between core melt and SCD seems fuzzy at best. "Core melt" seems to imply a high fraction of the core melting and loosing its original geometry. SCD seems to imply at most a minimal fraction of melt, with original geometry probably but not necessarily being maintained. In any case, if "2497" does indeed imply a lesser posture for the safety of nuclear plants than PRAs do, several interpretations seem plausible:

1. Current PRAs are generally too optimistic, the implication of which seems to have prompted critical reviews of "2497" by INPO.

2. Current PRAs are "correct" but have been mainly performed on the safer plants. It could be argued that a utility that finances a PRA may in fact be more risk-conscious and their plant "safer" than the norm.

3. NUREG/CR-2497 is overly pessimistic, at least at the top of its "best estimate" range, i.e. 4.5-3. However, even if the "double-accounting" of failure-frequencies is taken to overestimate risk by a factor of 2-3 (see p. 4-22), and the frequency distinction between SCD and core melt is made, their bottom range number of 1.7-3 is still somewhat higher than current PRA predictions, although not out of line.

4. There is such a tremendous uncertainty that all estimates are equally acceptable. Figure 1 plots Poisson 95% confidence bounds as a function of number of reactor years operating experience for 0, 1, 2, and 3 SCD events. Interestingly, another SCD event such as TMI-2 would raise the current lower bound frequency based on 1 SCD, i.e. TMI, by an order of magnitude. As it stands now most PRAs appear to predict core melt frequencies somewhat optimistically if TMI is considered a "representative" statistic, especially if only U. S. experience is considered in the data base.

Obviously, there is no totally defensible interpretation. If one accepts the premise that current PRAs are (more) "correct" and that the methodology in "2497" is useful but too pessimistic as exercised, then the individual events that dominate "2497" should be closely reviewed. This suggests the somewhat obvious recommendation that the NRC request the utilities whose "LER" event trees dominate risk, to critically review the "2497" assumptions used and provide their own best estimates and associated uncertainties. In fact, this would not appear to be an unreasonable request of any utility whose plant appears on the "52 significant precursor" list. From the information that I have received from the ACRS office, it appears that only one utility, the Dairyland Power Cooperative operating the LaCrosse BWR, chose to volunteer such a review. Not surprisingly, their review was very critical and pointed out the overly pessimistic assumptions they felt "2497" imposed.

Looking at the methodology described in Section 4, a weighting factor approach was used to multiply IE and failure frequencies that represented events that could be rectified. This approach seems reasonable but subject to wide variations in the weights that would be assigned by different analysts. The sensitivity of the ultimate SCD frequency predictions in "2497" to this weighting should be described.

The treatment of "potential demand failures" (see p. 4-2) seems to be based on some arithmetic averaging of true demands and potential demands with failure to detect malfunctions somehow factored in. Presumably one could refer to Appendix C and back out the actual algorithm using the event descriptions and minimum and maximum functions for demand failure. However, I believe this algorithm should be clearly explained up front. Intuitively, the arithmetic averaging seems likely to overpredict failure frequencies. In any case a discussion of the sensitivity of predicted SCD frequencies to these assumptions should also be discussed.

Not-at-power precursors are evaluated as occurring at power, presumably using weighting to adjust the probabilities. The weighting technique should be explained and potential impact on final SCD frequencies discussed.

Degraded equipment is arbitrarily assigned a demand failure probability of 10 times that of nondegraded equipment. Although justifying this assumption may be out of the scope of this study, the treatment (or non treatment) of partial failures may be important. The impact of this assumption on the results should be discussed.

With respect to the "double accounting" of failure information cited on p. 4-22, it would appear that careful consideration of this effect must be factored in to assure proper event tree bookkeeping. However, I did not have the time to fully investigate examples of how their LER information was factored into existing initiating event frequencies and system unavailabilities. The explanation in the report was something less than lucid and I would strongly suggest that an improved explanation of the complete mathematical model be provided in any subsequent or updated release of this report.

A final comment is directed at extracting more information with the basis provided by "2497" and concerns the "time on test" plots of Chapter 5. If the "experience" data largely fall below the 45° line, the implication is that most events occurred earlier in plant life and that event frequencies are diminishing with time or are at worst constant. Some reviewers suggested that these results simply mirrored the well known "wear in" effect reflected by the beginning portions of the "bathtub" curve. It would seem useful for such data to be analyzed carefully to determine whether the "wearin" period for different types of events could be estimated or more generally, the behavior of selected event frequencies established as a function of time. If sufficient data exist, and here I am referring to the total LER data base, this could be further correlated with different types of plant (PWR or BWR, Westinghouse or B & W or Combustion, etc.) and different systems (RHR, AFWS, etc.). It also would appear that such data could be used to glean equipment and operator training needs as a function of time. In short, there is a world of information to be gleaned from these LERs that could be used by utilities to reduce both risk and plant unavailability.

In summary, my suggestions are as follows:

- The NRC request the utilities with "significant precursors" to critically review the event trees and associated "severity ratings" initiating event frequencies and system unavailabilities used to calculate severe core damage for their plants. Rectification actions should be cited. Given that Browns Ferry and Rancho Seco lead to 32% of the predicted SCD frequency, it would be especially worthwhile to obtain their independent predictions of SCD frequency for their precursors.

- The mathematical model be better described with liberal use of equations and examples and the "double-accounting" be eliminated. I believe an addendum that covers these and reports on the various sensitivities of the results to the model assumptions, as (repeatedly) mentioned above, would be worth publishing. At the aforementioned meeting it was stated that sensitivity studies would be performed on the 1980-81 update to "2497".

- The time on test information be probed more deeply to correlate event occurrence with plant age, type of plant, and so forth as indicated above.

Sincerely,

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8M609, A15

Table 1. Severe Core Damage Frequency Prediction Comparison with PRA Core Melt Frequency Predictions

			Uncertainty Range[1]
Experience at Time of Report	$\frac{1\ \text{SCD (TMI-2)}}{432\ \text{RY}}$ = 2.3-3 SCD/RY		1.3-2 to 5.9-5
World Experience at Time of Report	$\frac{1\ \text{SCD (TMI-2)}}{\sim 1500\ \text{RY}}$ = 0.67-3 SCD/RY		3.8-3 to 1.6-5
U.S. Experience Now (~ 2/11/83)[2]	$\frac{1\ \text{SCD}}{600\ \text{RY}}$ = 1.6-3 SCD/RY		9.4-3 to 4-5
World Experience Now (~ 2/11/83)[2]	$\frac{1\ \text{SCD}}{\sim 2000\ \text{RY}}$ = 0.5-3 SCD/RY		2.8-3 to 1.2-5
NUREG/CR-2497	-	-	1.7-3 to 4.5-3[3]
Recent PRAs	Core Melt[4] Frequencies[5]		
	Mean	Median	Unspecified
WASH-1400	-	-	0.5-4
Zion	0.5-4	-	-
Limerick	-	0.15-4	-
Indian Point 2	5-4	4-4	-
Indian Point 3	2-4	0.94	-
German Risk Study	-	-	1-4[6]
AIF Task Force	-	-	1-4[6]

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(1) Uncertainty range numbers are 95% confidence bounds assuming a Poisson distribution (see attached Figure) for the frequency of SCD events given that one (TMI) has occurred.

(2) Ball park" extrapolations used to estimate current RY experience.

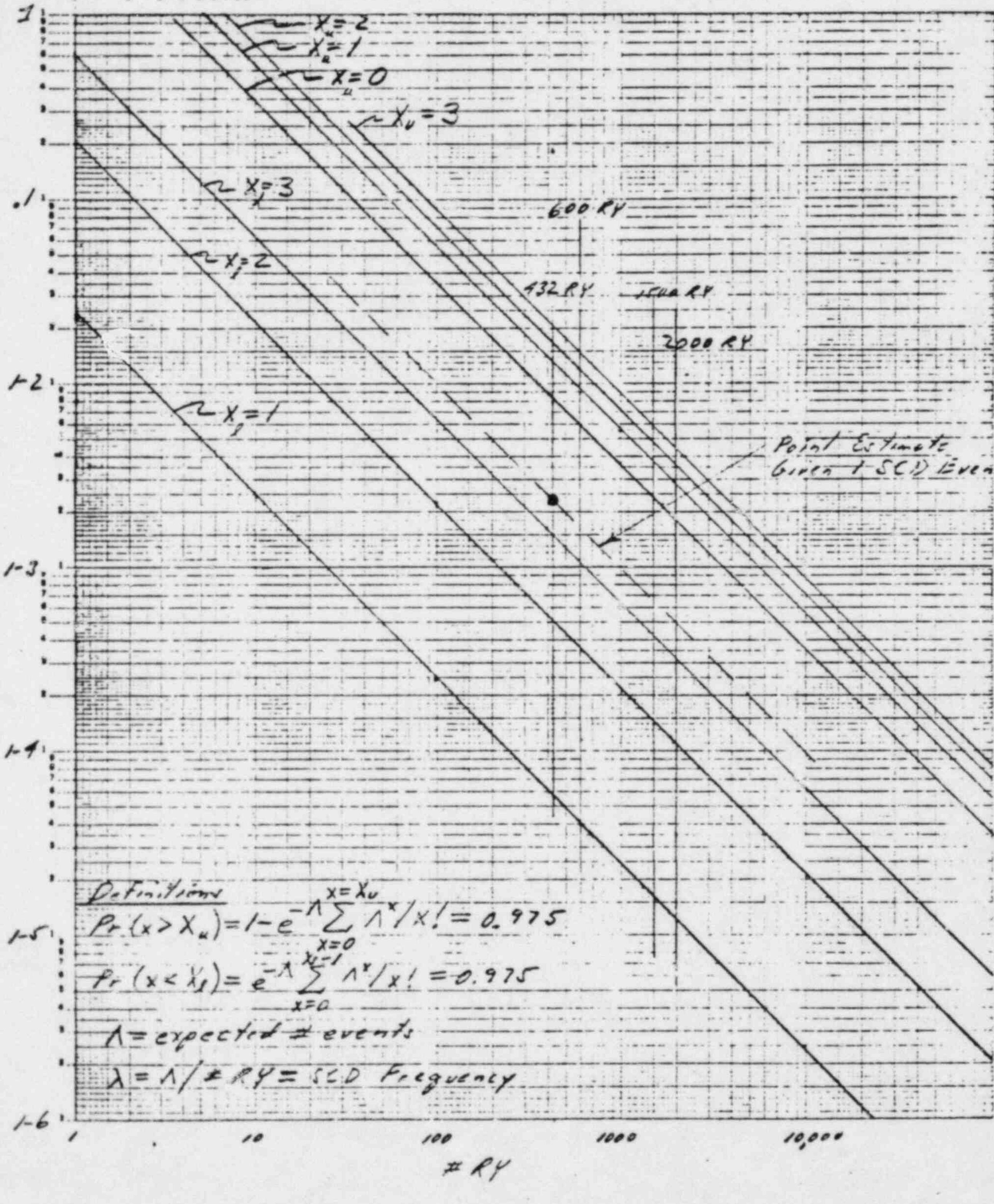
(3) Range accounts only for estimated effect of "double accounting", not for more general uncertainties.

(4) Per Cottrell presentation at ACRS Subcommittee Meeting of 2/9/83, a "reasonable" estimate of the ratio of SCD and core melt frequencies lies between 2 and 20.

(5) Median values are less than mean values because of the lognormal character of the final risk curves.

(6) Value taken from Figure 1 of NUREG/CR-2497.

Figure 1. 95% Confidence Bounds for SCD Frequencies Given 0, 1, 2, & 3 "Occurrences"



Definitions

$$Pr(x > X_u) = 1 - e^{-\Lambda} \sum_{x=0}^{x=X_u} \Lambda^x / x! = 0.975$$

$$Pr(x < X_l) = e^{-\Lambda} \sum_{x=0}^{X_l - 1} \Lambda^x / x! = 0.975$$

Λ = expected # events

$\lambda = \Lambda / \#RY$ = SCD Frequency

CFM
2/4/83