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NUCLEAR LIABILITY AFTER THREE MILE ISLAND

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ABSTRACT

This paper analyzes liability and insurance for nuclear power plants in light of the March 1979 accident at Three Mile Island. Existing estimates of the risks of nuclear power are reviewed and the estimates are compared with the evidence of Three Mile Island. A conclusion of particular interest is that private insurers' implicit estimates of the risks are more accurate than those of the government. Thus, there is reason to reconsider the existing liability and insurance arrangements, which are founded on the assumption that private insurers will overestimate the nuclear risk.

NUCLEAR LIABILITY AFTER THREE MILE ISLAND

The March 1979 accident at the Three Mile Island nuclear power plant, whatever its other effects, worsened the public perception of the safety of nuclear power.[1] What evidence did the accident actually provide on nuclear safety? To examine this question, this paper reviews the existing estimates of the probabilities and consequences of reactor accidents (the "nuclear risk"). Then some rough-and-ready methods of adjusting the estimates to account for the experience of Three Mile Island are illustrated. A conclusion of particular interest is that private insurers' implicit estimates of the nuclear risk — far larger than official government estimates -- are more accurate.

The current nuclear liability law, in effect since 1957, is based on the assumption that private insurers are too cautious about offering insurance. Such excessive caution and the resulting high premiums, the reasoning goes, would unduly restrict nuclear power unless counteracted by government action. Since Three Mile Island appears to vindicate insurers' judgments or even to suggest they underestimated damages, there is reason to reconsider policies shielding nuclear operators from the verdict of the private insurance markets.

1. The Reactor Safety Study.

Early attempts to estimate the risk of nuclear power plant accidents concentrated on trying to determine the maximum damage that could be caused. There was no attempt to calculate "objective" probabilities of the serious accidents postulated [8], [9]. The first full study attempting to estimate probabilities and consequences of the full range of accidents was released by the Nuclear Regulatory Commission in 1975. This report is known as the Reactor Safety Study and as the "Rasmussen Report," after project director Norman Rasmussen [12].

The Reactor Safety Study concluded that the probability of a serious nuclear accident was very low. For example, it predicted that most potential "meltdowns" of reactor cores would not involve even one fatality at the time of the accident ("early" or "prompt" fatality, as opposed to delayed or "latent" fatalities). But rare extreme accidents, with probabilities ranging downward to one in a billion per reactor per year, could cause as many as 3,300 early fatalities, 45,000 early illnesses, and $14 billion in property damage.[2]

The Reactor Safety Study's findings are quite controversial, and at the heart of the controversy is the study's basic approach. The Reactor Safety Study made its probability estimates by attempting to consider all events that could initiate a serious accident, and then tracing those events down probability trees to the possible outcomes. It is impossible, even in principle, to be sure that all potential accident sequences have been considered. Any omission would bias downward the final probability estimate. Thus there are fundamental difficulties with the Reactor Safety Study even if the study group proceeded perfectly in tracing its list of accident causes through to consequences. Moreover, there is convincing evidence that the study group did not proceed perfectly [7]. It remains true that the Reactor Safety Study is the most complete technical attempt to estimate the nuclear risk directly.

Using the monetary equivalents for damages of Table 1, results of the Reactor Safety Study are as displayed in Table 2[3]. In the controversy following the release of the Reactor Safety Study, the antinuclear Union of Concerned Scientists has made ad hoc corrections to study results in Risks of Nuclear Power Reactors. These results, which were not intended as a complete reworking but only to suggest the possible magnitude of error, are listed in Table 3. Monetary equivalents have again been drawn from Table 1.

2. The Denenberg Estimate

Another estimate of the nuclear risk has been made by Herbert S. Denenberg, former insurance commissioner of Pennsylvania. In an interesting coincidence, the Denenberg estimate was prepared for the Three Mile Island plant, in a 1973 licensing hearing [4] . Rather than attempting a full technical study like the Reactor Safety Study, Denenberg estimated the probability of a serious nuclear accident based on the premium charged by private insurers of nuclear power plants.

Before examining the results of the Denenberg inferences, it is worthwhile to consider whether it is legitimate to attach any meaning to private insurance premiums as reflecting an estimate of the potential loss. With such a short record of experience, nuclear insurers cannot set rates actuarially but instead use judgment. Thus the premium is only an amount judged to provide a sufficient return for offering the coverage. There is much less assurance that premiums will be adequate than there is for hazards with longer experience records.

Still, the premium is the educated guess of a party -- the insurer -- which faces rewards for correct judgment and penalties for incorrect judgment. Insurers have an incentive to try to guess correctly, so it is important to try to discover the implications of their guesses.

In making inferences about insurers' estimates of the nuclear risk, Denenberg noted than insurers charged $32,500 for the first million dollars of coverage on a typical nuclear reactor. The premium declined sharply until $40 million of coverage was reached, and then leveled off at $1,000 per million dollars of coverage. With a load factor of 0.42, meaning that 42 percent of premiums would cover expenses, 58 percent of paid-in premiums would be available to cover losses. Dividing (1,000 x 0.58) by $1 million of coverage, Denenberg inferred that the chance of an accident per reactor-year was 0.0058, or about 1 in 1700. Thus his 1973 estimate based on insurers' behavior showed the chance of an accident to be many times higher than indicated by the Reactor Safety Study. Table 4 lists probabilities of accidents in each of the coverage levels, calculated using the Denenberg method. The accident probabilities range from 1.885×10^{-2} (roughly 1 in 53) for an accident causing only $1 million in offsite damage to the 5.8×10^{-4} (roughly 1 in 1700) per reactor-year mentioned above for an accident causing $40 million to $95 million in offsite damage.

It should be clear that this 1 in 1700 probability is an inferred probability. Insurers did not say that the chance of a serious nuclear accident would be 1 in 1700 per reactor per year; rather, they accepted a gamble that would pay off only if the chance were less than 1 in 1700. This sort of information is useful for comparing estimates of the nuclear risk, even if no nuclear insurer ever said (or even thought) that the probability was 1 in 1700. To draw an analogy, drivers' behavior in buckling or not buckling seat belts provides valuable information about how they view safety, even if no driver ever computed the expected gains and costs from buckling up.

An important weakness of the Denenberg estimate is that it applies only to the limit of coverage offered by private insurance companies. At the time of his testimony, insurers were offering only $95 million of coverage. The 1/1700 figure, then, applies strictly only up to the coverage limit. Insurers' absolute refusal to offer additional coverage has troublesome implications for inferring the probability of more serious accidents, the incidents of particular policy interest. It might be argued that refusal to offer coverage amounts to an effectively infinite price, implying that insurers assign a probability of one to the occurrence of more serious accidents. Or it might be argued instead that insurers really believe the probability of more and more serious accidents continues to decline, but are unwilling to act on this belief and offer coverage because of inability to diversify against such an unusual risk. An insurer might believe the chance of a serious accident would be very small indeed and yet be reluctant to offer insurance with premiums based on expected value of losses, since these premiums would mount into a sizeable fund very slowly. An early accident could cause the insurer a large loss.

Finally, insurers' refusal to offer coverage for the more serious accidents might be taken simply as a reflection that existing institutions simply don't allow covering such risks. Under existing institutions, the general manager of the nuclear insurance pools has stated, no company would tie up its resources for less than $1,000 per million dollars of coverage.[4] The fact remains, though, that there have been many innovations and opportunities for innovation for decades in methods of providing nuclear coverage — but no interest by insurers in seeking new institutions designed so that they could offer greatly expanded private coverage.

It should be noted that there are two crucial but unstated assumptions underlying the Denenberg inferences: (1) Insurers do not earn above-normal profits, and (2) Insurers are risk-neutral. The first assumption may be in question, since private insurance of nuclear plants is administered through joint ventures of pools with ample opportunity for collusive behavior. Still, individual pool members do have the opportunity to offer additional coverage at pool-established rates and these individual companies have shown no sign they are being pressured to restrict availability of coverage. In any event, there is considerable question of ever being able to determine what "above-normal" profits would be for an insurance venture where the expected value of claims is so uncertain.

The second assumption, that insurers are risk-neutral, is necessary to label the part of the premium apart from the administrative loading as an expected value of claims. The assumption of risk neutrality seems unlikely to be met in view of the premium structure above $40 million. The premium declines in blocks for increasing amounts up to $40 million of coverage (see Table 4), but then remains constant. Since larger accidents are believed less likely, the constant premium may actually reflect additional compensation for assuming risk beyond the expected value of claims. With the expected value of claims declining between coverage levels of $40 million and $95 million, but premiums remaining constant, insurers may be exhibiting risk aversion in that region. Based only on this consideration, the 1/1700 figure would be an over-estimate of what insurers really think is the probability of an accident. Like the Reactor Safety Study, the Denenberg estimate has biases of its own.

3. The Naive Actuarial Approach.

To rely only on the achieved safety records of reactors is naive, and is usually taken as establishing an upper limit on the probabability of an accident. Thus, since 500 reactor-years have been recorded without catastrophic accident, the chance of such an accident per reactor-year is taken as being no more than one in 500. It should be clear that this is not an absolute upper limit. For example, there is a 19 percent chance that 500 reactor-years would pass without an accident even if the chance of an accident were as high as 1 in 300.[5] Moreover, accidents may become more likely as facilities grow older and components age. It is true that the "naive actuarial" approach is quite pessimistic, however. The evidence of 500 reactor-years without an accident would involve, by itself, a probabilty of 0/500, or zero. Inferring a probability of 1/500 assumes, contrary to fact, that a serious accident has occurred -- or will occur in the next instant. Naive actuarial probabilities can be used as plausible upper-range estimates, with recognition that they do not establish an absolute upper limit.

Insert Figure 1
about here

Results of the above direct and indirect methods of estimating the nuclear risk are presented on a common set of logarithmically scaled axes in Figure 1. The horizontal axis represents various dollar values of accident damage and the vertical axis marks off the probability that an accident causing given dollar damages will occur. A downward-sloping curve on Figure 1 indicates that the probability of worse and worse accidents becomes lower and lower. Note that because of the logarithmic scaling, moving one mark upward involves a tenfold increase in expected damages. Note also that a hyperbola plotting points of constant expected value would be represented by a downward-sloping straight line on the log-log scale.

The curve closest to the origin in Figure 1 represents the probability distribution of property damage from the Reactor Safety Study. It is not directly relevant to the nuclear insurance question, however, since it includes no damages for loss of lives and health.[6] The next curve out from the origin represents total damages, including compensation for loss of lives and health as calculated from the Reactor Safety Study in Table 2. Still farther out is a curve representing the Union of Concerned Scientists' revision of the Reactor Safety Study, calculated from Table 3. Consequences for each given probability are 10 to 100 times greater. The stepped function beginning at the upper left of Figure 1 represents insurers' estimates of the risk, as calculated in Table 4. The function is dashed to the right of the upper coverage limit, indicating that insurance is not offered for the more serious accidents. Finally, for reference, the "naive actuarial" probability of 1/500 (2×10^{-3}) per reactor-year is drawn in. It is clear that estimates of the nuclear risk are quite widely divergent.

The reliability of the existing estimates of nuclear risk can be judged in light of whatever evidence was provided by Three Mile Island. Using dollars as a measure of the severity of an accident, it is clear that the Three Mile Island accident was not very severe. Damage claims from the accident were settled for $25 million. If the relationship between probabilities of serious accidents and less severe accidents calculated in the Reactor Safety Study is correct, then an accident causing the damages of the Three Mile Island accident would occur 30 times as commonly as a reference accident causing $1 billion worth of damage. This information could be incorporated roughly into naive actuarial estimates as follows: Instead of assuming that one reference accident will occur, note that an accident 30 times as likely as the reference accident has occurred. The naive actuarial assumption is then that, in a specified number of reactor years, "one and 1/30" of an accident will have occurred. Changing the numerator of the naive actuarial probability from 1.0 to 1.033 involves an increase of only 3.3 percent, so that naive actuarial estimates remain virtually unchanged when revised in this manner. In the naive actuarial outlook, Three Mile Island provided very little information about the probabilities of catastrophic accidents.

Another method of incorporating the experience of Three Mile Island into risk estimates involves, again, the assumption that the Reactor Safety Study correctly estimated the relationships between various postulated accidents but understated all absolute probabilities. An accident causing the damages of Three Mile Island would have been predicted to occur once in 33,000 reactor-years but actually occurred after 500 reactor-years. The Three Mile Island accident's probability was understated by a factor of about 66, so one modification of the Reactor Safety

Study would place all expected values of damages higher by a factor of 66. The resulting values are very close to the corrections advanced by the Union of Concerned Scientists, higher than Reactor Safety Study results by a factor of 60.

A final perspective on Three Mile Island can be gained by comparing the 1/500 per reactor-year occurrence with the rate inferred from insurers' behavior in Table 4. The rate based on insurance premiums is about 1 in 1060, which is an underestimate rather than the conservative overestimate that might be expected. This rate, erring by a factor of two, is much closer than the Reactor Safety Study estimate. To the extent that a single event such as Three Mile Island supports any estimates, they are the inferred estimates of the private insurers and especially the Union of Concerned Scientists. More than supporting any one estimate, the Three Mile Island accident rules out an estimate -- that of the Reactor Safety Study -- as being implausible. If the chance of an accident causing $25 million in damages really is one in 33,000 per reactor-year, then under an exponential distribution there is only a 1.5 percent chance that such an accident would occur after only 500 reactor years, as it did.

The current nuclear liability law, the Price-Anderson Act, was adopted and twice extended on the basis of optimism about the nuclear risk. The law is founded on Congressional policymakers' beliefs that, first, the nuclear risk is small, and second, that the level of safety achieved by reactor owners is insensitive to the level of liability they face. Three Mile Island throws the first assumption into doubt. There is reason to doubt the second as well [14] . But in 1957 optimism prevailed and Congress passed Price-Anderson, limiting the liability of reactor owners to $560 million in apparent confidence that no accident as large as $560 million would ever occur. Because private insurers were willing to provide only $60 million in coverage, the government also arranged to cover the other $500 million at low rates. While the composition of the coverage has changed over the past 23 years, it remains strictly limited in amount. Further, the reactor owner cannot be sued for damages beyond the $560 million total. The Price-Anderson Act is extraordinary in the degree of insulation from damage claims it provides [1] . It is firmly based on the assumption that private insurers have overestimated the risk, so evidence to the contrary is of definite policy interest.

Opponents of nuclear power have mounted vigorous efforts to block renewal of Price-Anderson and are, at this writing, attempting to have the liability limit raised or abolished altogether. Would such moves be efficient? To derive the characteristics of an efficient level of liability (or, at least the "right" direction to move the liability level), the benefits and costs of providing additional coverage (Figure 2) must be considered.

Insert Figure 2
about here.

From the standard theory of risk and insurance, the benefit of additional coverage lies in the reduction of uncertainty about future levels of utility for potential victims of nuclear power plant accidents. Since an additional dollar of coverage is, ex ante, a public good for those in potentially affected areas, the benefit of the marginal dollar of coverage is a total of the private marginal benefits. Under the usual assumptions, the summed marginal benefits will increase if there is an increase in the income of potential victims, the number of potential victims, or the amount of damage that a nuclear accident could do.

The social cost of providing additional coverage is the expected value of the damage being insured against plus any social risk premium. The social risk premium vanishes for risks small enough to be completely diversified away.[7] There may exist possible nuclear accidents small enough that their risk can be completely diversified away, but clearly the catastrophic ones contemplated are large enough that they are properly thought of as having social costs beyond the expected value of damage. Thus the marginal cost of coverage in Figure 2 begins parallel to the horizontal axis but later turns upward for larger accidents.

It will be efficient, of course, to continue expanding coverage so long as the summed marginal benefits of another dollar of coverage exceed the marginal social cost of providing it. Though it would be extremely hard to say empirically at what level of coverage the summed marginal benefits equal the marginal social costs (point A in Figure 2), still it may be possible to identify some levels of coverage so small that the optimum has not yet been reached.

It is reasonable to argue that $560 million, the Price-Anderson level, is such a coverage level. At $560 million, it would seem possible to provide additional coverage whose cost is properly reckoned at its expected value and no more. In fact, the $560 million level was originally set in the mid-1950s so that paying damage claims would not disturb the government budget in the event of an accident.[8] If coverage can be provided beyond $560 million today at a cost equal to the expected value of the risk, then it is efficient in a risk-averse society to provide that coverage.

Taking another approach, consider the relative position of the summed marginal benefit and marginal cost curves for coverage. Their intersection must have been moving rightward in recent years, since population, income and reactor size (and so potential damages) have been increasing. These influences shift the marginal benefits farther up than the marginal cost in a society of risk-averters. The only influence that would call for less coverage at the optimum would be a decreased probability of accidents, which cannot be assumed with any confidence in face of the difficulties with the <u>Reactor Safety Study</u>.[9]

Thus the efficient liability level has been rising since 1957. The real liability level actually in force has been declining steadily, as inflation has shrunk the value of the $560 million nominal coverage provided under Price-Anderson. There is reason to believe both that the liability level is too low and that it has been moving in the opposite direction from an efficient level over the past 23 years.

Though some increase in coverage levels is appropriate, complete removal of the liability limit would not solve all the existing problems. Removal of the liability limit would not mean full coverage, since the resources available to pay claims would be limited to the worth of the reactor owner -- an amount below the money damages of the the most severe accidents. Further, reactor owners seeking private coverage might face inefficiently high premium levels because of private companies' inability to diversify against catastrophic risk. Complete reliance on private markets in nuclear insurance could have problems of its own.

The realistic choice for nuclear liability and insurance in the future is between more reliance on imperfect government institutions and more reliance on imperfect private insurance markets. Based on the historical record of government estimates which have been off by orders of magnitude and private market estimates off by a factor of 2, it would seem rash to continue overriding the private insurance market's verdict on nuclear power and its insurability.

Conclusion

Existing estimates of the nuclear risk, each with its own shortcomings and biases, differ quite widely from each other. The Three Mile Island accident lends support to the credibility of some of the more pessimistic estimates. Since existing nuclear liability and insurance provisions are based on optimism about the nuclear risk, there is good reason to re-examine those provisions. The efficient amount of coverage against the nuclear risk probably has risen in recent decades, while the inflation-adjusted amount provided has steadily declined. Thus there is reason to consider raising the amount of nuclear liability coverage.

FOOTNOTES

1. See the public opinion polling results reported in Appendix I of [6].

2. Reactor Safety Study, p. 83. There is some question whether the dollar damages calculated in the Reactor Safety Study adequately represent the study's own conclusions about the severity of damage. However, it is the dollar damage figure which has been used in the past for policy purposes and this paper will also concentrate dollar damage figures. See [11].

3. The conversion to monetary equivalents is made here strictly for comparability. There are, of course, troublesome difficulties in arriving at monetary equivalents for loss of life and health. See [5], chs. 45-46.

4. See [4], p. 4, fn. 3.

5. Suppose that the rate of occurrence of accidents characterizes an exponential distribution and that the chance of an accident is 1/300 per reactor-year. Then the chance of having an accident in 500 reactor-years would be $F(T) = 1 - \exp(-\mu T) = 1 - \exp(-1/300 \times 500) = 0.81$. The chance of not having an accident would be 0.19.

6. Though this innermost curve includes no damages for loss of life and health, the Nuclear Regulatory Commission has on occasion used it as though it did. It cited the Reactor Safety Study as showing that the chance of an accident with damages exceeding $560 million would be 2×10^{-6} per reactor-year, neglecting the claims for loss of life and health that surely would be filed in addition to property damage claims. See [11].

7. For a summary of the argument and references, see [2].

8. See [10], at 121-123.

9. The Reactor Safety Study has been withdrawn as an official document by the NRC, in view of the unreliability of its findings. For the technical basis of the withdrawal, see [13].

REFERENCES

1. Anderson, Dan R. "Limits on Liability: The Price-Anderson Act Versus Other Laws." The Journal of Risk and Insurance 45 (1978): 651-674.
2. Baumol, William J. "On the Discount Rate for Public Projects." In Public Expenditures and Policy Analysis, 273-290. Edited by Robert H. Haveman and Julius Margolis. (Chicago: Markham Publishing Co., 1970).
3. Burnett, Tobias, W.T. "The Human Cost of Regulatory Delays." Nuclear Technology 33 (1977): 203-211.
4. Denenberg, Herbert S. "Testimony Before the Atomic Safety and Licensing Board, Licensing Hearing for Three Mile Island Nuclear Power Plant," November 7, 1973. Reprinted in U.S. Congress, Joint Committee on Atomic Energy, Possible Modification or Extension of the Price-Anderson Insurance and Indemnity Act, Hearings Before the Joint Committee on Atomic Energy, 226-240. (94th Cong., 2d Sess., 1974).
5. Mishan, E.J. Cost-Benefit Analysis, 2d ed. (New York: Praeger, 1976).
6. Staff of The Washington Post. Crisis: Three Mile Island. (Washington: The Washington Post Co., 1979).
7. Union of Concerned Scientists. The Risks of Nuclear Power Reactors: A Review of the NRC Reactor Safety Study WASH-1400 (NUREG-75/014). Henry W. Kendall, Study Director. (Cambridge: Union of Concerned Scientists, 1977).
8. U.S. Atomic Energy Commission. Theoretical Possibilities and Consequences of Major Accidents at Large Nuclear Power Plants (WASH-740), March 1957.
9. U.S. Atomic Energy Commission. "WASH-740 Update File." Available for inspection and copying at U.S. Nuclear Regulatory Commission Public Document Room, 1717 H. St., NW, Washington, DC 20555.

10. U.S. Congress, Joint Committee on Atomic Energy. Government Indemnity, Hearing Before the Joint Committee on Atomic Energy (84th Cong., 2d sess., 1956).

11. U.S. Nuclear Regulatory Commisison. "Financial Protection Requirements and Indemnity Agreements." Federal Register 41 (1976): 40511-40521.

12. U.S. Nuclear Regulatory Commission. Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants (NUREG-75/014), October 1975.

13. U.S. Nuclear Regulatory Commision. Risk Assessment Review Group Report to the U.S. Nuclear Regulatory Commission (NUREG/CR-0400), September 1978.

14. Wood, William C. Insuring Nuclear Power: Liability, Safety and Economic Efficiency, forthcoming, JAI Press, Inc.

Table 1: Equivalency Factors Used in Comparing Health Effects

Health Effect	Equivalent Person-Days of Illness	Money Equivalent (a)
1 accident fatality	12,000	$300,000
1 latent cancer death	6,000	150,000
1 air pollution premature death	1,000	25,000
1 case of chronic respiratory disease	10.0	250
1 case of acute radiation sickness	30.0	750
1 thyroid nodule	30.0	750
1 case of children's respiratory disease	3.0	75
1 person-day aggravated heart-lung disease symptoms	0.8	20
1 asthma attack	0.4	10

Source: Tobias W. T. Burnett, "The Human Cost of Regulatory Delays," Nuclear Technology 33 (1977): 205.

a. Calculated at $25 per person-day of illness as in original.

Table 2: Accident Consequences Calculated in the Reactor Safety Study

Chance per Reactor-Year	Early Fatalities	Early Illnesses	Property Damage \$10^9	Latent Cancer Fatalities [a]	Thyroid Nodules [a]	Genetic Effects [a]	Total Latent Fatalities [b]	Money Damages, \$10^9 [c]
2×10^{-4}	< 1.0	< 1.0	< 0.1	< 30	<30	< 30	80 [d]	.012 [e]
1×10^{-5}	< 1.0 [f]	< 1.0 [f]	0.15 [f]	810	6,000 [f]	40 [f]	1,000	.319
1×10^{-6}	< 1.0	300	0.9	5,100	42,000	750	6,700	1.937
1×10^{-7}	110	3000	3	13,800	104,000	1800	17,900	5.799
1×10^{-8}	900	14,000	8	25,800	180,000	3300	32,900	13.351
1×10^{-9}	3300	45,000	14	45,000	240,000	5100	54,800	23.424

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Source: Reactor Safety Study, p. 83, Tables 5-4 and 5-5, with corrections and adjustments as noted below.

a. These figures are presented per year in the Reactor Safety Study; to get totals we multiply by 30 years. Thus the figures above represent effects summed over the 30-year period after the accident in which the latent consequences would manifest themselves. See Reactor Safety Study, p. 83.

b. Total latent fatalities were calculated but not presented in the Reactor Safety Study's Main Report. These figures, based on Reactor Safety Study results, are presented in Risks of Nuclear Power Reactors, p. 123.

c. Based on monetary equivalents presented in Table 1.

d. Interpolated (on logs) from Risks of Nuclear Power Reactors, p. 122, Fig. 10-3.

e. Latent fatalities only, due to lack of point estimates in other categories.

f. Read from Figures 5-3, p. 88; 5-4, p. 89; 5-6 p. 91; 5-7, p. 92; 5-8, p. 93 in Reactor Safety Study.

Table 3: Accident Consequences Calculated in the Risks of Nuclear Power Reactors

Chance per Reactor-Year (a)	Early Fatalities (b)	Early Illnesses (b)	Property Damage $10^9 (c)	Latent Cancer Fatalities	Thyroid Nodules	Genetic Effects (d)	Total Latent Fatalities	Money Damages,(e) $10^9
2×10^{-4}	<10	<10	0.15	810	36,000	240	5,864	1.057
2×10^{-5}	<10	3,000	0.9	5,100	252,000	4,500	36,390	6.550
2×10^{-6}	1,100	30,000	3	13,800	630,000	10,800	97,200	18.405
2×10^{-7}	9,000	140,000	8	25,800	1,080,000	19,800	179,700	38.570
2×10^{-8}	33,000	450,000	14	45,000	1,440,000	30,600	303,900	70.903

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Source: Risks of Nuclear Power Reactors, p. 125, Table 10-2, with additions and adjustments noted below.

a. Presented here per 1 reactor-year (original expressed per 100 reactor-years). Each figure is 20 times the corresponding probability from the Reactor Safety Study.

b. These are 10 times the corresponding Reactor Safety Study results; see Risks of Nuclear Power Reactors, p. 119: "Correction of Prompt Risk of Nuclear Accidents."

c. Property damage figures are said to be understated, but no numerical correction is offered in Risks of Nuclear Power Reactors (see p. 127).

d. These figures are 6 times the corresponding Reactor Safety Study results, incorporating a doubling of exposure and a tripling for radiobiological response. See Risks of Nuclear Power Reactors, p. 123.

e. Based on monetary equivalents in Table 1.

Table 4: Accident Consequences Inferred from Insurers' Behavior

Coverage level ($$10^6$)	Premium ($/$$10^6$)	(1 - load factor)	"Expected Value of Claims" ($/$$10^6$)	Inferred Chance Per Reactor-Year
1	32,500	.58	18,850	1.885×10^{-2}
2-5	16,250	.58	9,425	9.425×10^{-3}
6-10	6,500	.58	3,770	3.77×10^{-3}
11-20	3,250	.58	1,885	1.885×10^{-3}
21-40	1,625	.58	942.5	9.425×10^{-4}
41-60	1,000	.58	580	5.8×10^{-4}
61-80	1,000	.58	580	5.8×10^{-4}
81-95	1,000	.58	580	5.8×10^{-4}

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Source: Calculated by the author from method used in Herbert S. Denenberg Testimony.

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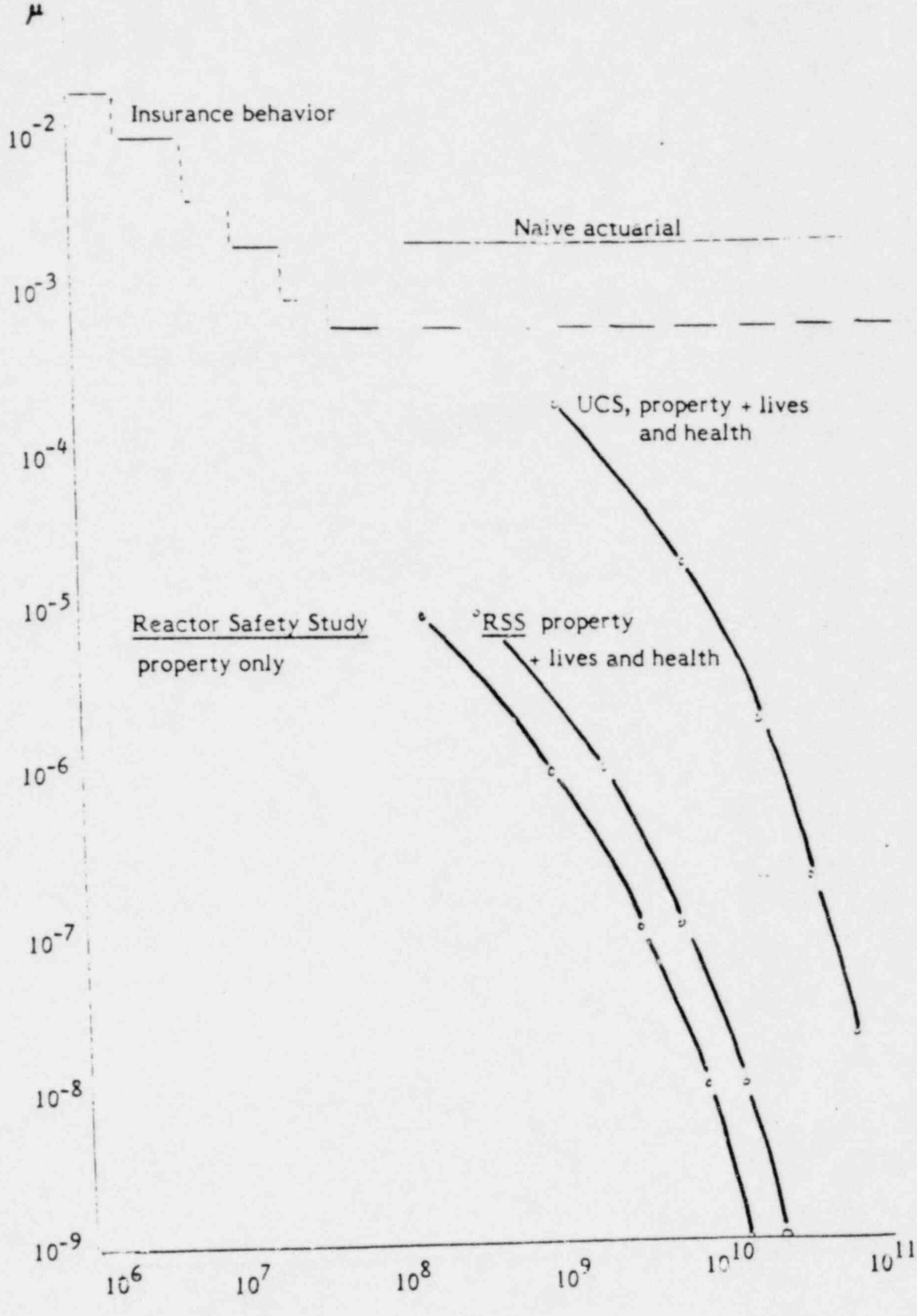

Figure 1. Probability (μ) Distributions for Damages (D) Per Reactor Year

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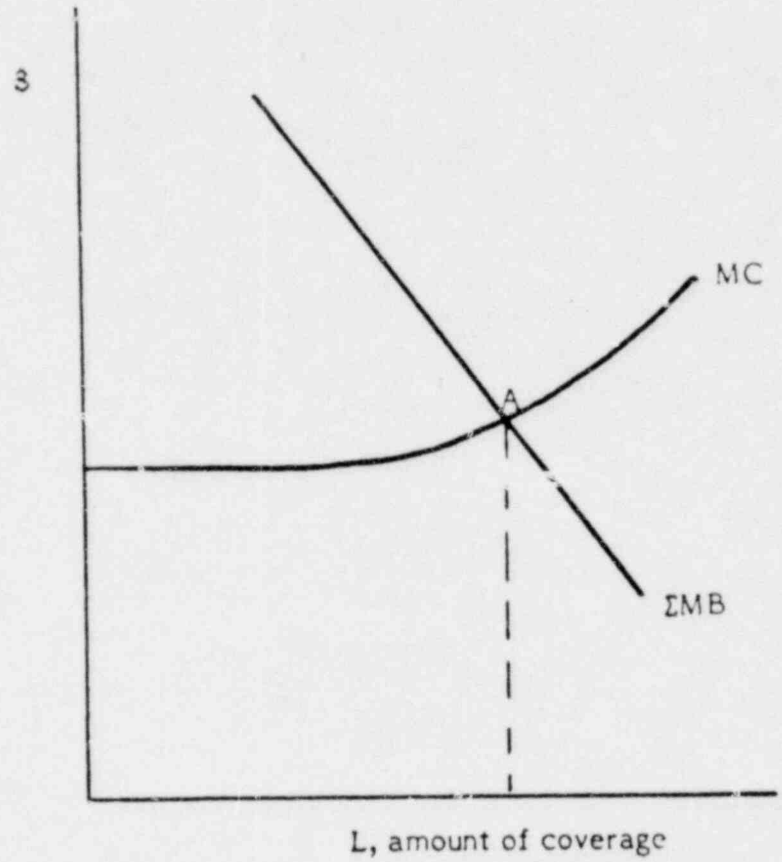

Figure 2. Costs and Benefits of Coverage