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Design, Costs, and Acceptability of an Electric Utility Self-Insurance Pool for Assuring the Adequacy of Funds for Nuclear Power Plant Decommissioning Expense

Prepared by P. L. Chernick, W. B. Fairley, M. B. Meyer, L. C. Scharff

Analysis and Inference, Inc.

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FOREWORD
BY
NUCLEAR REGULATORY COMMISSION STAFF

The NRC staff is reappraising its regulatory position relative to the decommissioning of nuclear facilities. As part of this activity, the NRC has initiated a series of studies through technical assistance contracts. These contracts are being undertaken to develop information to support the preparation of new standards covering decommissioning.

In addition to the basic series of studies on the technology, safety, and costs of decommissioning reference nuclear facilities, the NRC staff has also initiated studies to assist its evaluation of the financial aspects of decommissioning nuclear facilities. The first contractor study on decommissioning finance issues was:

Financing Strategies for Nuclear Power Plant Decommissioning, NUREG/CR-1481, Temple, Barker & Sloane, Inc. through the New England Conference of Public Utilities Commissioners, Inc. for the U.S. Nuclear Regulatory Commission, July 1980.

This is the second study. Results of this study will be incorporated into future revisions of the NRC staff report:

Assuring the Availability of Funds for Decommissioning Nuclear Facilities, NUREG-0584, Robert S. Wood, Office of State Programs, U.S. Nuclear Regulatory Commission. The earliest version of NUREG-0584 was published in July 1979. Revision 1 was issued in December 1979 and Revision 2 was issued in October 1980 in light of new information that became available.

Persons wishing to comment on NUREG/CR-2370 should mail their comments to:

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ABSTRACT

This Report summarizes a feasibility study of an electric utility self-insurance pool for assuring the adequacy of funds for nuclear power plant decommissioning expense. The feasibility study was comprised of three components: (1) the design of such a self-insurance pool; (2) the estimation of the expected costs of coverage for such a pool; and (3) the testing of the acceptability of such a pool to the electric utility industry. Five conclusions can be generally drawn from this feasibility study. First, a self-insurance pool is an appropriate method of assuring the adequacy of funds for decommissioning. Second, the expected costs of coverage for decommissioning insurance are non-trivial in absolute terms, but are a small percentage of total nuclear power generation costs. Third, the concept of a self-insurance pool for decommissioning expense is generally acceptable to the electric utility industry, while the actual use of such a pool for accident related coverages seems more acceptable than for non-accident related coverages. Fourth, the degree of assurance that funds would be available for decommissioning seems to be good. Fifth, the use of any type of insurance arrangement, including a self-insurance pool, for non-accident related coverages seems to raise problems of insurability and moral hazard which, while not necessarily insurmountable, require careful attention if non-accident coverages are to be offered.

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PREFACE

This Final Report provides a summary of work conducted by Analysis and Inference, Inc. for the Office of State Programs, U.S. Nuclear Regulatory Commission. This work was conducted between May and November, 1981, pursuant to Contract No. NRC-01-81-001.

This project entailed an examination of the concept of a self-insurance pool comprised of owner/operators of commercial nuclear power plants to assure the adequacy of funds for decommissioning. The project included three distinct, but interactive, analytical tasks. First, a reasonable design for such a self-insurance pool was produced in order to allow cost estimates to be produced and in order to test the acceptability of a self-insurance pool to the electric utility industry. Second, the expected costs of the pool were estimated. Third, the acceptability of the pool to the industry had to be tested.

Any project of this scope necessarily requires the assistance of many outside parties. We were particularly fortunate in obtaining the assistance of many informative and thoughtful persons in conducting this work. First, we were aided by the nine owner/operators who agreed to review an earlier draft of this report and who commented upon that draft: Boston Edison Company, Consolidated Edison Company, Commonwealth Edison Company, General Public Utilities, Northeast Utilities, Pacific Gas and Electric Company, Southern California Edison Company, Tennessee Valley Authority, and Yankee Atomic Electric Company. Second, we were assisted by the comments of our project advisory panel on an earlier draft of this report: Professors Joseph Ferreira, Howard Kunreuther, C. Arthur Williams, and Richard Zeckhauser. Third, several individuals and organizations generously supplied needed information and documents: Mr. Charles Bardes of American Nuclear Insurers, Mr. Hubert Nexon of Nuclear Electric Insurance Limited, Mr. Peter Lederer of Baker and McKenzie, and Mr. Quentin Jackson of Nuclear Mutual Limited. Fourth, we were aided by comments, criticisms, and guidance from two members of the Nuclear Regulatory Commission staff: Mr. Robert Wood and Mr. Frank Cardile. Finally, we were helped by our energetic research assistant, Mr. Edward Forst. Of course, none of these helpful individuals and organizations are responsible for any omissions or errors; sole responsibility for this report resides with the authors.

FINAL REPORT:

DESIGN, COSTS, AND ACCEPTABILITY OF AN ELECTRIC UTILITY SELF-INSURANCE POOL FOR ASSURING THE ADEQUACY OF FUNDS FOR NUCLEAR POWER PLANT DECOMMISSIONING

I. INTRODUCTION

This Final Report summarizes work conducted between May and November, 1981, by Analysis and Inference, Inc. for the Office of State Programs, U.S. Nuclear Regulatory Commission, pursuant to Contract No. NRC-01-81-001. This Report describes a possible design for an electric utility self-insurance pool for assuring the adequacy of funds for decommissioning, estimates the costs for such a pool, and then tests the acceptability of such a pool to the electric utility industry. A self-insurance pool is considered as one possible approach to solving the problem of how to assure the availability of funds for decommissioning; it is not put forth as the only approach or even the best approach.

This Final Report is organized as follows. Section II contains a brief discussion of the purposes to be served by the proposed self-insurance pool. Section III describes a proposed design for the self-insurance pool, and includes a description of the organizational form and structure of the proposed pool and a discussion of premium shape, coverage extent, and insurable event definitions. In Section IV, the cost estimation methodology and the cost estimates are presented separately for two distinct types of coverages: accident-related events and non-accident related events. Conclusions are contained in Section V. A short bibliography is presented in Section VI. Details of the tax effect calculations are presented in Appendix A, while the details of the cost estimation methodology and results are presented in Appendix B. A discussion of the acceptability of the self-insurance pool to the electric utility industry is contained in Appendix C. Appendix D contains a discussion of the collectibility in base rates of the premiums for the self-insurance pool. Appendix E contains a brief outline of three alternative financial assurance mechanisms that could be used in place of traditional insurance arrangements for non-accident coverages.

One cautionary point should be made at the outset. This Report contains a large amount of detail concerning a possible design, and an attached set of cost estimates, for a self-insurance pool. This level of detail was necessary, both to elicit responses from the electric utility industry on acceptability issues, and to determine potential problems that might be inherent in such a pool. However, this Report is essentially just a feasibility study of one approach to solving the problem of assuring funds for decommissioning. The actual details of how the self-insurance pool would work, if it in fact is set up in the future, are properly matters for the electric utility industry and the U.S. Nuclear Regulatory Commission to decide. This Report therefore should not be read as a proposed "prospectus" for such a pool.

II. PURPOSES OF THE SELF-INSURANCE POOL

Electric utilities in the United States generally obtain positive net salvage value from large generation and transmission facilities when they are retired. In other words, the resale or scrap value of most utility property exceeds the removal cost, in some cases quite substantially. Accordingly, before the advent of commercial nuclear power plants, decommissioning costs rarely presented electric utilities with a problem; instead, decommissioning usually was a modest source of cash and revenues.

Commercial nuclear power plants, which are almost certain to have substantial net salvage costs, presented electric utilities with a new problem: how should decommissioning expense be financed, given the existing background of utility accounting and ratemaking practices? The solution to this problem which is currently generally accepted by the electric utility industry is to pay for decommissioning from a utility's general revenues, and to finance decommissioning by collecting (in base rates) depreciation expenses over the life of the unit which include the projected decommissioning costs. The revenues from these depreciation expense provisions in rates do not currently go into segregated funds specifically created for decommissioning expenses in most cases; rather, they go into the utility's general funds.

If one makes four assumptions, the status quo seems satisfactory: (1) that a utility remains solvent; (2) that the decommissioning expense is collected over the correct number of years (i.e. decommissioning does not occur prematurely); (3) that there is no accident at the unit which causes decommissioning to cost much more than the original estimate; and (4) that decommissioning expense provisions in depreciation expense and thus in base rates are adjusted over time as more accurate decommissioning expense estimates become available. These four assumptions, however, point out the problems inherent in current practices.

A large accident, such as the 1979 incident at TMI 2, can create the need for very substantial decontamination and decommissioning expense not currently covered by existing nuclear insurance programs. The current plans to create additional first-party property insurance coverage do not completely solve this problem, although they do alleviate it. This is the case because the need for decontamination and decommissioning efforts can exist after, and above and beyond, complete property losses. The assumptions listed above, which (if fulfilled) make the status quo satisfactory, point out the needs for some type of decommissioning insurance.

A brief description of nuclear insurance programs may be helpful to explain the current situation. Three categories of nuclear insurance are currently available: (1) replacement power insurance; (2) first-party property damage insurance; and (3) third-party liability insurance.

First, replacement power coverage is offered by Nuclear Electric Insurance Limited (NEIL), an electric utility self-insurance pool. NEIL offers indemnity coverage for pre-specified amounts, which may not exceed 90% of the increased cost of the replacement power, for months 7 through 30 after an accident-initiated outage.

Second, first party property damage coverage is currently being offered by three groups: Nuclear Mutual Limited (NML), which is also an electric utility self-insurance pool, American Nuclear Insurers/Mutual Atomic Energy Reinsurance Pool (ANI/MAERP), a group of commerical insurance companies which are, respectively, stock and mutual companies, and NEIL. NML offers \$450 million (as of August 1, 1981) of first-party property damage coverage to member insureds, but does not offer coverage to all owner/operators. ANI/MAERP offers \$375 million (as of April 1, 1981) of first-party property damage coverage to all owner/operators, and is hoping to raise this to about \$450 million by January 1, 1982. ANI/MAERP is also hoping to offer additional layers (analogous to the liability layers offered under Price-Anderson liability coverages, see below) by early 1982: a second layer (above the \$450 million mentioned previously) of about \$350 million, provided by retroactive assessment of insured owner/operators, and a third layer (above the first two layers) of about \$100-\$200 million, which would be underwritten directly by ANI/MAERP, like the first layer. NEIL is offering \$118 million of additional first-party property damage coverage (i.e. above NML or ANI/MAERP coverage) and hopes to increase this amount substantially by the beginning of 1982.

Third, third-party liability coverage is offered by American Nuclear Insurers/Mutual Atomic Energy Liability Underwriters (ANI/MAELU), a group of commercial insurance companies which are, respectively, stock and mutual companies. This liability coverage is provided pursuant to the Price-Anderson Act, 42 U.S.C. §2210, in three layers: (1) the first \$160 million of coverage is provided as "guaranteed cost insurance" which means it is underwritten directly by ANI/MAELU; the second layer, which is currently approximately \$350 million, provided by a retroactive assessment of up to \$5 million per reactor for the approximately 70 reactors currently in operation; and the third layer, which is the remaining coverage up to the Price-Anderson limit of \$560 million of total coverage (and total liability), which is provided by the United States.

These limits of coverage should be compared to possible post-accident decontamination costs (which are estimated currently to substantially exceed \$1 billion for TMI 2, for example) and to current initial capital costs of large, 1150 MW LWRs (which currently cost in the \$1 to \$2 billion range for plants coming on line in 1981). Thus it appears to be the case that the currently planned increased limits of first-party property damage reduce, but do not eliminate, the apparent need for some type of decommissioning expense coverage.

Three specific purposes can thus be identified for decommissioning insurance. First, although utility solvency is not the sole purpose or the responsibility of decommissioning insurance, the existence of such insurance would certainly be helpful in future situations like TMI 2. Second, decommissioning insurance which covers accident-initiated decommissioning (which is premature, causing depreciation reserves to be inadequate, and which may also cause substantial and unforeseen additional decontamination expense) obviously has some protective value. Third, decommissioning insurance which covers non-accident-initiated premature decommissioning, especially if the premature decommissioning is very early in the unit's life or if it stems from a problem which will cause decommissioning to be more difficult and costly than expected, would also offer some substantial protection.

More generally, there is a public health and safety interest in ensuring that nuclear power plants are safely decommissioned. There is also a general economic interest in preventing utility insolvency. Finally, there may be some general public interest in spreading at least a portion of unforeseen nuclear accident or problem costs across the class of ratepayers who enjoy the benefits of relatively cheap nuclear power, instead of having these costs be borne exclusively by the ratepayers of one particular utility or by having them borne more widely by taxpayers.

Thus decommissioning insurance, which could cover both accident-initiated and non-accident initiated events, has the potential for achieving some specific purposes in furthering the financing of decommissioning by owner/operators and also for achieving some broader societal goals.

III. DESIGN OF THE SELF-INSURANCE POOL

A. Organizational Form and Structure of the Pool

1. Organizational Form of Pool

One organizational form for the pool seems substantially better than any alternative: an offshore corporation which insures its own members and which is an "ownership-share" corporation. Incorporation is necessary to limit the insured utilities' liability for insured events; an unincorporated association of utilities could result in joint and several liability for the utilities themselves for any excess losses over reserves, which would seem to be an intolerable outcome for the member utilities. The corporation should be an offshore corporation, not organized to do business in the U.S., in order to minimize U.S. federal income tax liability (for the pool itself) and U.S. securities regulation problems. This results in substantial net savings. Because it would only insure member insureds (i.e., membership would be a condition precedent to coverage, and coverage would be the only purpose and benefit of membership), the "ownership-share" structure makes sense, in which ownership shares (stock) would be held proportional to some measure of responsibility for the output or capacity of the pool (say, as measured by premium dollars paid in, or number of units insured, or amount of coverage purchased).

Care should be taken to make sure that no member insured of the self-insurance pool owns 10 percent or more of the corporation, as this could result (under certain circumstances) in the corporation being considered to be a "controlled" foreign corporation, which in turn would cause the loss of some of the attractive consequences of being off-shore.

In sum, this solution, an offshore "ownership share" corporation, is the one that has been settled on by the two existing electric utility self-insurance pools, NML and NEIL, and appears to be the obvious choice for the organizational form of the pool.

2. Membership Eligibility Requirements

A fairly difficult question arises on the issue of whether the proposed self-insurance pool should be forced to accept any U.S. owner/operator of a commercial nuclear power plant as a member insured, or whether the pool should be permitted to exclude certain owner/operators because they are deemed to be bad risks or for any other reason.

Mandatory acceptance by the pool of owner/operators who apply is attractive because it would help ensure that there would not be undecommissioned plants, which threaten public health and safety because they were not being properly decommissioned, due to the lack of a financially responsible owner/operator. Mandatory acceptance by the pool is unattractive, however, for two reasons: (1) it might make the owner/operators who perceive themselves as "good" risks among owner/operators less interested in joining the pool; and (2) it might convince owner/operators that they could take less care in operating plants or in reserving for decommissioning expense (that is, it might result in "moral hazard").*

Although the answer to this question is by no means clear or obvious, it seems to make sense to encourage mandatory membership. That is, the pool should be required to accept all owner/operators as member insureds, and all owner/operators should be required to obtain coverage. As a result, the pool should also be allowed, and even encouraged, to lessen any resulting tension caused by any resulting "good risk/bad risk" conflict of interestand rate units and owner/operators differentially (for premium purposes) with respect to variables shown to have some connection (even if not compelling) to riskiness. See §III(A)(3), below. This tentative solution, although it does have the drawbacks of imposing a possibly unnecessary mandatory requirement on owner/operators and of possibly creating "moral hazard," and although it would possibly be quite difficult for the NRC to enforce, would at least protect the public from the risk of un-decommissioned plants and would also minimize within-pool conflicts over the relative riskiness of different units and different owner/operators.

3. Differential Risk Classification

The decision to attempt to require (or at least encourage) mandatory acceptance by the pool of owner/operators as member insureds essentially requires that the pool be allowed to rate risks differentially. This makes sense for two related reasons. First, differential rating provides the only escape valve for the tensions that otherwise might arise between different member insureds over the issue of relative riskiness of various units. Second, premiums of different size would provide at least some additional incentive for owner/operators (and their respective state rate regulators) to be responsive to the risks created by different operating procedures and different reserving practices.

It should be emphasized that this project did not attempt to determine which risk classification variables would be appropriate for use by the self-insurance pool in question, nor did it attempt to determine how risk classification variables should be used in calculating premiums. The electric utility industry's comments on a possible list of risk classification variables are contained in Appendix C. One of the advantages of a self-insurance pool, and of the insurance approach in general, is that the subject of risk classification may be appropriately left to the electric utility or insurance industries, respectively. More specifically, it should be emphasized that this project did not attempt to determine

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*This second possible source of moral hazard could be partially alleviated by allowing or encouraging the pool to require certain reserving practices or certain operation and maintenance practices as a condition of membership.

the extent to which (if any) indicated rates for individual reactors should be weighted back towards the average rate, either for reasons of actuarial credibility or on the grounds that the average rate provides a Bayesian prior, and also did not attempt to determine the extent to which (if any) indicated rates for individual reactors should be tempered for reasons of utility theory. See generally Kahn (1974) on actuarial credibility theory, and Ferreira (1978) on tempering.

B. Insurable Event

There seem to be eight possible insurable event definitions, corresponding to the eight possible combinations of three two-way choices, as outlined below:

No.	Definition of Insurable Event
(1)	Accident, Requiring Decommissioning, Coupled with Financial Incapacity
(2)	Accident, Requiring Decommissioning, Regardless of Financial Incapacity
(3)	Economic/Technological/Engineering Obsolescence, Requiring Decommissioning, Coupled with Financial Incapacity
(4)	Economic/Technological/Engineering Obsolescence, Requiring Decommissioning, Regardless of Financial Incapacity
(5)	Accident, Requiring Additional Decontamination Effort prior to Decommissioning, and Decommissioning, Coupled with Financial Incapacity
(6)	Accident, Requiring Additional Decontamination Effort prior to Decommissioning, and Decommissioning, Regardless of Financial Incapacity
(7)	Economic/Technological/Engineering Obsolescence, Requiring Additional Decontamination Effort prior to Decommissioning, and Decommissioning, Coupled with Financial Incapacity
(8)	Economic/Technological/Engineering Obsolescence, Requiring Additional Decontamination Effort prior to Decommissioning, and Decommissioning, Regardless of Financial Capacity

These eight possible insurable event definitions are shown diagrammatically in Figure 1, below.

Several points are in order at this time.

TYPE OF COVERAGE

Initiating Event		Decommissioning		Additional Decontamination Effort Prior to Decommissioning, and Decommissioning	
	Accident	Coverage if Financial Incapacity Present (1)	Coverage Regardless of Financial Capacity (2)	Coverage if Financial Incapacity Present (5)	Coverage Regardless of Financial Capacity (6)
	Economic/ Technological/ Engineering Obsolescence	Coverage if Financial Incapacity Present (3)	Coverage Regardless of Financial Capacity (4)	Coverage if Financial Incapacity Present (7)	Coverage Regardless of Financial Capacity (8)

Figure 1: Definitions of Eight Relevant Insurable Events

Note: Not all of the eight insurable events outlined here are equally probably or equally important from the public policy viewpoint of minimizing the danger that nuclear power plants would not be quickly and efficiently decontaminated and decommissioned. For example, events (7) and (8) may seem substantially less probable, and less deserving of attention, than events (5) and (6) respectively. See Appendix B for a detailed discussion of the costs and needs for the various possible coverages.

First, including events (5) through (8) is the primary cause of the need to examine coverage amounts on the order of magnitude of $500 million to $1 billion, as discussed in III(C)(1)(c), below. Because the line between "normal" decommissioning, which includes some substantial decontamination work (on the one hand) and additional decontamination effort required in addition to "normal" decommissioning (on the other hand) is difficult to draw, considering coverage for events (5) through (8), seems reasonable.*

Second, the phrase "economic/technological/engineering obsolescence" is meant to be a catch-all, including various initiating events of a non-sudden nature. These non-sudden events would include, for example, situations in which reactors became too radioactive to permit economical maintenance and ref[illegible] situations where retrofit requirements imposed for health a[illegible]y reasons by the NRC could not be economically justified in light o[illegible] the unit's remaining life, and situations where deterioration of major components (say, the NSSS) due to wear and tear could not be corrected economically.

Third, the possible inclusion of a financial incapacity test (events (1), (3), (5), and (7)) is unconventional but attractive in this situation. Inclusion of financial incapacity as a condition precedent to payment by the pool to the owner/operator is not a common type of condition in commercial insurance. This type of requirement makes the coverage more difficult to price (by the insurer) and more difficult to evaluate (by the insured). Two types of moral hazard could conceivably result from the use of a financial incapacity test as part of the definition of the insurable event. First, most objective measures of financial incapacity (such as a bond rating or a fixed charge coverage ratio) are to some extent within the control of the utility involved, through its choice of accounting methods. Second, utilities' incentives to take certain steps (such as the creation of single-asset utilities to own and operate nuclear plants) might be increased by the use of a financial incapacity test. On the other hand, providing for coverage only in the case of financial incapacity makes sense in that it would decrease total costs substantially while still providing assurance that plants would, in fact, be decommissioned.

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*Indeed, it could be argued that coverage for events (5) through (8) really lies at the heart of the problem at hand. "Straight" decommissioning, without any additional decontamination effort beyond that contemplated for an average decommissioning, seems likely to be within the capabilities of most or all owner/operators given current decommissioning scope of effort determinations and current decommissioning cost estimates, at least if multiple units are not involved. It is only when additional and extraordinary decontamination costs are added to decommissioning costs that the entire combined decontamination/decommissioning enterprise is placed at risk.

One might not expect to encounter the "accident" situation without also incurring some degree of financial incapacity; to the extent that this is correct, it is logical to offer the "accident" coverages without the requirements of financial incapacity as a condition precedent to coverage. That is, coverages (1) and (5) may, in fact, be just about as inclusive as coverages (2) and (6), respectively, and the added complication of the financial incapacity test may not be justified in light of the modest expected savings. By comparison, with respect to the "obsolescence" coverages, it is easy to conceive of many events which would not result in financial incapacity. Accordingly, it would seem that coverages (3) and (7) should offer substantial cost savings over coverages (4) and (8), respectively, as they provide significantly narrower, and thus less valuable, coverage. This would lead one to conclude that the financial incapacity test might prove to be a more important feature in the "obsolescence" coverages than in the "accident" coverages.

Because the inclusion of a financial instability condition as part of the insurable event definition is not a common practice, the cost estimates presented below in §IV(B) and in Appendix B do not take into consideration the possible cost savings that could be achieved by replacing coverages (2), (4), (6), and (8) with coverages (1), (3), (5), and (7), respectively. However, this option (to include a financial instability test as a condition precedent for coverage of losses) remains open to the pool should the premiums be deemed too high for the coverages which allow for recovery regardless of financial condition. See the discussion in Appendix E.

Fourth, it may make sense to replace a fixed amount deductible with a deductible equal to reserves to date for each unit. Certainly, reserving practices should be a required type of data submitted by the insured owner/operator to the pool, at least for use as a risk classification variable. As reserves grow (regardless of whether they are contained in a depreciation reserve, or a fully funded or partially funded trust outside the assets of the owner/operator), it would provide substantial cost savings to have total coverage shrink proportionately.

Fifth, decontamination leading to re-start should not need coverage, and is therefore excluded from discussion. The reasoning behind this exclusion goes as follows. If an owner/operator plans to re-start a unit after a decontamination effort, the remaining life of the unit must (almost by definition) be adequate to justify the decontamination expense in light of the expected value of the unit's future generation. If the owner/operator has made this cost/benefit analysis correctly, the capital markets should agree with the determination, and thus capital to finance the decontamination effort should be forthcoming.

The discussion in the preceding paragraph notwithstanding, one peculiar problem associated with offering the type of coverage considered in this Report results from the possible distorting effect such coverages would have on an owner/operator's "decommission vs. restart" decision after a major accident at a nuclear power plant. An example will illustrate this problem. Assume that coverage is only offered for decontamination expenses associated with decontamination efforts leading to decommissioning, as contemplated in this Report, and not for decontamination expenses associated with decontamination efforts leading to restart. Assume further that a substantial accident involving radioactive contamination within the plant occurs at a nuclear power plant which has a remaining value before the accident of $500 million. Finally, assume that either decontamination effort (decontamination leading to decommissioning and decontamination leading to restart) will cost $400 million, and that either decommissioning or restart will cost an additional $200 million each. In this example, providing coverage only for decontamination leading to decommissioning and decommissioning would create an incentive for the owner/operator to decommission rather than to restart, even although it makes more sense (from the point of view of the entire system) to restart, given the costs assumed.

In general, then, it seems reasonable to assume that in most cases, coverage for decontamination leading to restart expenses is not needed, because if it in fact makes economic sense to restart a unit, financing for the decontamination leading to restart plus restart expenses should be available from the capital markets. However, it must be remembered that, in designing the self-insurance pool discussed here, that this is not necessarily always true and further that offering only decontamination leading to decommissioning plus decommissioning coverage may distort the incentives provided to the owner/operator.

In conclusion, cost estimates for coverages (1), (3), (5), and (7) are not included in §IV(B) and Appendix B. It is likely that the costs for coverages (1) and (5) would be somewhat lower than the costs for coverages (2) and (6), respectively, while it is likely that the costs for coverages (3) and (7) would be very substantially lower than the costs for coverages (4) and (8), respectively. Cost estimates were produced for the remaining four coverages as follows:

Coverages for Insurable Event	Coverage Limit
(2)	$500M and $1B
(6)	$500M and $1B
(4)	$100M and $250M
(8)	$100M and $250M

See §IV(B), and Appendix B, below.

C. Structure of Coverage and Shape of Premium

1. Coverage Shape

An important set of questions revolve around what might be termed "coverage shape," i.e., how large and extensive the coverage should be in terms of dollars of protection. (Extent of coverage in terms of covered events is discussed above in §III(B), "Insurable Event.") Three sub-questions are involved here: (1) deductibles; (2) co-insurance, and (3) limits on coverage. These will be discussed in turn.*

(a) Deductibles. Deductibles provide some level of economic incentive that precludes the owner/operator from ignoring losses altogether, and also provide some help in keeping total costs down. Accordingly, the concept of providing coverage only subject to some deductible seems to make good sense. The size of the deductible is interrelated to the size of the coverage limit (see §III(C)(1)(c), below) and to the definition of the insurable event. In loosest terms, a deductible of some 5-10% of the total coverage seems reasonable, at least for "straight decommissioning" insurance. ("Straight decommissioning" insurance means insurance meant to cover normal decommissioning only, and not additional decontamination effort in addition to that usually entailed in decommissioning.) A $5 million deductible seems appropriate if one is only covering decommissioning, say to a limit of $50 - $100 million. By contrast, if one is offering "additional decontamination leading to decommissioning, plus normal decommissioning" insurance, which might involve coverage of $1 billion or even more, a deductible of $50 - $100 million seems reasonable. A workable estimate for the deductible seems to be 5% of the applicable maximum.

(b) Co-Insurance. Co-insurance refers to not covering all of a loss cost, by percentage of the loss. Co-insurance differs from a deductible in that a deductible is an exclusion from coverage of 100% of loss costs below a fixed amount, while co-insurance is an exclusion from coverage of a certain percentage of a loss cost, possibly above a deductible or below a coverage limit. Like a deductible, co-insurance has two desirable effects: it reduces total premium costs, and it creates at least a modest incentive to control losses. Because co-insurance operates across the full range of a loss, the incentives provided by co-insurance may be more useful than those provided by deductibles.

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*To the extent that any of the exclusions from coverage discussed in this section are thought to result in an inadequate degree of assurance that units will in fact be properly decommissioned, the self-insurance pool could conceivably fulfill a secondary function as a source of loans for additional funds needed to decommission a unit but not provided directly by the pool due to the limitations on coverage discussed in this section.

Also like a deductible, co-insurance ceases to make sense to the extent that it destroys the purpose of the insurance. By this it is meant that co-insurance cannot be so large as to destroy the insured's ability to pay the co-insured portion of the loss cost. This is a relevant consideration here, as it makes no sense to push an owner/operator back into bankruptcy or financial instability, one of the outcomes this insurance is designed to prevent, merely because of an onerous co-insurance percentage. On balance, a 10 percent co-insurance percentage retained by the owner/operator, above (and in addition to) the deductible and below the limit on coverage, if any, seems reasonable. Of course, this is an arbitrary number, and could be moved up or down some as a matter of taste.*

(Note: The term "co-insurance" is used in the fire insurance industry and nuclear insurance industry to have a meaning different from the meaning given to "co-insurance" here. See Holtom (1973) at 92, 386-387, 691 for the fire insurance meaning of co-insurance. Co-insurance is used here, as it is in the health insurance industry, to mean that the insured pays a fixed percentage of the total loss costs. It thus can be thought of as a fixed percentage deductible, as opposed to a flat amount deductible.)

(c) Limits on Coverage. The third and most difficult issue to be resolved with respect to coverage shape is the question of upper limits (if any) on coverage. It seems clear that actual damages, rather than a fixed indemnity amount, is the right measure of loss payment. It is not so clear, however, up to what limit insurance coverage for damages should exist.

It is generally accepted wisdom that decommissioning will cost roughly \$50-\$100 million; accordingly, there would seem to be little need for coverage above \$100 million for decommissioning expense coverage alone. However, two factors argue against this initial conclusion: (1) current decommissioning cost estimates should be viewed as including high degrees of uncertainty; and (2) additional decontamination expense, after an accident, leading to decommissioning, could easily cost \$1 billion or more in 1981 dollars. Further, the dividing line between decontamination leading to decommissioning and subsequent decommissioning (which includes a "normal" amount of decontamination effort) is a fine one at best. Accordingly, it appears to make sense to price coverages of \$500 million and \$1 billion for expenses associated with decontamination leading to decommissioning, plus decommissioning expense. This discussion applies to accident-related decommissioning. With respect to non-accident related

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*If deductibles or co-insurance are thought to create too large a risk of financial instability, the pool could serve an additional function by loaning the owner/operator the amount of the deductible plus the insurance in case of a loss.

decommissioning, substantially lower coverage limits seem appropriate. Ranges of $100 million to $250 million seem to reflect possible costs of non-accident related premature decommissioning, in 1981 dollars, although this varies by type (BWR vs. PWR) and size (in MWe) of the reactor. The initial decision was made to price coverage at arbitrary levels of $100M and $250M of coverage, and then to recommend actual coverage levels as follows:

large LWR	$250M
small LWR	$100M

No distinction is made in these recommended coverage levels between BWRs and PWRs; however, there is some reason to believe that BWRs are slightly more expensive to decommission than PWRs. All coverage limits (and attached premiums discussed below) should be indexed by some appropriate index, such as steam plant or nuclear steam plant construction costs, so that the value of the coverage and the costs of the premiums do not decrease in real terms over time. All discussions in this report are thus in 1981 dollars.

2. Premium Shape

One of the first important questions to be answered when one considers how to finance a self-insurance pool is how to structure or shape the premiums. Self-insurance pools by definition have no capital to start with, other than capital donated directly by member insureds. Thus capital contributions, whether labeled as such or as "reserve premiums" (i.e., a portion of premium that is explicitly hoped to become a portion of earned surplus), must be made by member insureds, either before the pool opens or during its early operation. Additionally, self-insurance pools can retroactively modify the premium due for any past period if experience for that period was sufficiently adverse to require such an action.

The possibility of these two other types of premium payments (which are called reserve premiums and retroactive premiums) in addition to the usual type of premium payment (which are called ordinary premiums) raises the questions of the relative desirability of the three types of premium charges. Two issues stand out in the electric utility self-insurance pool context: (1) tax status, and (2) collectibility in base rates. These will be discussed in turn.

(a) Tax Status. There does not seem to be any problem with the tax status of ordinary premiums and retroactive premiums. Both fit within the classic status of "ordinary and necessary" business expense and thus should qualify easily for deductible status as expenses for FIT purposes for the member insureds. Reserve premiums, however, present a somewhat different picture. Whether or not it is labeled as such, a payment which serves the purpose of being a contribution to a self-insurance pool's capital is much closer to a capital transfer than it is to an "ordinary and necessary" business expense. If viewed as a capital transfer (analogous to a capital contribution by a parent to a newly created, wholly owned subsidiary), the payment would not necessarily be a taxable event, and should thus be viewed as possibly not deductible for the member insured's FIT purposes. In sum, the choice between (on the one hand) ordinary premiums and retroactive premiums (deductible) and (on the other hand) reserve premiums (possibly not deductible) is important to the member insureds because of the possibly different tax status of the premiums, although it should also be remembered that mere labels are not the determinative factor here. That is, if all premiums were termed "ordinary premiums," but a portion of the initial premium flow was a fact used by the pool for the purposes of accumulating a capital reserve, that portion of the ordinary premium which was in fact being used to create reserves might also be held to be non-deductible for FIT purposes.

(b) Collectibility. The three possible types of premium payments might differ in their probable "collectibility" in the member utilities' base rates. In general, rate regulators allow "reasonable and prudent" business expenses to be collected by utilities in their base rates. The details of the current status of utility law on the collectibility in base rates of insurance premiums are discussed below in Appendix D. It suffices to say here that it is likely that ordinary premiums would be collectible in base rates, but that the status of both reserve premiums and retroactive premiums are a little less clear. With respect to reserve premiums, the argument could be made that they are merely temporary loans of capital, and not true expenditures, and thus not properly collectible in rates. To the extent that reserve premiums are considered expenditures, they might be argued to be capital expenditures rather than ordinary expenses. If viewed as capital expenditures, they might be treated for rate purposes either as additions to rate base or as expenditures better amortized than expensed. With respect to retroactive premiums, the argument could be made that these premiums do not represent a payment by utility X for a necessary purpose that benefits utility X's rate payers as much as they represent a payment by utility X to take care of a problem of utility Y and utility Y's rate payers. Of course, no one can predict what rate-making treatment will be afforded a particular accounting item. At this point, no more can be said beyond the generalization that it is highly likely that ordinary premiums would be collectible as expenses in base rates, that it is likely that retroactive premiums would be collectible, but might be amortized rather than expensed for rate purposes, and that it is likely that reserve premiums would not be collectible as expenses, but would more properly either be amortized or capitalized by being added to rate base.*

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*Of course, obtaining PUC approval to join the self-insurance pool prior to the operation of the scheme should improve the probabilities that these expenditures would prove to be collectible in rates. Additionally, the collectibility of these expenses should also be improved if the NRC ordered such coverages to be obtained by owner/operators.

IV. COST ESTIMATES FOR THE SELF-INSURANCE POOL

A. Miscellaneous Issues Relating to Cost

1. Tax Effects

The details of tax calculations are discussed in Appendix A. This section will briefly summarize the results of the tax status of the various types of premiums, both before and after a rate case.

Because of the differences between various states' tax laws and rate regulatory schemes, and because of the different tax situations of various owner/operators, no definitive single answer can be given to the question of how taxes will effect premium payments. Further, because of the large uncertainty in the underlying premium estimates, the application of apparently precise tax effects can lend a false sense of precision to the final estimates. Despite these problems, the following general tax multipliers should be applied to premiums to obtain a rough idea of effective costs of the various premium payments at the various times.

(a) Tax Effects on Cash (applicable after the expense has been incurred, but before collection of the expense in base rates has begun):

1. Ordinary Premiums and Retroactive Premiums

Effective cost = $P[1-(.46+(1-.46)(a))][1+.04+b]$

where P=premium
a=relevant state income tax rate, if any, expressed as a decimal
b=relevant state premium tax rate, if any, expressed as a decimal

See §§ II(E) and II(F) of Appendix A.

2. Reserve Premiums

Effective costs = $P[1+.04+b]$

where P=premium
b=relevant state premium tax rate, if any expressed as a decimal

See §§ II(E) and II(F) of Appendix A.

(b) Tax Effects on Rates (applicable after collection of the expense in base rates has commenced):

Effective cost = $P \quad 1 + .04 + b$

where P = premium
b = relevant state premium tax rate, if any, expressed as a decimal

See §IV of Appendix A.

In summary, for ordinary premiums and for retroactive premiums, before new premium expenses are collected in base rates, the rate payer pays nothing and the utility and the U.S. Treasury roughly split the expense in cash terms. For reserve premiums in cash terms, before the expense is collected in base rates, the utility pays the premium times a premium tax loader. After the new premium expenses are collected in base rates, the utility passes on the new expense to the rate payer, with any relevant premium taxes added as a multiplier.

2. Collectibility in Base Rates of Premium Payments

In general, it seems reasonable for planning purposes to assume that premiums paid into a self-insurance pool for decommissioning expense insurance will be allowed for rate-making purposes. Specifically, ordinary premiums should be collectible, as ordinary and necessary business expenses, in base rates. Reserve premiums should be collectible, either by being amortized or by being capitalized as additions to rate base. Retroactive premiums should be collectible, either by being expensed or by being amortized. Further, it seems reasonable to assume that the collectibility in base rates of all types of premium payments would be enhanced if each owner/operator obtained prior regulatory approval for joining the pool from rate regulators. Finally, it seems reasonable to assume that the collectibility of this expense in owner/operators' base rates would be still further enhanced if such insurance coverage was required by the N.R.C. A detailed discussion of the reasons behind these conclusions is contained in Appendix D.

B. Cost Estimation Methodology and Cost Estimates

1. Introduction

This section summarizes briefly the cost estimation methodology, and the actual cost estimates produced, for both accident and non-accident coverages. Both the methodology and the resulting estimates are described in greater detail in Appendix B.

Two preliminary points should be made at this time. First, it should be noted that these accident and non-accident coverage cost estimates were estimated separately. The cost estimates discussed are for each type of coverage, respectively, and would have to be added together to produce estimates for both accident and non-accident coverage for a nuclear power plant. Second, these cost estimates are expected costs of coverages. A self-insurance pool might decide to charge premiums which were higher or lower than the expected costs of coverages, for various reasons; see Appendix C for the positions of several owner/operators on the question of whether premiums should be set at, above, or below the expected costs of coverages.

2. Accident Events

a. Methodology

First, various definitions of the insurable event were considered. The insurable event definitions used by the three existing types of nuclear insurance (first-party property damage insurance, third-party liability insurance, and replacement power insurance) were examined. Similarly, the definitions of accident events used in the Reactor Safety Study and used by the Nuclear Regulatory Commission for safety evaluations and for emergency planning in licensing proceedings were examined. It was determined that the accident event definition used by Nuclear Electric Insurance Limited (NEIL) for replacement power insurance would provide a suitable definition of the accident event, with several modifications.

Second, a model was developed for insurance premium calculations. This model included the following terms: an expected loss term, an expense loader term, and a residual term which included all other factors, such as profit and investment income effects, risk aversion effects, and effects of provisions for refunds, retroactive premiums and reserve premiums, which would affect the total rate level. The expected loss term was in turn modeled by examining three other terms: a probability of large or maximum loss event term, a cost of a large or maximum loss event term, and a ratio of total losses to losses resulting from large or maximum events term.

Third, various approaches to estimating the probabilities of large or maximum loss events were taken. Historical experience for three different sets of U.S. reactors were examined. Estimated probabilities were also examined by estimating the revenue accumulation rates implicit in current nuclear insurance programs. These revenue accumulation rates, once such factors as profit, investment income, and risk aversion loadings were removed, and after consideration was taken of the ability of some of the insurance programs to collect retroactively for adverse experience, provide ranges for probability estimates. The Reactor Safety Study (RSS) was also examined as a possible source of useful probability estimates. The RSS estimates were found to be not useful, for four possible reasons: (1) the RSS estimates may be biased; (2) the RSS accident event definitions may be different enough from existing insurance programs' accident event definitions, and from the accident event definition used herein, to be not relevant for present purposes; (3) the RSS and existing insurance programs may be based on different information or different opinions; and (4) the model used in this Report for extracting probability estimates which are consistent with existing nuclear insurance program premiums may be incorrect. It was concluded that RSS estimates were not useful for present purposes, but that probabilities inferred from historical data and from nuclear insurance program premiums provided a reasonable range for estimating decommissioning insurance expected coverage costs.

Fourth, actual expected coverage cost estimates were produced by estimating the various necessary input values and by using them in the model described previously.

b. Cost Estimates

The expected costs of accident-initiated coverages are displayed in detail in Table B-5 of Appendix B and are summarized in Table 1, below.

TABLE 1

ESTIMATES OF EXPECTED COVERAGE COST FOR ACCIDENT-INITIATED DECOMMISSIONING INSURANCE*

Nominal Coverage Limit	$500		$1000	
Decommissioning Reserve Target	$ 50	$250	$ 50	$250
Effective Coverage Limit	$427.3	$337.5	$887.3	$787.5
Expected Costs of Coverage	$0.63- $2.51	$0.50- $1.99	$1.22- $4.89	$1.10- $4.39

*See Table B-5 in Appendix B for details. All figures in millions of 1981 dollars; expected coverage costs are per reactor-year.

3. Non-Accident Events

a. Methodology

The cost estimation methodology for non-accident events differed substantially from the methodology for accident events.

First, the definition of the insured event for non-accident coverages was considered; it was defined as including all events, not covered by the accident coverage, which result in inadequacy of reserves for decommissioning. This could result from prematurity of decommissioning, from cost overruns in the decommissioning process, or both.

Second, the question of whether or not non-accident events were insurable events was examined. Three sub-questions were identified: (1) whether non-accident events are speculative risks; (2) whether insuring against non-accident events would create excessive moral hazard; and (3) whether insuring against non-accident events would create adverse selection. To some extent, of course, these three sub-questions are interrelated and deal with similar or overlapping matters. It was concluded that insurance for non-accident events would raise serious questions, especially of moral hazard, and lesser questions of speculative risk and of adverse selection. These problems are potentially serious. Careful attention would have to be paid to all of these questions before such coverages were actually offered.

Third, the frequency of non-accident events was considered. The small amount of data on premature decommissionings to date was displayed. Two methods (the product-limit method and the reduced-set method) were used to convert the survival data to a survivorship function. (These two methods are the continuous analogues of two traditional electric utility depreciation methodologies, the annual-rate method and the composite original group method.) It was recognized that, due to the fact that the existing data is very sparse and due to the problems inherent in extrapolating data on smaller earlier vintage plants to larger and later vintage plants, any inferences drawn from the data are necessarily weak. The retirement curve L-3 with a 20-year life from Winfrey (1935) was selected as the curve most similar to existing data. A 30-year life for the same curve was also used for sensitivity purposes; the 30-year life was not directly supported by the data, but could not be rejected on the basis of the data either.

Fourth, the average cost of decommissioning was examined. Current engineering estimates of decommissioning expenses were considered to be subject to too many uncertainties, resulting from an apparent industry-wide tendency to underestimate nuclear construction costs and resulting from the tendency of costs to escalate for projects conducted over long periods of time with potential changes in scope, to be used directly for insurance ratemaking. A model was developed, based on past escalation rates in nuclear construction cost estimates, which produced "myopia factors" in cost estimates, which were applied to current engineering estimates of decommissioning costs, to produce decommissioning costs for which insurance coverage might be appropriate or necessary.

b. Cost Estimates

Cost estimates were produced for two models of coverages, a "deterministic" model and a "stochastic" model. These two models can be thought of as either being models of how nuclear plants will in fact be decommissioned in the future or models of coverages to be offered in light of possible future decommissioning patterns. These cost estimates, which are for expected costs of coverage, are summarized in Table 2 below, which is taken from Table B-14 in Appendix B.

TABLE 2

TOTAL NAIDE EXPECTED COVERAGE COSTS, IN MILLIONS OF 1981 DOLLARS PER REACTOR YEAR*

Year of Coverage	$100M Coverage	$250M Coverage	$100M Coverage	$250M Coverage
30-Year Life Average 0-30	0.49	1.24	0.65	1.61
30-Year Life Average 30-72	--	--	3.08	7.70
20-Year Life Average 0-20	0.74	1.86	0.975	2.42
20-Year Life Average 20-48	--	--	4.62	11.55

*See notes to Table B-14 in Appendix B for details.

V. CONCLUSION

This Report has summarized work done between May and November, 1981 by Analysis and Inference, Inc. for the Office of State Programs of the U.S. Nuclear Regulatory Commission pursuant to Contract No. NRC-01-81-001. A feasibility study was conducted of an electric utility self-insurance pool for assuring the adequacy of funds for nuclear power plant decommissioning expense. The feasibility study contained three components: (1) the design of such a self-insurance pool; (2) the estimation of the expected costs of coverage for such a pool; and (3) the testing of the acceptability of such a pool to the electric utility industry. The detailed design for the pool (presented in §III, above) and the detailed cost estimates (presented in §IV above and in Appendix B, below) were necessary in order to test the acceptability of the concept of a self-insurance pool. It should be noted, however, that this Report is a feasibility study, and should not be read as a proposed prospectus for any future self-insurance pool.

The following general conclusions can be drawn from this work:

(1) A self-insurance pool is an appropriate method for assuring the adequacy of funds for nuclear power plant decommissioning expense, and the designing of such a pool does not present any insurmountable obstacles, at least for accident-initiated events.

(2) The expected costs of coverage for decommissioning insurance provided by such a pool are non-trivial, and appear to be on the order of half a million to five million dollars per reactor per year for a billion dollars of accident-related coverages, depending on various coverage designs and other input values. The expected coverage cost for non-accident-related coverages appears to be on the order of one to six million dollars per reactor per year for a typical large LWR, but may be much smaller under some coverage designs or much larger for very old reactors.

(3) The concept of such a self-insurance pool is generally acceptable to the electric utility industry. The use of such a pool is more acceptable to the electric utility industry for accident related coverages than for non-accident related coverages.

(4) The degree of assurance provided by such a pool that funds would be available for decommissioning expense seems to be good.

(5) The use of any type of insurance arrangement, including a self-insurance pool, for non-accident related coverages seems to involve certain problems of insurability and moral hazard not present for accident related coverages. These are potentially serious and would deserve careful attention if non-accident coverages are to be offered.

VI. BIBLIOGRAPHY

This bibliography lists references used in the production of this Report. It is not an exhaustive list of relevant work in the field. References used to produce the cost estimates, presented in Appendix B to this Report, are collected in a separate Bibliography at the end of Appendix B. Other Appendices also list references used at the end of each Appendix.

This Bibliography is divided into six sections, as outlined below. Of course, several entries could be placed into more than one category.

A. Costs of Decommissioning

B. Financing Methods for Decommissioning

C. Probabilities and Outcomes of Accidents

D. Nuclear Insurance Pools

E. General

F. Operating Data

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APPENDIX A:

TAX EFFECTS

I. INTRODUCTION

This Appendix discusses the details of the tax effects upon utilities of making premium payments into a self-insurance pool. Two types of tax effects are examined: (1) tax effects on cash; and (2) tax effects on rates. The first type of tax effect, tax effects on cash, are the tax effects relevant between the time an electric utility begins to incur the new premium expense and the time the utility begins to collect in its base rates for that new expense after a base rate case. By contrast, the second type of tax effect, tax effects on rates, are the tax effects relevant after the utility begins to collect for the new expense in base rates.

This Appendix is organized as follows. Tax effects on cash are discussed in Section II. Section III describes tax effects on rates. The interaction of cash effects and rate effects are discussed in Section IV. Finally, the applicability of marginal (as opposed to average effective) tax rates are discussed in Section V. Brief conclusions are presented in Section VI.

One cautionary point should be made immediately. The incidence of corporate income taxes is a difficult and unsolved problem in economics. Whether a corporate tax is absorbed in whole or in part by stockholders, by consumers, or by management and employees, or by some combination of these groups, is the subject of a substantial amount of discussion, study, and dispute. The discussion contained in this Appendix thus is limited to a description of the tax calculations regulators will put in rate decisions. It should be emphasized that this is not necessarily identical to saying this particular tax or that particular tax saving will be passed on to the customer or not. For example, in a year in which all expenses remained constant except for one tax expense which increased, a regulator might allow a rate increase of exactly the same amount. However, in another year in which all expenses escalated sharply, the same regulator regulating the same utility might employ the same tax calculation in allowing a rate increase, but might also reduce other allowed expenses accordingly to produce an overall rate level deemed acceptable. Thus, true incidence of the tax expenses might be unknown because it would be confounded with other rate level modifications. In other words, the apparent precision of the algebra of tax effects should not disguise the underlying uncertainty of the incidence of corporate taxes.

II. TAX EFFECTS ON CASH

A. Income Taxes

With respect to income taxes, if a payment (P) is deductible for FIT purposes, the effective cost of the payment to the utility is given by:

$$\text{effective cost} = P(1 - x) \tag{A-1}$$

where x is the applicable FIT rate. As the marginal FIT rate is currently 46 percent, this means that the effective cost, tax-effected for FIT purposes only, is given by:

$$\text{effective cost} = P(1 - .46) = .54P \tag{A-2}$$

Now, many states also have state income taxes (or, what is essentially the same thing, state franchise taxes which measure the franchise to be taxed by some income measure). The combined effective cost,where two income taxes are applicable, and where one tax is deductible for the purposes of the other tax (as is the case for FIT and state income tax purposes),is given by:

$$\text{effective cost} = P(1\text{-total effective tax rate})$$

$$= P(1-((\text{FIT rate})+(1-\text{FIT rate})(\text{state rate}))) \tag{A-3}$$

which happens to be algebraically equivalent to:

$$\text{effective cost} = P(1-((\text{state rate})+(1-\text{state rate})(\text{FIT rate}))) \tag{A-4}$$

An example will make this clear. In Massachusetts, the marginal state income tax rate on ordinary corporate income is 6.5%. The overall effective cost of a premium P, tax-effected for both the 46% FIT rate and the 6.5% Massachusetts tax rate is thus:

$$\text{effective cost} = P(1-((.46)+(1-.46)(.065)))$$

$$= P(1-(.46 + .0351))$$

$$= P(1-.4951)$$

$$= .5049$$

$$= P(1-((.065) + (1-.065)(.46)))$$

$$= P(1-(.065 + .4301))$$

$$= P(1-.4951)$$

$$= .5049\ P$$

In general, for two income tax rates, a and b, the total effective cost is given by (assuming one is deductible for the purposes of the other):

$$\text{effective cost} = P(1-((a) + (1-a)(b))) \tag{A-5}$$

$$=P(1-((b) + (1-b)(a))) \tag{A-6}$$

$$=P(1-b-a+ab)$$

B. Premium Taxes

With respect to premium taxes, the tax effect of a premium tax depends upon whether it is paid by the insured or the insurer. To get a payment of P dollars to an insurer where a premium tax of y is paid by the insured, the total payment required is given by:

$$\text{total payment required} = P(1+y) \tag{A-7}$$

By contrast, if the insurer must pay a premium tax of y out of premium taken in, to retain P dollars in the insurer, total payment required is given by:

$$\text{total payment required} = P/(1-y) \tag{A-8}$$

For example, there is a Federal premium tax of 4%. If this tax were paid by the insured, the total payment required would be given by:

$$\text{total payment required} = P(1.04) \tag{A-9}$$

By contrast, if the insurer paid this tax on total premium taken in, to retain P dollars in the insurer, total payment required is given by:

$$\text{total payment required} = P/(1-.04) = P/.96 \tag{A-10}$$

$$= 1.041667\ P$$

C. Federal Income Tax Status of Self-Insurance Pool

It is a straight-forward task to construct an off-shore corporation which would have no FIT liability for underwriting income. NEIL and NML were created as Bermuda corporations in order to (among other things) reduce FIT liability. The key requirement is that the offshore corporation be not deemed to be "doing business" in the United States. 26 U.S.C. §§842, 861(a)(7). The only remaining FIT liability would be the 30% FIT rate which is applicable to income from fixed income securities in the U.S. (i.e., interest and dividends on notes, bills, bonds, and preferred stock, but not on bank deposits). 26 U.S.C. §881. As no FIT liability would apply to premium income in general or to underwriting income, no tax effect need be applied to the pool itself.

Similarly, U.S. shareholders of a "controlled" foreign corporation may be taxed on certain income of such a "controlled" foreign corporation. 26 U.S.C. §§951, 953, 954. However, this type of taxation can be avoided by making sure the pool does not constitute a "controlled" foreign corporation (that is, that no more than 25% of the pool be owned by U.S. citizens whose ownership shares are 10% or more of the pool).

D. Federal and State Premium Taxes

There is a 4% Federal excise tax on insurance premiums paid by domestic insureds to foreign insurers. 26 U.S.C. §§4371. In addition, some states have separate premium taxes on premiums paid by resident insureds to insurers, regardless of the insurer's residence. These are payable by the insured on premium payments, and thus should be tax-effected by equation (A-9), above, rather than by equation (A-10).

E. Deductibility of Premium Payments by Utilities

It also appears relatively easy to structure a self-insurance pool so that premium payments would be deductible for income tax purposes for member utilities as they would be "ordinary and necessary business expenses." 26 U.S.C. §162; Treas. Reg. §1.162-1(a). Case law has developed the principle that the distinction between true insurance premiums (which are deductible) and true self-insurance reserve payments (which are not deductible) hinges on whether or not the risk of loss is transferred to the insurer and distributed by the insurer among other risks. This obviously happens in the case of traditional property/casualty insurance, and obviously does not happen where a party insures itself by making a reserve payment to an internal account. Helvering v. LeGierse, 312 U.S. 531 (1941). It is thus easy to make sure that the pool under discussion actually removes the burden of loss from the insured itself. This would occur under the plan we have in mind, as long as retroactive premiums did not simply flow the loss back to the specific insured suffering the loss. Thus we should tax-effect premium payments as if they were fully deductible for federal and state income tax purposes.

The preceding discussion applies to ordinary premiums and to retroactive premiums. It does not apply to premium reserve payments, which are much closer to capital contributions than they are to premium charges. The tax law on such premium reserve payments is unclear, but it is probably prudent at this time to view premium reserve payments as transfers of capital, and thus as not constituting "ordinary and necessary business expenses," and thus as probably not being deductible.

F. Combined Tax Effects on Cash

In light of the foregoing discussion, we should tax-effect all premium payments (except premium reserve payments) for Federal taxes as follows:

$$\text{effective cost} = P(1-.46)(1.04)$$

$$= .5616\ P$$

This calculation ignores state income and state premium taxes, because these state taxes vary widely from state to state. The general formula below will allow the reader to add in his own state tax effect:

$$\text{effective cost} = P\left[1 - (.46 + (1-.46)(a))\right]\left[1 + .04 + b\right]$$

where a = relevant state income tax rate, if any

b = relevant state premium tax rate, if any

It appears that no tax effects should be applied to reserve payments, as they should be viewed (for tax purposes) as transfers to capital, and thus as not constituting by themselves taxable events.

III. TAX EFFECTS ON RATES

A. Tax Consequences on Rates in General

Rate case calculations generally proceed in two steps. First, a post-tax "revenue deficiency" is calculated by adjusting test year revenues and expenses for known and measurable changes. The difference between the revenues and the expenses (expenses include the appropriate return on capital) is the "revenue deficiency." It is an after-tax revenue requirement. Rate increases, however, are pre-tax; that is, the public pays in rates for both the after-tax expense incurred by the utility and for the tax on the net revenue itself.

For Massachusetts, with a 6.5% state franchise (income) tax on corporate income, the total effective tax rate (TETR) is:

$$\begin{aligned} \text{TETR} &= (1.00 - 0.46)\ (0.065) + (0.46) \\ &= 0.0351 + 0.46 \\ &= 0.4951 \\ &= (1.00 - 0.065)\ (0.46) + (0.065) \\ &= 0.4301 + 0.065 \\ &= 0.4951 \end{aligned}$$

The ratio of revenue needed for taxes on increased revenues to indicated post-tax revenue deficiency is thus 0.980590:

$$= \frac{0.4951}{(1 - 0.4951)} = \frac{0.4951}{0.5049}$$

$$= 0.980590$$

The ratio of total pre-tax revenue needs to indicated post-tax revenue deficiency is thus 1.980590 (= 1.00 + 0.980590):

$$\frac{1}{1 - 0.4951} = \frac{1}{.5049} = 1.980590$$

B. Specific Rate Case Tax Calculations

Examples are provided below on pages 37 and 38 of specific rate case tax calculations. Table A-1 shows how an after-tax revenue deficiency is "grossed up" to obtain a pre-tax revenue deficiency (line 9 on Table A-1). The taxes shown on lines 4 and 5 of Table A-1 are actual taxes paid in the test year, adjusted for known changes; by comparison, the tax calculation involved in "grossing up" the after-tax revenue deficiency to the pre-tax revenue deficiency (i.e., the calculation employed to get from line 8 to line 9 on Table A-1) is a hypothetical tax calculation, which is done at the marginal tax rates.

Table A-2 re-displays the calculations done in Table A-1 as a cost of service exhibit. Note that the income tax amounts (lines 2 and 3 of Table A-2) are labeled "allowances." These allowances include both the actual taxes paid in the test year, adjusted for known changes, and the hypothetical tax paid on the increased revenues to be obtained from the rate increase. In other words:

(line 2, Table A-2) + (line 3, Table A-2)

= (line 4, Table A-1) + (line 5, Table A-1)

+ (line 9, Table A-1) - (line 8, Table A-1)

TABLE A-1: REVENUE DEFICIENCY AND TAX ALLOWANCE CALCULATIONS

(all dollar figures $000)

1.	Total Operating Revenues (excl. fuel)	352,972
2.	Total O&M Expenses (excl. fuel), Including Depreciation and Taxes Other than Income Taxes, Before Income Taxes	241,868
3.	Income Before Taxes	111,104
4.	Less: Massachusetts Franchise Tax	4,060
5.	Less: F.I.T.	28,034
6.	Net Income, After Tax, Before Rate Relief	79,010
7.	Less Return on Rate Base (= 9.68% X 1,031,367)	99,836
8.	Revenue Deficiency After Tax	20,826
9.	Revenue Deficiency Before Tax (20,826 X 1.980590)	41,248

TABLE A-2: COST OF SERVICE CALCULATION

(all dollar figures $000)

1.	Total O&M Expenses (excl. fuel), Including Depreciation and Taxes Other than Income Taxes, Before Income Taxes	241,868
2.	Massachusetts Franchise Tax Allowance	6,741
3.	F.I.T. Allowance	45,775
4.	Return Required on Rate Base (= 9.68% X 1,031,367)	99,836
5.	Total Cost of Service	394,220
6.	Total Operating Revenues (excl. fuel)	352,972
7.	Revenue Deficiency (Before Taxes)	41,248

IV INTERACTION OF CASH EFFECTS OF TAXES WITH RATE EFFECTS OF TAXES

Tax effects on cash and tax effects on rates must be considered separately because of two considerations: first, rate cases are not necessarily decided every year, to coincide exactly with tax returns and tax years; and second, tax results are not necessarily reflected exactly in rates. To demonstrate why these two effects of taxes (cash effects and rate effects) should be considered separately, it is helpful to construct the hypothetical system in which they could be considered together.

In this hypothetical system, the following conditions would have to obtain: (1) the test year for rate case purposes would coincide exactly with the fiscal year for tax purposes for the utility in question; (2) there would be a rate case decided each year, instantaneously, upon the close of the combined test year/fiscal year for tax purposes; and (3) the rate case determination each year would reflect exactly all tax consequences of the test year's results. In this hypothetical system, there would be no lag between cash consequences and rate consequences, and one could consider tax effects on both cash and rates in a single step. Assuming (for simplicity) a .50 marginal F.I.T. rate, and a $1.00 premium expense, the transaction would look like this:

(1) utility X pays $1.00 in premium;
(2) this payment is deductible, so utility X (for cash purposes) pays $0.50 and U.S. Treasury (for cash purposes) pays $0.50 as a tax expenditure;
(3) but, because rate case occurs instantaneously, utility X's operating expenses for rate purposes goes up $1.00, utility X's F.I.T. expense goes down $0.50, and utility X's post-tax revenue deficiency goes up $0.50;
(4) therefore, utility X's pre-tax revenue deficiency goes up $1.00; and
(5) therefore, utility X collects the $1.00 premium charge directly from ratepayers, and pays $0.50 back into the U.S. Treasury, so the net effect is a flow-through to the ratepayer of the $0.50 in F.I.T. expense and of the $0.50 in (tax-effected) premium expense.

Because the real world differs from the hypothetical system described above, however, we should conceptualize the tax effects of these insurance premiums in two stages. In the first stage, after the utility has incurred the expense but before it has begun to collect that expense in new base rates, the cash effects of taxes are relevant; see §II(F) of this Appendix. After the utility has had a base rate case, and after the new base rates are in effect, the rate effects of taxes provide the relevant effect, netted with the cash effects, as discussed in this section. Of course, because the premium charges may vary over time, the exact netting out of the various payments described in step (1)-(5), above, may not occur exactly, but instead may result in a series of leads and lags in the various cash flows.

In conclusion, the deductibility for income tax purposes of insurance premiums is cancelled out after a new rate case by the calculational methodology displayed in Tables A-1 and A-2. Accordingly, only premium tax effects remain. Therefore, the tax effect on rates of a premium P is given by:

$$\text{effective cost} = P\ (1 + .04 + b)$$

where P = premium

b = relevant state premium tax rate, if any, expressed as a decimal

V. THE APPLICABILITY OF MARGINAL TAX RATES

Electric utilites in the U.S. currently are taxed at the following F.I.T. corporate income tax rates, for tax years starting in 1981 or before:

Net Taxable Income Bracket	Tax Rate
$0 - $25,000	17%
$25,000 - $50,000	20%
$50,000 - $75,000	30%
$75,000 - $100,000	40%
above $100,000	46%

See 26 U.S.C. §11(b) (1981).

The Economic Recovery Tax Act of 1981, P.L. 97-34, August 13, 1981, changed some of the infra-marginal bracket rates. The various corporate income tax rates are now as follows:

	Rate for Tax Years Beginning in		
Taxable Income	1981	1982	1983 and later
under $25,000	17%	16%	15%
$25,000 - $50,000	20%	19%	18%
$50,000 - $75,000	30%	30%	30%
$75,000 - $100,000	40%	40%	40%
over $100,000	46%	46%	46%

See §231(a) of the Economic Recovery Tax Act of 1981, amending 26 U.S.C. §11(b). Note that the maginal corporate income tax rate remains at 0.46 under the Economic Recovery Tax Act.

In fact, largely due to various tax deferrals, such as accelerated depreciation for tax purposes (26 U.S.C. §167 (1)) and the investment tax credit (26 U.S.C. §46 (f)), and partly due to the averaging effect of the lower tax brackets, electric utilities do not on average pay 46% of their taxable net income in actual tax liability payments. The industry average effective tax rate is probably currently in the 15% to 20% range. There are some major electric utilities which have paid zero or close to zero F.I.T. in some recent years.

Because of the disparity between the marginal F.I.T. rate and the average effective F.I.T. rate, the question arises as to which rate should be used for tax-effecting premium payments made by owner/operators into a self-insurance pool after the payments are made but before they are collected in base rates. The marginal F.I.T. rate appears to be the relevant marginal rate, for reasons which will be discussed below.

First, the marginal (as opposed to the average effective) tax rate is the relevant tax rate because it is a reasonable assumption that any self-insurance premium paid by an electric utility for decommissioning expense insurance will be a marginal expense for the utility. In other words, each utility has a given set of revenues and expenses, which result in a given set of tax deductions, exemptions, and credits in a certain manner. In order to examine the effects of imposing a new expense on a particular utility, the new expense should be considered to be a marginal expense and all other revenues, expenses, and tax effects of other revenues and expenses should be held constant for the purposes of examining this new expense's tax effect. Assuming that this is a realistic view of the way owner/operators would in fact behave when faced with a new expense of this type and magnitude, then the marginal tax rate is the relevant tax rate. (Note: to the extent that an owner/operator might in fact behave as if this was <u>not</u> a marginal expense, say by accepting this expense and simultaneously reducing some other expense by the identical amount in order to have total expenses match some previously budgeted amount, then this expense is in some sense not a marginal expense, and the marginal tax rate is not necessarily appropriate. However, this scenario seems unrealistic enough to permit its rejection, and to permit the use of the marginal tax rate.)

Second, as few if any electric utilities large enough to be owner/operators of commercial nuclear power plants would have net taxable income below $100,000 per year, it is appropriate to use the highest bracket's marginal tax rate of 46% for the industry as a whole. The possibility that one owner/operator's taxable net income in any one year might be below $100,000 as a result of fortuitous tax effects and adverse revenue and expense experience definitely exists, but it is unlikely enough to demonstrate the reasonableness of using 46% as the industry-wide value for the marginal F.I.T. rate.

VI. CONCLUSION

Because of the differences between various states' tax laws and rate regulatory schemes, and because of the different tax situations of various owner/operators, no definitive single answer can be given to the question of how taxes will affect premium payments. Further, because of the large uncertainty in the underlying premium estimates, the application of apparently precise tax effects can lend a false sense of precision to the final estimates. Despite these problems, the following general tax multipliers should be applied to premiums to obtain a rough idea of effective costs of the various premium payments at the various times.

A. Tax Effects on Cash (applicable after the expense has been incurred, but before it has been collected in base rates):

1. Ordinary Premiums and Retroactive Premiums

$$\text{effective cost} = P\ (1-(.46 + (1 - .46)\ (a)))\ (1 + .04 + b)$$
$$= P\ (1- .46 - a + .46a)\ (1 + .04 + b)$$

where P = premium

a = relevant state income tax rate, if any, expressed as a decimal,

b = relevant state premium tax rate, if any, expressed as a decimal.

See §§II (E) and II (F) of this Appendix, above.

2. Reserve Premiums

$$\text{effective cost} = P\ (1 + .04 + b)$$

where P = premium

b = relevant state premium tax rate, if any, expressed as a decimal

See §§II (E) and II (F) of this Appendix, above.

B. Tax Effects on Rates (applicable after the expense has been collected in base rates)

$$\text{effective cost} = P\ (1 + .04 + b)$$

where P = premium

b = relevant state premium tax rate, if any, expressed as a decimal

See §IV of this Appendix, above.

In summary, for ordinary premiums and for retroactive premiums, before new premium expenses are collected in base rates, the ratepayer pays nothing and the utility and the U.S. and state treasuries roughly split the expense in cash terms. For reserve premiums, in cash terms, the utility pays the premium times a premium tax loader, before the expense is collected in base rates. After the new premium expenses are collected in base rates, the utility passes on the new expenses to the ratepayer, with the relevant premium taxes added as a multiplier just as in the case of the reserve premium before a rate case.

APPENDIX B:
COST ESTIMATION METHODOLOGY AND COST ESTIMATES

I. INTRODUCTION

This appendix presents the methodologies used for estimating insurance premiums for two different types of decommissioning/decontamination insurance, and estimates expected coverage costs. Expected coverage cost is defined as the expected value of losses and expenses; as discussed below, it may differ from the premiums actually charged. This introduction describes the insurance types, and discusses the significance of the coverage cost estimates.

The first type of insurance, discussed in §II below, covers the costs of decontaminating and decommissioning commercial nuclear power reactors which are damaged in an accident and which, as a result of the accident, must be decommissioned. The second type of insurance, discussed in §III below, covers shortfalls in the owner/operator's decommissioning reserve due to decommissionings which occur prematurely due to non-accident causes, due to decommissioning being more expensive than estimates, or both. Non-accident premature decommissioning in this sense may stem from technological or economic obsolescence, from an NRC order protecting public health or worker safety, from mechanical failure, or from any other non-accident related cause. The non-accident premature decommissioning may be sudden, for example, as a result of a change in regulatory standards. Or it may be predicted years in advance, for example, as a result of excessive deterioration rates, of radioactive accumulations, or of escalation in operating costs. This non-accident premature decommissioning event is thus very broadly defined; it may make sense to restrict this definition, possibly by the addition of a financial instability test for the owner/operator as a condition precedent to payment by the pool, as discussed in §III(B) of the text of this Report.

It is important to note that the expected coverage cost estimated in this Appendix will not necessarily be the same as the premium rates actually charged by the pool, nor necessarily the same as the average loss and expense experience (after the fact) of the pool.

The actual premiums charged may differ from the expected coverage cost for several reasons. First, the pool may design and offer coverages different from those contained in this Report. The pool could use different coverage limits, deductibles, co-insurance provisions, insurable event definitions, and so on; all of these could cause substantial changes in the actual premiums charged.

Second, this Report generally assumes that ordinary insurance premiums will be set at or near the expected value of losses plus expenses--referred to herein as expected coverage cost. However, the pool need not charge an ordinary annual premium based upon the expected annual coverage cost of the insurance program. The pool might charge premiums which are higher than the expected coverage costs of the insurance program in the first few years in order to accumulate reserves quickly; conversely, the pool might charge premiums which are lower than the expected costs of the insurance program and rely instead on retroactive premium adjustments to pay losses if experience requires. Hence, the coverage cost estimates presented here may be thought of as estimates of the total expected costs to the pool, rather than as predictions of the pricing behavior of the pool.

A third factor which could cause actual premiums to deviate from the expected coverage cost, and could also cause the expected coverage cost to deviate from actual loss and expense experience, is the considerable uncertainty in the estimates. This uncertainty is present in all cost estimates and probability estimates in this Report, as in other estimates related to commercial nuclear power reactors. To gain some perspective on this problem, it may be useful to note that:

1. Actual power reactor construction costs have often been twice as large as the original cost estimates, even in real (inflation-corrected) terms. The data collected by Golay (1980) on twenty-two plants, including at least 30 individual reactors, docketed by the NRC from 1967 to 1970 indicates that none were completed for less than 150% of their expected cost (in current dollars) and that some cost four times as much as expected.*

2. Reactor construction costs have varied widely. Golay's (1980) extreme ratios of actual to expected costs (1.5 and 4.0) both occurred in the 1968 docket. In 1977, the Crystal River reactor was completed for $457 per kilowatt, and the slightly larger Farley 1 was completed for $819 per kilowatt or 80% more. The 1967/68 reactor cohort discussed in §III (C) below, showed variations in normalized real cost from as little as $160 per kilowatt, to as much as $371 per kilowatt.

3. Power reactors have often required one and a half times the length of construction originally expected. In some cases, the actual time to completion has been two or three times as long as projected.**

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*It is also significant that some reactors docketed as early as 1967 have not yet reached commercial operation; these stragglers may be even more expensive, and show larger cost overruns, than the units reported by Golay.

**The "World List of Nuclear Power Plants," published periodically in Nuclear News, shows the actual or expected commercial operation date to be later than the originally scheduled in-service date for every unit in the United States for which both dates are provided, except for Big Rock Point.

4. Construction periods are also highly variable, even for units of the same vintage. Maine Yankee received a construction permit in 1968 and was in commercial operation in 50 months; the corresponding interval for Diablo Canyon 1 (which received a permit in 1968, several months before Maine Yankee's) will be at least 170 months.

5. Operation and maintenance (O&M) expense for nuclear power plants has proven to be very hard to predict. O&M expenses have increased at about 10% annually in real terms since 1970; these increases appear to have been completely unanticipated.

6. The capacity factors for large nuclear power reactors have been much lower than expected. Mature reactors were at one time expected to lose only about 20% of their potential output due to outages and deratings; it is now generally acknowledged that these losses will be closer to 40% (Easterling, 1979; Perl, 1978).

7. The Reactor Safety Study acknowledges a great deal of variability in its best estimates.* Typically, these "approximate uncertainties" are represented by factors of 5 above and below median probability estimates, and factors of 3 or 4 and occasionally as much as 6 above and below median consequence estimates for various environmental effects. For individual release categories, the 90% confidence intervals on event probability presented in the RSS vary in width from a factor of 20 to a factor of 100.

8. Estimates of decommissioning costs vary widely. For PWRs, the estimates range from \$31 million to \$88 million, all in 1978 dollars (Smith, et al., 1978). For BWRs the range is from \$31 million to \$100 million (Oak, et al., 1980).

Thus, it is unrealistic to suppose that this Report could identify the coverage cost of the proposed insurance programs with very great accuracy. If 90% confidence intervals could be achieved which were as narrow as an order of magnitude overall, it would seem to satisfy the basic requirements of this problem. The uncertainty in the coverage cost estimates will be discussed at the conclusion of the section discussing the derivation of the estimate for each coverage.

The coverage cost estimates described below could differ from the actual costs of coverage or after-the-fact long-term loss and expense experience for two reasons. First, as noted above, there is considerable uncertainty in the parameters used in this work, and the true (unknown) probabilities

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*The RSS has been criticized for overstating the accuracy of its estimates. See NRC, 1978. Accordingly, the RSS confidence intervals may not be wide enough, and conclusions based upon them should be used only with great caution.

and average costs may be different from those used below. Second, even if the inputs used are the correct values, the actual *post hoc* outcomes may differ from the predictions, especially in the short term. In practice, these two effects are difficult to separate, especially for rare events in continually changing circumstances.

II. ESTIMATION OF EXPECTED COVERAGE COST FOR ACCIDENT-INITIATED DECOMMISSIONING EVENTS

The goal of this section is to estimate the expected cost of providing insurance for accident-initiated decommissioning events (AIDEs). This section begins by defining accident-initiated events, sometimes called accident events. Descriptions of accident events are drawn from several sources. Two of these sources, the policies of existing nuclear insurance plans and the Reactor Safety Study (RSS), are among those later discussed in estimation of the insurance premiums. The purpose of each program or report, and the concept of accident event employed for each, are discussed. A definition of the class of events that is assumed to be covered under the decommissioning insurance is derived from this discussion.

The next section deals with estimating the probability of occurrence for accident events. Estimates are drawn from three sources: historical experience, premiums from the existing nuclear insurance coverage, and the RSS Study. Deriving an estimate from historical experience requires defining a universe--in this case, a set of nuclear reactors relevant to the analysis--from which it is possible to estimate the probability of an AIDE occurring. The second method of estimation establishes a mathematical model of the insurance premiums for existing insurance programs. The probabilities of occurrence for the various sets of insured accident events are then inferred from the model using assumed or estimated values of the other parameters. The probability of an AIDE is then estimated from the probabilities of these similar insured accident events. The third set of probabilities is obtained directly from the results of the RSS.

The several probability estimates are then summarized and contrasted. Finally, the expected coverage costs for accident-initiated events are estimated using the best available probability estimates, and the accuracy of these estimates is discussed.

A. Definition of Accident Events

1. Accident Events Covered by Existing Insurance Programs

Four nuclear insurance programs currently exist; they are:

a. American Nuclear Insurers'* liability insurance (ANI/L), a pool of commercial insurers which provides third-party liability coverage required by the Price-Anderson Act;

b. ANI property insurance (ANI/P), a related commercial pool which provides first-party property coverage to the reactors themselves;

c. Nuclear Mutual Limited (NML), a utility self-insurance pool, which provides first-party property coverage in parallel to ANI/P, for about 40 percent of the operating reactors; and

d. Nuclear Electric Insurance Limited (NEIL), a utility self-insurance pool covering replacement power costs on an indemnity basis for accident-initiated events of over six months' duration.

Although these programs differ in many respects, a common thread among them is that they all insure some set of accident-initiated nuclear incidents. From the policies of ANI/P and NEIL,** the set of events which would be covered under each plan was determined. Table B-1 describes and compares the ANI/P and NEIL policies with regard to the definition of an insured accident event.

Each policy provides a basic definition of an insured accident event, accompanied by a list of clauses and exclusions to the basic definition. Overall, the policies are very similar. The basic definitions of an insured accident event are the same; differences reflect the type of coverage.

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*As used here, ANI includes the corresponding associations of mutual insurance companies; therefore, "ANI/L" is meant to include Mutual Atomic Energy Liability Underwriters (MAELU), and "ANI/P" is meant to include Mutual Atomic Energy Reinsurance Pool (MAERP). ANI is also used to include all reinsurers. All references to premiums and coverages are to the premiums charged and the coverages extended by the pools to the utilities.

**The policy for NML was not available; the policy for ANI/L was available, but ANI/L coverage did not seem as relevant to the AIDE coverage under discussion as did NEIL and ANI/P.

TABLE B-1
(Page 1 of 6)

DEFINITION OF INSURED EVENT UNDER NEIL AND ANI/P POLICIES

DEFINITION OF INSURED EVENT	NEIL*	ANI/P**
NEIL:		
"...damage to or destruction of real or personal property at a Nuclear Power Generating Unit specified in the Declarations ("Unit"), caused by RADIOACTIVE CONTAMINATION AND ALL OTHER RISKS OF DIRECT PHYSICAL LOSS, EXCEPT AS HEREINAFTER PROVIDED, resulting in the Unit in question ceasing to generate electric power."		
ANI/P:		
"...RADIOACTIVE CONTAMINATION AND ALL OTHER RISKS OF DIRECT PHYSICAL LOSS, EXCEPT AS HEREINAFTER PROVIDED, to the property described in the Declarations and situated at the location(s) specified therein."		
CLAUSES		
a. The Insurers..."AGREE to indemnify the Insured and legal representatives..., without allowance for any increased cost of repair or reconstruction by reason of any ordinance or law regulating construction or repair, and without compensation for loss resulting from interruption of business or manufacture..."		X***
Debris Removal and Decontamination Clause		
b. "Subject to all of its other provisions and stipulations, this policy		X

	NEIL*	ANI/P**
b. (Cont'd)		
covers expenses necessarily incurred by the Insured in removing debris of and in decontaminating the property covered by this policy following direct physical damage to such property caused by any peril not excluded hereunder. In no event shall this policy insure against loss occasioned by enforcement of any law, ordinance, or order of any state, municipality or other governmental authority which necessitates the demolition of any portion of the property covered hereunder which remains undamaged."		
Property of Others		
c. "Subject to all its other provisions and stipulations, this policy, without increase in the amount(s) thereof, also covers property of officers and employees of the Insured, and such loss to property of others against which the Insured, prior to loss, has agreed to provide insurance, or for which the Insured is liable, all while such property is situated at a location specified herein...;"		X
Removal from Premises		
d. "If property covered hereunder is necessarily removed from a specified location for preservation from imminent physical damage, this policy also covers, for a period of ten days, during removal and at any place to which such property has been removed."		X

TABLE B-1
(Page 3 of 6)

	NEIL*	ANI/P**
PREFACE TO EXCLUSIONS 1-15		
NEIL:		
"This policy does not cover any outage or delay in start-up resulting from:"		
ANI/P:		
"This policy does not insure against loss by:"		
EXCLUSIONS****		
1. Gradual accumulation of radioactive contamination	X	X
2. Radioactive contamination at site, resulting from matter released from source outside site, unless matter is released while such source is in transit from site	X	X
3. Neglect of the Insured to use all reasonable means to save and preserve property at and after a loss		X
4. Unexplained or mysterious disappearance of property, or shortage disclosed upon taking inventory	N.A.	X
5. Any fraudulent, dishonest or criminal act done by or at instigation of any insured, partner or joint adventure in or of any insured, officer, director or trustee of any insured	X	X
6. Order of civil authority except acts of destruction at the time of and for the purpose of preventing the spread of fire, provided such fire did not originate from "war risk" as herein excluded	X	X

TABLE B-1
(Page 4 of 6)

	NEIL*	ANI/P**
7. Any governmental act, decree, order, regulation, statute or law prohibiting or preventing, directly or indirectly, the commencement, recommencement or continuation of operations at site	X	N.A.
8. Any local, state or federal ordinance or law regulating construction or repair of buildings or structures, or suspensions, lapse or cancellation of lease or license, contract or order, or interference at site by strikers or other persons with rebuilding, repairing or replacing the property or with resumption or continuation of business	X	
ANI/P: This exclusion from NEIL is similar to Clause a from ANI/P, above		
9. Theft, pilferage, burglary, larceny; appropriation or concealment of any property by any person to whom property is entrusted	N.A.	X
10. Depletion, depreciation, wear and tear; or deterioration, including that of fuel element cladding	X	X
11. Or attributable to manufacturing or processing operations which result in damage to stock or materials while they are being worked upon		X
12. Dampness, dryness or extremes or changes of temperature of atmosphere; rust, corrosion, or erosion (ANI/P: "...unless caused by peril not otherwise excluded.")	X	X
13. Water damage		
-Flood, surface water, waves, tidal water, tidal wave, overflow of bodies of water or spray from any of foregoing, wind-driven or not -Water which backs up sewers, drains -Below-surface water, including that which exerts pressure on or flows, seeps, or leaks through sidewalks, walls, doors, etc. -Release of water impounded by a dam (ANI/P: unless provided by endorsement)	X	X

TABLE B-1
(Page 5 of 6)

	NEIL*	ANI/P**
14. Earthquake, volcanic eruption, landslide, subsidence or sinking of land or other movement of foundation	X	X
15. Windstorm, tornado or hurricane	X	
PREFACE TO EXCLUSIONS 16-20		
ANI/P: "This policy does not cover:"		
EXCLUSIONS		
16. accounts, bills, currency, deeds, evidences of debt, money or securities	N.A.	X
17. records, manuscripts, drawings, media, data storage devices, etc., for loss in excess of cost of reproducing them from copies (no liability assumed for gathering data)	N.A.	X
18. land	N.A.	X
19. animals, lawns, plants, shrubs, or trees	N.A.	X
20. vehicles licensed for highway use, aircraft or watercraft, except when used in connection with operation of the property	N.A.	X
21. War Risk Exclusion Insurers shall not be liable for loss caused directly or indirectly by: -hostile or warlike action in time of peace or war by: a) government, sovereign power, or other authority b) military, naval or air forces c) agency of such government, power, authority or forces -any weapon of war employing nuclear fission or fusion whether in time of peace or war -insurrection, rebellion . . . or action taken by governmental authority in defense against such	X	X

	NEIL*	ANI/P**

ENSUING LOSS CLAUSE

NEIL:

With respect to Exclusions 10, 12-15 inclusive, the Insurer shall be liable for any Outage or delay in start-up resulting from an ensuing peril not otherwise excluded, but then only for the loss caused by the ensuing peril.

ANI/P:

With respect to Exclusions 9-14 inclusive, the Insurers shall be liable for ensuing loss by fire, explosion, radioactive contamination or any other peril not otherwise excluded.

* Policy from Nuclear Electric Insurance Limited (NEIL), 1979, is source of all references to NEIL.

** Policy from Nuclear Energy Liability - Property Insurance Division (NEL-PIA), Property Division, 8/1/77, is source of all references to ANI/P. This policy originally was used for the Property Division of NEL-PIA. When NEL-PIA changed its name to ANI in 1978, the policy was used for ANI/P, the property division of ANI.

*** Definitions of symbols: 'X' indicates that the item, or paraphrased version, appears in policy corresponding to the column; 'N.A.' indicates that the item appears to be non-applicable to the policy.

**** In general, exclusions in the Table are paraphrased from items in text of the policies. Effort has been taken to insure that the original meaning is unchanged.

As can be seen in Table B-1, the basic definitions of the insured event are very broad and vague. For ANI/P, the definition is clarified somewhat by various clauses of the policy. However, for both policies, the nature of coverage is really determined by the exclusions.

The twenty-one exclusions fall into three categories: items excluded by both NEIL and ANI/P; items excluded by ANI/P but not by NEIL; and items excluded by NEIL but not ANI/P. Nine items are excluded by both ANI/P and NEIL:

- Conditions which inevitably occur over time: gradual accumulation of radioactive contamination (1)*; depletion, depreciation, etc. (10)

- Radioactive contamination stemming from outside the insured site (2)

- Criminal acts by the insured (5)

- Civil authority or government: orders of civil authority, except in case of fire (6); hostile or warlike action by government or military, weapon of war, rebellion or government defense against rebellion (21)

- Natural occurrences or disasters: dampness, dryness, temperature changes, rust, corrosion, erosion (12); water damage (13); earthquake, volcanic eruption, etc. (14).

The second category is all events excluded by ANI/P and not by NEIL; 9 of the 21 items fall into this grouping. ANI/P excludes losses due to:

- Failure to use reasonable means to preserve property at or after loss ("contributory negligence") (3)

- Losses attributable to manufacturing or processing operations resulting in damage to stock or materials (11) (possibly non-applicable to NEIL)

- Property loss, due to damage: Accounts, bills, money, etc. (16); records, manuscripts, data storage devices, etc. in excess of reproduction costs (17); land (18); animals, lawns, etc. (19); vehicles not licensed for property operation (20) (apparently non-applicable to NEIL)

- Property loss, not due to damage: unexplained or mysterious disappearance (4); theft, burglary, etc. (9) (apparently non-applicable to NEIL).

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*Figures in parentheses refer to the list of exclusions in Table B-1.

The third and final category is all events excluded by NEIL, but not by ANI/P; the remaining three exclusions fall here. NEIL excludes outages resulting from:

- Governmental act, decree...law prohibiting or preventing commencement or continuation of operations (7)
- Local, state, federal ordinance or law regulating construction or repair of buildings, cancellation of lease, license or contract, interference by strikers with building or continuation of business (8)*
- Natural disasters: windstorms, tornados, hurricanes (15).

The last item in Table B-1 is an "ensuing loss" clause for each policy. This clause is quite important in that it extends the breadth of coverage, in some cases, to "intervening events," or events occurring after the initial accident event. Table B-2 describes the effect of the ensuing loss clause, in terms of the excluded events, for each policy.

2. Accident Events Investigated in the Reactor Safety Study

The Reactor Safety Study (RSS) was originally sponsored by the U.S. Atomic Energy Commission (AEC), and later completed under the U.S. Nuclear Regulatory Commission (NRC). According to the Executive Summary, published in 1975, the RSS was designed to ". . . estimate the public risks that could be involved in potential accidents in commercial nuclear power plants of the type now in use." The study concluded, in part, that "the only way that potentially large amounts of radioactivity could be released is by melting the fuel in the reactor core." Therefore, the accident event mainly of interest to those conducting the RSS study was one which involved the release of radioactivity from the core, and in particular, those which involved core melting to some degree. The RSS defined two sets of categories of accident events: a nine-category scale for PWR-type reactors; and a five-category scale for BWR-type reactors. These categories measure the degree of radioactive release. The low end of the scales corresponds to high levels of radioactive release, and the upper ends indicate low levels of radioactive release. The RSS categories will be discussed in more detail, in §II (C) below.

3. Other Sources for Definition of Accident Events

The U.S. Nuclear Regulatory Commission uses another categorization scheme for nuclear accidents, which is employed in safety evaluations and emergency planning. This categorization scheme first appeared in a Proposed

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*Exclusion 8, which appears in NEIL's policy, is very similar to the clause a in Table B-1, found in ANI/P's policy.

TABLE B-2

DESCRIPTION OF EFFECT OF ENSUING LOSS CLAUSE
UNDER NEIL AND ANI/P

NEIL

Initial Event*	Intervening Event	Outcome
Excluded events 1, 2, 5-8	Anything	No coverage
Excluded events 10, 12-15	Anything but excluded events 1, 2, 5-8, 10, 12-15	Intervening event only covered
Anything but excluded events 1, 2, 5-8, 10, 12-15	Anything	Initial event covered. Intervening event(s) also covered, if not otherwise excluded

ANI/P

Initial Event	Intervening Event	Outcome
Excluded events 1-6, 8	Anything	No coverage
Excluded events 9-14	Anything but excluded events 1-6, 8-14, and events in clauses a-d	Intervening event only covered
Anything but excluded events 1-6, 8-14 and events in clauses a-d	Anything	Initial event covered. Intervening event(s) also covered, if not otherwise excluded

*All event numbers in Table B-2 refer to exclusion numbers in Table B-1.

Annex to Appendix D of 10 Code of Federal Regulations Part 50. This categorization scheme ranges from class 1 accidents (too minor to require advance planning) to class 9 accidents (beyond the design basis of the plant to withstand), and does not vary between PWRs and BWRs. This categorization scheme has never been adopted formally as a regulation by the N.R.C., but is viewed as an "interim" statement of N.R.C. policy. See Offshore Power Systems (Floating Nuclear Power Plants) Docket No. STN 50-347, Slip Opinion at 1-2 (September 14, 1979).

This categorization scheme is not useful for our present purpose in defining accident events. First, the categories do not match well with the set of accident events requiring decommissioning insurance, which is the subset of accident events of interest to our analysis. More importantly, the eventual goal is to produce probability estimates for this subset of accident events, and no satisfactory probability estimates are known to have been produced for these categories. Therefore, this categorization scheme was not employed in our analysis.

4. Accident-Initiated Decommissioning Events

An accident-initiated decommissioning event, or AIDE, is an accident at a reactor which results in permanently shutting that reactor down and discontinuing electricity generation, and which also causes additional radioactive contamination* so that the scope of decontamination effort required for decommissioning exceeds that required by a normal decommissioning. The AIDE insurance is being designed to cover decommissioning costs resulting from an AIDE. The set of AIDEs has some events in common with each set of events discussed in this section. For example, those events investigated in the RSS which involve core melting of sufficient severity to warrant decommissioning the plant would be considered AIDEs.

The nuclear insurance policies define insured events using a basic definition, a series of exclusions to that definition, and numerous clauses as shown in Table B-1. The NEIL definition of an insured event, with several changes, would provide a suitable definition of an AIDE. First, NEIL's condition that the event result in power outages of at least six months' duration would be replaced by the condition that the event result in decommissioning the plant. Second, a condition requiring that the scope of the decontamination effort for an insured event be greater than that required for ordinary decommissioning would be included. The NEIL definition, with these changes and any logical modifications resulting from these changes, would provide a suitable description of an AIDE for use in an insurance policy statement.

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*That is, additional contamination above the expected contamination at decommissioning at the end of normal service life.

B. A Model for Insurance Premiums

In this section, a model is defined which describes the components of insurance premiums charged either by an industry self-insurance pool or by commercial insurers. One component of premiums is expected losses, or the losses which an insurance program would expect to incur in a reactor-year due to insured accident events. Estimation of expected losses involves estimation of the occurrence probability for these accident events. Probability estimation for the sets of events covered by the existing insurance programs will be derived in §II (C), below. This section shows how the probability estimates and other factors can be employed to describe an insurance premium.

An insurance premium per reactor-year of coverage for the decommissioning coverage can be modeled as follows:

$$R = E\,[L] \cdot A \,/\, (1\text{-}N) \tag{B-1}$$

where

R = premium

$E\,[\cdot]$ = expectation operator,

L = losses in reactor-year,

A = the product of all factors which affect the level of the premium, other than expected losses and expenses, and

N = insurance program expenses, expressed as a fraction of program's premium

The A factor includes those elements of traditional profit considerations such as investment income and compensation for assuming risks, as well as the effects of provisions for refunds, retroactive premiums, reserve premiums, and any other features of the policy which cause the effective value of the premium, expected losses, or expenses to deviate from their apparent values. If there are no such features, then A equals unity. It seems reasonable to assume that A, like N, is constant between reactors in any year for a particular program, but may vary among programs and years.

To estimate the expected value of losses, E[L], from existing data, losses from events of interest can be separated into two categories: losses due to maximum events and all other losses. A maximum event is defined as an event which results in a payout by the insurer of the maximum coverage limit under the insurance plan. If such a limit exists, then the maximum payout is known with certainty. The expected losses can then be described by the following identity:

$$E[L] = E[L_m]\,/F_m \tag{B-2}$$

where

$E [L_m]$ = expected losses associated with maximum events in a reactor year,

and $F_m = \frac{E [L_m]}{E [L]}$ = ratio of the expected value of the losses from maximum events to the expected value of total losses.

F_m can be estimated from the historical ratio of losses resulting from maximum events to the total losses.

The expected losses associated with maximum events, $E [L_m]$, can be modeled as:

$$E [L_m] = S_m \cdot P_m \tag{B-3}$$

where

S_m = cost of a maximum event to the insurer; by definition, this is the maximum coverage limit under the policy, if such a limit exists,

and P_m = probability of a maximum event occurring during a reactor-year.

Here, S_m is obtainable from the insurance policy itself,* and P_m is an unknown but fixed term. Substituting (B-2) and (B-3) into (B-1) yields

$$R = (S_m \cdot P_m/F_m) \cdot A / (1-N)$$

which can be rearranged to obtain

$$R = S_m \cdot P_m \cdot A / F_m (1-N) \tag{B-4}$$

Estimates for factors in the right-hand side of equation (B-4) will be discussed in succeeding sections.

Concentrating on losses due to maximum events is a reasonable approach in estimating the insurance premiums for the sizes of ceilings on coverages that have existed to date.

In nuclear accident experience to date and under existing kinds of ceilings, the fraction of total losses for both property and liability coverage which is due to maximum events is quite large,** as will be shown. If F_m is very

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*This is one advantage to deriving premiums using this model: the cost of a maximum event to the insurer is almost always defined, and need not be estimated.

**The same would have been true for NEIL, had it been in operation.

large, say, .99, R is not sensitive to large (even order of magnitude) changes in the number and cost of small insured events. If F_m is small then this approach should be replaced by direct estimation of E [L] .

Where the maximum event is undefined (that is, no coverage limit exists) or where large-but-not-maximum payouts are expected to occur with a high probability, good judgmental estimates of probabilities and costs over a wide range of costs must be substituted,and past experience is a little less helpful. Nevertheless, it will be convenient to follow even in this case the paradigm established by equation (B-4) for the maximum event case by defining a "major event" as an event of some specified minimum size, estimating the frequency, P_j, with which such an event would occur in a year, and specifying by S_j the expected cost of such a major event. Then, where F_j is the fraction of losses resulting from major events, we can estimate E [L] as $S_j \cdot P_j/F_j$ and write an equation analogous to (B-4) as:

$$R = S_j \cdot P_j \cdot A/F_j \ (1-N) \qquad \text{(B-4a)}$$

This approach to estimating E [L] is useful below for representing the premium charged by ANI/L. It really represents nothing more than an analytical device for helping to determine E [L] judgmentally. Where total losses are heavily affected by many small losses another approach to representing premiums would be more helpful.

C. Estimation of Probability

As defined earlier, P_m is the probability of a maximum event occurring during a reactor-year, where a maximum event is one which results in payout by the insurer of the maximum coverage limit under the particular policy in question. This section will estimate the probability of an AIDE (P) from historic experience; estimate the probabilities of maximum events (P_m) or of major events (P_j) for the set of events currently covered by an insurance pool, based on the pool's rates*; and compare the event probabilities of the RSS with those obtained from the former approaches.

It is important to recognize that the probabilities being estimated almost certainly vary between units, due to size, vintage, manufacturer, technology, and plant-specific factors, and across time as reactors age. Thus, point estimates of accident probability obtained from historical experience will partially depend on the distribution of these factors among reactors considered in the estimation. The range of values derived from existing insurance premiums should reflect this distribution in the set of insured reactors. Where possible, the effect of plant-specific factors on the estimates derived will be discussed.

1. Estimating Probability from Historical Experience

One estimate of the probability, P, of an accident-initiated decommissioning event occurring in a reactor-year is the historical ratio of actual AIDEs to reactor-years of exposure. Such a probability estimate can be derived from a data set considered relevant to the AIDE insurance. Specifically, the numerator of the ratio estimate is the number of events considered to be AIDEs which occurred to reactors in the data set, and the denominator is the total number of years during which reactors in the data set engaged in commercial operation. A relevant data set can be very specifically limited, as by in-service date, geographic region, unit size in MW, or manufacturer of the nuclear steam supply system (NSSS). At the other extreme, a relevant data set can be very broadly defined, to include research reactors, naval propulsion reactors, or even foreign reactors.

In order to be useful in assessing accident probabilities for U.S. commercial reactors, the data set should reflect technologies, regulatory schemes, and operating modes comparable to those of the reactors of interest. It is also essential that information on reactor operation and accidents be available. These considerations eliminated all foreign units, non-power reactors, and non-commercial reactors from the data set. An extensive engineering and regulatory analysis would be required to determine whether

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*The probabilities most relevant to estimating AIDE coverage costs will also be identified.

any foreign LWRs could be included in the data set; such an analysis was beyond the bounds of the present study.*

Two data sets were felt to be large enough to not provide extremely unstable estimates while still being small enough to exclude clearly irrelevant comparisons.

(a) All U.S. Commercial Light Water Reactors (LWRs)

The first population of reactors consists of all 73 light water reactors (LWRs) in the U.S. that produced commercial quantities of electric power. These consist of the 79 reactors listed in NRC (1981b) as "operating" or "permanently or indefinitely shut down" except six reactors which are not LWRs: (i) Ft. St. Vrain (high-temperature, gas cooled); (ii) Peach Bottom 1 (high-temperature, gas cooled); (iii) Fermi 1 (sodium cooled); (iv) Carolinas-Virginia Tube Reactor (heavy water); (v) Piqua (organically cooled and moderated), and (vi) Hallam (sodium graphite). Of these six excepted, only Ft. St. Vrain is still operating. One AIDE, the accident at Three Mile Island Unit 2 (TMI 2), occurred at reactors in this data set, which contains 517 reactor-years.**

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*For example, it would be necessary to determine that an accident which would lead to the decommissioning of a U.S. LWR would also cause the decommissioning of a foreign LWR, that differences in regulatory standards do not cause accident probabilities to diverge substantially, and that any decommissioning accidents which occurred would be reported publicly.

**Reactor-years for all three data sets were measured from commercial operation date (COD) to 2/1/81, or the date of last operation, if that was earlier. The commercial operation date was not readily available for BONUS, Elk River and Pathfinder; the slightly earlier first electricity generation date was used to approximate the COD for these three reactors. Every month of experience since 2/1/81 adds about six reactor-years of experience to the data set. Reactor-years as calculated above generally include temporary outages. Such outages were prevalent after the accident at TMI 2 in March, 1979; the number of reactors actually in operation dropped considerably for a period of time. Although the above calculation of reactor-years includes this post-TMI period, it is somewhat questionable that this period is typical of other nuclear experience to date.

(b) All U.S. Commercial LWRs Greater than 300 MW Capacity

The second population of reactors contains 64 reactors, and includes most present-day commercial power reactors. It excludes the non-LWR units excluded in (a), and also nine small, early LWRs: (i) BONUS (16.5MW); (ii) Elk River (22MW); (iii) Pathfinder (66MW); (iv) Indian Point 1 (265MW); (v) Humboldt Bay (63MW); (vi) Dresden 1 (200MW); (vii) Yankee Rowe (175MW); (viii) Big Rock Point (72MW), and (ix) La Crosse (50MW).

Only the last three of these nine units are still engaged in power production. All nine units entered commercial operation before 1970; except for two larger reactors* which entered service twenty months before La Crosse,** all the 64 larger reactors were built later than the nine small reactors. No more such small reactors are under construction or planned for U.S. operation; the next smallest U.S. LWR is San Onofre 1 at 450MW, or 70% greater capacity than Indian Point 1, the largest reactor among the nine excluded. Thus, in terms of both vintage and size, these small reactors are distinctly different from the remaining units. The 300MW cutoff is standard in statistical analysis of nuclear power plant capacity factors (Komanoff, 1978; Easterling, 1979; Koppe and Olson, 1979; Joskow and Rozanski, 1979). Again, TMI 2 is the only AIDE in the large LWR category, which includes a total of 416 reactor-years.

Depending on one's assessment of the relevance of the experience with the small demonstration reactors to predicting accident rates for large reactors, either of the above populations is useful. For comparison, an additional population of reactors can be defined.

(c) All U.S. Commercial Power Reactors

This population includes 79 reactors: the six non-LWR power reactors excluded from category (a), above, as well as the other reactors in category (a). The accident at Fermi 1 constitutes a second AIDE within this data set, which contains 539 reactor-years. Thus, an estimate of P based on this data set would be 2/539 = 1/270 reactor-years. The applicability of this figure to the existing and planned set of commercial power reactors is highly questionable, however, and it is not utilized in this Report.

Probability estimates obtained in this manner can be thought of as "average" probabilities across all reactors in the population. These estimates will depend on the distribution of reactor-types in the population. For instance,

*Connecticut Yankee and San Onofre 1.

**But after the other eight small reactors.

much of the data was accumulated from smaller reactors; the larger power reactors, those over 1000MW, comprise only about fifty of the reactor-years. If one probability were assumed to exist for all reactors being investigated, then the occurrence of accidents could be assumed to follow a Poisson process. More realistically, however, mixture models can be used to allow for differences in accident probabilities among reactors. These models posit a distribution of underlying AIDE probabilities rather than a single probability for all reactors.

Vintage of the reactors under investigation will also affect the estimates. The average age of reactors in the populations defined is six to seven years, which is a relatively short length of experience. In data set (b), 21 of the 64 reactors contributed 5 years or less to the reactor-year pool, and 58 reactors contributed 10 years or less. Therefore, many of the reactor-years which have occurred are accumulated from early operating years of the reactors. Data from these years will provide good future estimates only if reactor experience in future years is similar to experience to date.*

In light of these considerations, the probability estimates derived in this section should be regarded as average probabilities across all reactors in the population, at their present ages. These probabilities may change across time for any reactor, and overall as the "fleet" of in-service reactors changes in composition. When more data becomes available, mixture models and other techniques may be useful in modeling these non-constant probabilities.

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*Further discussion of problems encountered in developing historical estimates can be found in Fairley (1981).

2. Estimating Probabilities from Existing Insurance Programs

Four nuclear accident liability programs exist, as described earlier; they are:

a. American Nuclear Insurers' liability insurance (ANI/L);

b. ANI property insurance (ANI/P);

c. Nuclear Mutual Limited (NML), and

d. Nuclear Electric Insurance Limited (NEIL).

It seems reasonable to assume that the probabilities for the relevant events used in designing the premiums for the corresponding insurance programs will differ substantially from one another, and perhaps from the probability to be used for AIDE insurance as well. Specifically, large NEIL events might well cause little or no property damage, and thus might be small ANI/P or NML events. Similarly, large property insurance (ANI/P or NML) events like TMI 2 may be less than maximum liability (ANI/L) events. The following ranking of probabilities for maximum events thus seems likely on an a priori basis, listed in order from highest to lowest expected probability of occurrences:

a. NEIL

b. ANI/P, NML

c. ANI/L

However, it is possible for large ANI/L events to occur without significant property damage, so the order of items (b) and (c) is somewhat speculative.

The probability of an AIDE would presumably be somewhat lower than that of a maximum event for the property insurance programs, everything else (such as distribution of reactor types) being equal. This is the case because not all large property loss-causing events would require decommissioning, while all decommissioning-causing accident events would cause property damage. On the other hand, no clear relationship would seem to exist between the probabilities of maximum events for ANI/L and for AIDE insurance on an a priori basis.

If equation (B-4) is a reasonable representation of the components of premiums for an existing insurance program, the probability estimates underlying the premiums for that program can be derived by rearranging the terms of equation (B-4) to obtain:

$$P_m = R \cdot F_m \cdot (1-N) \;/\; (S_m \cdot A) \tag{B-5}$$

Similarly, if equation (B-4a) applies to a particular program, then

$$P_j = R \cdot F_j \; (1-N) \;/\; (S_j \cdot A) \tag{B-5a}$$

The actual values (or reasonable estimates thereof) for R, F_m, N, and S_m in equation (B-5), or for R, F_j, N, and S_j in equation (B-5a), are obtained relatively easily for each of the four existing nuclear insurance programs. However, the value of A for each coverage is somewhat more complex to estimate, due to the numerous factors which comprise A and to the interdependence between some of those factors and P_j or P_m. For example, premiums for both ANI coverages may reflect investment and risk loaders; ANI/L also has a refund program. Premiums for both existing self-insurance pools may reflect the provisions for retroactive premiums; NML also has an automatic refund program, while NEIL has the option of providing refunds, and may also anticipate investment income. The value of investment income, of retroactive premiums, and of refunds, depends in part on the frequency of large losses. Thus, it is convenient to estimate a "revenue accumulation rate," equal to $P_j \cdot A$ or $P_m \cdot A$, as a preliminary step in deriving probability estimates. The revenue accumulation rate can be interpreted roughly as the fraction of a total dollar liability to which the pool is exposed $(S_m / ((1-N) \cdot F_m))$ that is collected as premiums (revenue) each year. Revenue accumulation rates are derived by substituting in equations (B-5) or (B-5a) estimated values of S_m or S_j, F_m or F_j, R and N.

In estimating "revenue accumulation rates," values for substitution into equations (B-5) and (B-5a) were derived from the experience of each insurance pool. Table B-3 summarizes the parameter values discussed below.

a. ANI/L: Premium ranges and averages are given in ANI (1981a, p. 7). The \$160 million maximum coverage is required for all reactors by the Price-Anderson Act (see 42 U.S.C.A. §2210). A breakdown of historical payouts by event is available (ANI, 1981b) but without sufficient detail to allow restatement in constant dollars. In any case, the TMI accident, with about \$28 million in payments and settlements and \$50 million in reserves (Kibbee, 1981), totally dominates the reactor-related liability payments to date. Other reactor-related liability incidents to date have cost ANI a total of less than \$350,000. This result suggests that the losses for ANI/L may be assumed to be dominated by relatively infrequent large losses, but not necessarily maximum events. Thus, the major event model is applicable and equation (B-5a) can be used for probability estimation. Since TMI involved relatively small off-site release of radiation, a \$25 million result (which may still be exceeded considerably even at TMI) may be assumed to be the low end of the large loss range; \$160 million is the coverage limit and hence the high end of the range. If the relative frequencies of various large losses within this range are uniform, S_j is \$92.5 million. If the relative frequencies of large losses are inversely proportional to their size, S_j is approxi-

TABLE B-3

DERIVATION OF REVENUE ACCUMULATION RATES FOR EXISTING NUCLEAR INSURANCE PROGRAMS; INPUTS AND RESULTS; ALL VALUES FOR 1981

Insurance Program	ANI/L*	ANI/P	NML	NEIL
Type of Pool	commercial	commercial	self-insurance	self-insurance
Event Covered	third-party liability	first-party property	first-party property	replacement power
Coverage				
For a maximum event (S_m)		\$300M	\$375M	\$156M
For a major event (S_j)	\$73-93M			
Annual premium per reactor (R)**	\$0.273-0.75M***	\$1.0-1.75M	\$1.38M	\$1.51M
Expense Loading (N)	30%	30%	15%	15%
Fraction of losses				
Due to maximum events (F_m)		75%	75%	65%
Due to major events (F_j)	99%			
Revenue Accumulation Rate,				
Based on maximum events ($P_m \cdot A$)		1/571 -1/327	1/426	1/187
Based on major events ($P_j \cdot A$)	1/492 -1/140****			

* ANI/L uses Eq. (B-5a); the other three programs use Eq. (B-5)

** For single-unit sites

*** Average premium = \$0.380M

**** From extreme combinations of R and S_j; for the average R, the range of S_j implies $P_j \cdot A$ = 1/353 to 1/277 mately \$73 million. From experience to date, F_j is about 99%.* The expense fraction N is estimated as 30%, using a range of values presented in ANI (1981a) and Hartman (1974).

b. ANI/P: Premium range is taken from ANI (1981a), as is the assumption that all insureds take the full \$300M of property coverage (ANI, 1981a). The expense fraction is estimated as 30%, using a range of values presented in McClure (1972). Since ANI/P losses are only available by year incurred, rather than by event, the 75% value of the maximum-event fraction (F_m) for ANI/P is the ratio in constant dollars of a \$300M loss for TMI 2 to the total losses through 1980, which include TMI 2.

c. NML: Virtually no information is currently available on NML rates. However, GPU (1980, p. 29) reports the premium for what appears to be a second \$375M layer of coverage for TMI 1. The expense fraction is taken from Anderson (1977), as 15%. Since no information is available on NML losses, the ANI/P value of the maximum-event fraction was used for NML.

d. NEIL: The value of the premium used is the basic premium for a single-unit plant, taken from NEIL (1979, p. ii). The maximum basic coverage for a single unit is \$156M, for the last two years of a 2.5-year outage. Coverage for units at multiple-unit sites is harder to define, since it varies with the number of units on simultaneous outages; accordingly, multiple-unit rates were not analyzed for this purpose. Coverages of less than the basic level are available, but the coverage/premium ratio remains constant. The expense loading for NEIL is assumed to be the same as for NML, the other self-insurance pool. The maximum-event fraction was estimated by computing the losses which would have occurred since 1970, if NEIL had existed and insured all commercial reactors in that period. Two maximum NEIL events (TMI 2 and Fermi 1), each of which would have been covered for 78 full-week equivalents, occurred in this time frame, as did several smaller

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*In an effort to estimate the probability of large nuclear accidents from ANI/L premiums, similar to the method employed here, Denenberg (1973) used for the premium value the pool's stated rate for the last million dollars of coverage and a 42% expense ratio, and derived a value for the probability equal to 1 in 1700. For a normal insurance policy, this procedure would eliminate the effect of small losses, by examining only the incremental rate for large losses. However, since all owner/operators are required to carry the full commercially available liability insurance, it is not apparent that the internal structure of the premium has any significance to the insurer. Hence, this Report does not follow Denenberg's methodology, but rather determines an average rate attributable to large (or maximum) events.

accidental outages, only a few of which exceeded 26 weeks* A total of 239 weeks of full indemnity would have been paid, 156 of which would have been for maximum events, resulting in an F estimate of 65%.

The values of R, S_m, N and F_m, from equation (B-5), or the corresponding major event factors from equation (B-5a), are summarized in Table B-3 for each of the four existing nuclear insurance programs, along with the revenue accumulation rates derived therefrom. It is interesting to note that the revenue accumulation rate values of $P_m \cdot A$ or $P_j \cdot A$ estimated from the various insurance coverages do in fact fall in the order expected for the underlying probabilities by the a priori analysis. In other words, the $P_m \cdot A$ estimated for NEIL is greater than the $P_m \cdot A$ obtained for the property coverages (ANI/P and NML), and the $P_j \cdot A$ estimate for ANI/L is about the same as that for $P_m \cdot A$ of the property pools, despite the use of major, rather than maximum, events for ANI/L.** However, the A values may vary widely between programs, so it would not be surprising if the revenue accumulation rates fell in a different order than the underlying probabilities.

Before attempting to separate the probabilities from the A factors, it is useful to identify any extraneous values from Table B-3, which displays the results of using the extreme values of premiums for each coverage.

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*These outages, their dates and durations are: Brown's Ferry 1 cable fray fire (3/22/75, 72 weeks, not counting 7 weeks NRC attributes to regulatory action), Rancho Seep turbine blade failure (6/30/75, 34 weeks), Crystal River poison rod coupling failure and resultant damage to steam generator (3/13/78, 28 weeks), Duane Arnold safe end failure (6/17/78, 38 weeks), and Yankee Rowe turbine failure (/19/80, 40 weeks). Note that effects on second units (TMI 1, Browns Ferry 2) are neglected due to separate rates for multiple-unit sites and lower indemnities for multiple outages.

**If medium-size ($25 million average) and full-limit losses ($160 million) are assumed to be equally likely for ANI/L and to heavily dominate the expected losses, then equation (B-5) would be applicable. If a maximum event costing $160M and a medium-sized event (or series of smaller events) costing $25M occurred, then estimated values of S_m = $160M, F = 86%, and $P_m \cdot A = 1/695$ could be used to derive the average coverage cost. However, treating the $25 million losses as events likely to be correlated to early decommissioning, the rate of interest for current purpose would still be about 1/350.

For ANI/L, the relevant value of the cost of a major event, S_j, varies with plant location: the expected loss from a major accident at a remote plant is small, while that at a plant near a population center is large. This variation in S_j may well be the primary cause of variation in premiums between plants. The discussion of ANI/L rating factors in Hartman (1974) indicates that location (measured by local population density and property value) and size (measured as thermal capacity) are the major sources of variation in premiums for power reactors. The extreme high value of the revenue accumulation rate, $P_j \cdot A$, of 1/140 for ANI/L results from combining the \$73 million S_j estimate with the \$750,000 maximum premium; if this premium is actually associated with a plant at which any large accident is very likely to become a \$160 million liability (due to the number of plaintiffs and the value of economic activity in the surrounding area), S_j is close to \$160 million and $P_j \cdot A$ would be more like 1/308. This latter estimate falls in the range of the estimates of $P_j \cdot A$ derived using the average premium \$0.380 million, and from the minimum premium, \$0.273 million.

Similar, but perhaps smaller, problems occur at the other end of the range of revenue accumulation rates. For example, the lowest ANI/P values for $P_m \cdot A$ may be associated with the smallest plants, which are not worth \$300M, even at replacement value. (For example, for LaCrosse to collect \$300M in property insurance, even for a total loss, it would have to be valued at \$6,000/KW, an extremely high value.) Also, the lowest values of $P_m \cdot A$ for ANI/L and ANI/P may represent "operating" reactors which were not, in fact, scheduled to operate during the policy year. Humboldt Bay and Dresden 1 still require insurance against earthquake, windstorm, and releases of their radioactive inventory, and are apparently considered to be "operating reactors," at least by ANI/L, although they were not scheduled to operate in 1981. Thus, the extreme values of revenue accumulation rates derived in Table B-3 for both ANI pools should be viewed with some caution, especially the highest value for ANI/L.

In estimating the value of A for each pool, it is necessary to determine whether the premium should include provisions for risk aversion (which would generally increase A), for investment income* (which would decrease A), for refunds (which would increase A), and for reserve and retroactive premiums (which would decrease A). These four considerations will be dealt with in turn.

The extent to which insurer risk aversion may influence rates must be assessed separately for ANI and for the self-insurance pools (NML and NEIL). For the self-insurance pools we would not necessarily expect any risk aversion effect to be seen. Since the insurers and the insured are

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*Net of increased coverage limits.

the same persons, participation in the pool reduces risk. Therefore, no extra incentive (above expected cost) should be necessary to entice members to join. In fact, risk aversion would cause individual members to join, even if they thought they were paying more than their fair share. This is presumably a major reason for the feasibility of the pool. Since the sum of the members' shares of total liability equals unity (there are no insurers who are not insured, or vice versa), there is no reason to believe that risk aversion affects average rates, though it might.

ANI could conceivably demand and receive a premium for accepting a non-diversifiable risk. While this may be true, it is important to note the possibility that even though insurers believe they should get a risk aversion premium, the market does not in fact grant one to them. An analogy from regulated insurance rates to this situation is the perception or claim by many auto insurers that they should or do, earn a positive "underwriting margin." In fact, study reveals that the actual margin is negative because the market recognizes the value to insurers of investment income derived from the investment of premiums and adjusts the margin to reflect that income. See Fairley (1979) and Hill (1979).

The non-diversifiable element of risk usually encountered in insurance (and other industries) results from the correlation between a particular risk and the general market. Such systematic risks contribute to the overall variability in return even for investors with fully diversified holdings, and so cannot be diversified away. Presumably, major nuclear accidents are uncorrelated with the economy as a whole (except to the extent the accident affects the economy); hence, systematic risk may not affect nuclear insurance rates.

The possibility exists, however, that the nuclear insurance risk may be "non-diversifiable" in another sense due to the sheer size of the possible loss; perhaps each member of ANI is exposed to substantial and unavoidable reductions in profits, because the potential loss is so large in relation to the total industry. While the <u>stockholders</u> of the stock-company members of ANI (but not necessarily all the members of the mutual companies) can diversify their holdings so that each investor is exposed to only a trivial risk, the <u>companies</u> may require some incentive to assume risks which may result in expensive financial distress. Fortunately,* the exposure of the insurance industry due to a nuclear accident is not large compared to the size of the industry and the normal fluctuations in its status. For example, a total loss to ANI from a single incident in 1980 would have been

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*The situation is fortunate both in that no theory exists for predicting the size of the hypothesized risk aversion effect; and in that insurer financial distress is not desirable.

$460 million ($300 million for property and $160 million for liability), of which 50% is reinsured abroad. The remaining $230 million loss, which would be paid over two or more years, would represent only about 4% of 1980 profits for those members of the domestic property/casualty industry recently evaluated in the Value Line Investment Survey, and considerably less than 1% of their net worth (Value Line Investment Survey, Insurance (Property/Casualty) Section, April 24, 1981). Since not all property/casualty companies are members of ANI, and since some ANI members accept larger exposure than others, some companies will bear larger relative risks. Nonetheless, a sample* of the individual members did not appear to be exposed to losses greater than 10% of 1980 profits or 1% of net worth. (The pools impose "minimum requirements as to financial soundness in relation to size of desired participation"; ANI, et al., 1979.) The insurance industry is much more sensitive to ordinary variations in profitability (the "underwriting cycle") than to nuclear-related losses; in the last trough of the underwriting cycle, the profits of many insurers fell 40% to 50% within two years.

The conclusion that nuclear insurance losses are not of extraordinary concern to insurers is supported by an examination of annual reports of ANI members for 1979, in which the Three Mile Island accident (which featured prominently in many electric utilities' annual reports) was generally barely mentioned, if it was discussed at all. Total catastrophic losses were usually five or ten times greater than the insurer's share of TMI loss reserves, and specific hurricanes, tornadoes, and other events were often discussed in greater detail than was TMI. The underwriting cycle frequently dominated discussions of variability in underwriting profits. Overall, nuclear insurance does not seem to pose a substantial risk to the members of ANI.

In sum, a consideration of the potential basis for risk aversion compensation in premiums reveals no basis for such compensation in the industry self-insurance pools like NML and NEIL and no obvious or substantial basis in the sizes of risks for such compensation to commercial insurers. For the latter, however, this is not suggesting that compensation for some type of risk aversion is altogether absent but only that its existence and magnitude are presently imponderables. Note that the "expense" portions of the premiums described above and listed in Table B-3 are 15% for NML and NEIL but 30% for ANI/L and ANI/P. It is possible that part of the difference between the two expense estimates is accounted for by risk aversion compensation--which of course, being a theoretical construct,

*The sample was from the companies listed by Value Line which were members of ANI as of September, 1978, directly or through subsidiaries. Exposure may be even lower with reinsurance.

is not explicitly labeled as such.* It should be observed here, however, that the expense estimates also record accounting predictions and are not themselves actual measures of market compensation for individual categories. For all of these reasons the risk aversion portion (sub-factor) of the A factor is taken to be 1.0 for calculations below made on all insurance programs. For NML and NEIL this will be literally a realistic assumption to make. For ANI/L and ANI/P it may be realistic if the expense percentage actually includes a risk aversion factor. If risk aversion exists and it is not included in the expense percentage, then A will be underestimated to a degree and probability estimates will be overestimated to a degree. Specifically, for example, if there were a 10% risk aversion premium not already included in the expense loading factor, then probability estimates would be over-estimated by 10%.

The investment income loader is more significant than that for risk aversion. The pools may hold premiums for substantial periods of time before they are used to pay expenses and losses; at high interest rates, the value of holding this money may be significant in rate setting. For the nuclear insurances, three periods may be identified which collectively represent the duration for which funds are held. The first period extends from the payment of the premium to the average time of an insured event within the term of coverage; for all nuclear insurances, this period

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*Hartman (1974) states that ANI/L's "expense" fraction actually includes allowances for "profit and contingencies" (2.5% of premiums) and "catastrophes" (7.5% of premiums). Comparison of data in ANI, et al. (1979) and ANI (1981a) indicates that ANI/P 1957-79 cumulative expenses were $40 million, out of premiums of $242 million, for a 16.5% average actual expense fraction, as compared with the 30% expense fraction discussed in the text. The additional portions of the expense fraction (profits, contingencies, and catastrophes) for both ANI coverages may be intended to cover unforeseen and variable expenses, to accumulate loss reserves (especially the "catastrophe" loader), or to compensate the members of ANI for assuming risk, regardless of whether such compensation would have been required in a competitive market. Thus, it is possible that the effective loss portion of ANI premiums is actually larger than 70%; the revenue accumulation rate would be proportionately larger as well. Alternatively, it is possible that ANI is receiving some compensation for risk aversion, and including that compensation in the expense fraction, possibly with some loss and expense reserves. Therefore, the loss portions of the ANI premiums may have been underestimated, by excluding a portion of the "expense" fraction which is actually intended to pay for losses. It is unlikely, however, that the loss portions have been overestimated, by including in the loss portion any compensation for risk aversion, since if risk aversion exists, it appears to exist in the expense fraction. Since only the loss portion affects the revenue accumulation rates, those rates may similarly be slightly underestimated, but probably do not include any risk aversion premium.

is assumed to be six months.* The second period stretches from the occurrence of an insured event to the payment of the loss by the insurer, which varies with the type of insurance. For NEIL, the average dollar on a maximum loss would be paid 16 months after the accident occurs; this is simply the average date of the prescribed indemnity payments. For the property coverages, the TMI experience indicates that a 1.4-year lag may be typical; from Kibbee (1981) $70 million was paid in 1979 (an average of 4 months after the accident), $143 million was paid in 1980 and the first quarter of 1981 (16 months later), and the remaining $87 million was expected to be paid in the rest of 1981 and perhaps into the first quarter of 1982 (29 months after the accident, if payment extends through February, 1982). For ANI/L, the major TMI payment to date was made in February, 1981, almost two years after the accident (Kibbee, 1981). However, some smaller claims (up to $300,000) have required a decade to settle (ANI, 1981b). The TMI figure is assumed to be typical of major events.

These first two periods of investment income will reduce the value of A, and hence increase the estimate of P_m or P_j.

Since the risk-free interest rate** in 1980 (when 1981 rates were being set) for three-year maturities was about 11.5%, it is appropriate to reduce the value of A by a factor of 1.115 raised to the sum of the number of years in the first two periods (from payment of premium to the middle of the policy year and from accident to payment).*** These sums are about 2.5 years (or possibly much more) for ANI/L, about 1.9 years for property coverage, and 1.8 years for NEIL. The value of A for ANI/L decreases by a factor of 1.31; values for the other coverages decrease by factors of 1.22 to 1.23.****

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*It is assumed that all nuclear insurance premiums are paid as of the first day of the premium year.

**The risk-free interest rate is the appropriate rate for crediting investment income; see Fairley, 1979.

***Throughout this section, interest is calculated for the average length of the period of interest. Due to the nonlinearity of compound interest accrual, it would be more precise to calculate interest for each possible length of the period, and to average the results. Since the distribution of most of the variables involved are not well known, this additional detail is unwarranted for the current application.

****For reasons discussed below, this adjustment will not be applied in this form for NML.

The third period of interest for investment income is not encountered in ordinary insurance: the period between this premium year and the first premium year with an accident. Making the rough assumption that accidents are generated by a simple Poisson process, the expected time to the first accident (in reactor years) can be estimated from the probability of an accident. With about 70 operating reactors and another 10 or so scheduled to come on line annually, probabilities of 1/200 to 1/500* result in an expected time to ANI/L's next major accident of about 2.5 to 5 years.** This period would produce large amounts of investment income (27¢ to 60¢ per dollar of premium at 10% interest), and would allow premiums to be correspondingly lower, all other things being equal. However, all other things are not equal; specifically, the coverage limits tend to increase over time. From 1970 to early 1981, ANI/L limits increased 6.9% annually, and ANI/P limits increased 12.3% annually. Both ANI pools are attempting to raise their limits (ANI, 1981c); ANI/P has already raised their limit by 25% for late 1981, and proposes to increase 1982 limits another 20% (Kibbee, 1981). It seems reasonable to assume that NML limits track ANI/P, and that NEIL will also raise its limits at roughly the rate of inflation. If the loss portion of the premium earns interest at the same rate that the exposure increases, the two effects cancel out and probability estimates from current limits and current premiums are not biased by neglecting the time to the first policy year with an accident.

From 1970 to the beginning of 1981, risk-free U.S. Treasury securities with 3-year maturities averaged a 7.6% annual return, while the consumer price index increased at an average annual rate (compounded) of about 7.8% in the same period. If the lower end of the maximum event range for ANI/L has risen with inflation and the upper end has risen at 6.9%, ANI/L's investment income has just about kept pace with the increased cost of large accidents. Unless ANI/L is planning to hold coverage to the $160 million level, it seems reasonable to expect a continuing balance between investment income, and the loss due to a major event, S_j. ANI/P's limits have increased at the rate of 12.3%; if ANI/P continues to increase its limits at 4.4%*** above the risk-free rate, then the effective value of the coverage limit is actually larger by roughly 3.5 to 7 years**** of escalation at 4.4%, or about 16% to 35%.

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*These probabilities are consistent with the final results derived below. In general, the process of using preliminary probability estimates to estimate investment income and hence derive a better probability estimate should be iterative. The range of uncertainty in the final results eliminates the value or need for this additional precision.

**The corresponding period for ANI/P, which covers fewer reactors, is about 4 to 7.5 years.

***1.123 / 1.076 = 1.044.

****The first six months are included in the first period, discussed above.

The offsetting effects of inflation and interest during the third interval thus appear to have no net effect on the value of A for ANI/L or (by assumption) NEIL, and the net effect on the ANI/P estimate is to increase A by about 16% - 35%. The effect on NML (which does not hold premiums beyond the end of the policy year), will be considered below.

Three of the pools have refund programs or options. ANI/L and NML refund the unused fraction of the loss portion of premiums at the end of 10 years and one year, respectively. NEIL has the option to make refunds, but no obligation to do so. The refund provisions of the self-insurance pools will be considered below, along with their ability to collect retrospective premiums. ANI/L is a special case, and is examined first.

At first glance, it may appear that the ANI/L practice of refunding in ten years whatever loss portions of premiums were not actually required to pay losses is a substantial *de facto* premium reduction. However, two factors combine to make this effect quite small. First, at the average 1980 interest rate for 10-year risk-free investments (11.46%), a dollar ten years hence is only worth 34¢ today. Second, even if the probability of a major event is very low (about 1/500 per reactor-year), the probability of getting through the ten years without a major event (assuming 10 reactors come on line per year) is only 8%. This refund provision was more significant when there were fewer reactors and lower interest rates. While not all major events will be expensive enough to wipe out the refunds, the insureds can expect to get back no more than 34% of the loss portion of the premium and probably much less. The value of A for ANI/L should be increased by the inverse of the portion of premiums ANI/L expects not to return, producing factors in the range 1.52 to 1.04.*

The self-insurance pools have much broader options in terms of collecting funds from their members than do the ANI pools. NML refunds the unused fraction of the loss portion of the premium at the end of the coverage year, but may assess members for retroactive premiums up to fourteen times their ordinary annual premiums. NEIL collects an explicit reserve premium from new members (or those increasing their coverage) equal to 13% of the ordinary premium, may assess a retrospective premium of five times the ordinary annual premium, and may distribute profits back to its members. Thus, as discussed in the Introduction to this Appendix, the connection between the expected coverage cost (the expected value of losses and expenses) and the actual premium charged by either of these pools is tenuous. However, it is possible to set some limits on the impact of the retroactive, reserve, and refund provisions, and to determine by reference to the ANI pool rates whether the self-insurance pools appear to rely heavily on these special features.

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*1/.66 to (.08/.66 + .92).

NML insures approximately 36 reactors. At a probability of 1/400 per reactor-year, the chance of a large loss in the coverage year is about 9%. Thus, the expected amount of money both including and generated from a dollar of premium paid to NML at the time an accident occurs can be computed as .09 times 1.06, the value if an accident occurs in the coverage year,* plus .91 times .08, the value if no accident occurs in the coverage year,** or $0.168. This is equivalent to increasing A by a factor of 5.95, including the effects of the first and third periods between premium payment and loss payment, as discussed above, but not the effect of the second period (the lag between loss occurrence and loss payment). This period may be taken as 1.4 years, from ANI/P's experience with TMI 2, so A is reduced by investment income in the second period by $1.115^{1.4} = 1.165$. The total impact of the refund, investment income, and limits growth considerations is to increase A by a factor of 5.10.

The preceding paragraph assumed that retroactive premiums are not utilized. In fact, NML may retrospectively call upon its members for as much as 14 times the ordinary premium in the event of an accident. Thus, the value of the policy to NML may be as much as 14 + 1.06 = 15.06 times the ordinary premium, if an accident occurs in the coverage year. Averaging this result with the average value if no accident occurs this year (still 0.08), the value of A is multiplied by 0.70 rather than the 5.95 calculated without the retrospective premiums. The correction for second-period interest is reduced somewhat, since retrospective premiums are collected after the accident; if the average holding period is halved to 0.7 years, A is reduced by a factor of 1.079. The total effect of refunds, investment income, limits growth, and retrospective premiums is to reduce A by multiplying it by a factor of 0.65.

NEIL has no limit on its refunds to members, so A may be increased by virtually any multiple, depending on NEIL's expectation of such refunds. The effect of the 13% reserve premium spread over 20 years is very small, decreasing A by about 2%. The retroactive premiums may effectively increase the value of the premium by adding five times the probability of an accident occurring in a year (about one-third, for seventy reactors at 1/200 chance of an accident occurring), making the average effective premium as much as 2.67 times the nominal premium. If the retrospective premium is received contemporaneously with the payment of losses, no investment income is earned on the retrospective premium, and the effects of the retrospective provision is additive with the investment income on the ordinary premium. The maximum net effect of investment income, reserve premiums,

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*1.00 + six months of interest at 11.5% = $(1.115)^{1/2}$ = 1.06.

**Investment income this year divided by the real rate of increase in limits, compounded for the average period until the first accident, or $0.115/(1.044)^{8}$ = .08.

and retrospective premiums is thus to multiply the effective value of the premium by 2.91*, or equivalently, to multiply A by 0.34. If retrospective premiums are not used, the net effect of the investment income and reserve premiums alone is a factor of 0.81.

The preceding discussion is summarized in Table B-4. The range of maximum event probabilities which are consistent with the premiums of the self-insurance pools are very broad, because of the uncertainty in assessing the pool's plans for utilizing retrospective premiums, and in the case of NEIL, refunds. The ANI estimates of P_j or P_m, however, are very similar to the corresponding revenue accumulation rates. As previously observed, the low end of the ANI ranges are of questionable relevance. Taking the components of A for ANI/L one at a time, without the other counterbalancing components, produces extreme P_j estimates of 1/748 and 1/211. The corresponding extreme P_m's for ANI/P are 1/770 and 1/265. Overall, there is strong support for the conclusion that the existing commercial pools base their rates on underlying probabilities of events roughly comparable to AIDEs of about 1/400, with extreme estimates around 1/750 and 1/200.

The results in Table B-4 for the self-insurance pools are not inconsistent with the results for the ANI pools. In fact, the NEIL range of P_m estimates is higher than the ANI ranges, as expected, and the NML estimate varies substantially from the ANI ranges only if NML is not expecting to use retrospective premiums to cover most maximum losses.**

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*Investment income (1.22) plus reserve premium (0.02) plus retrospective premiums (1.67) equals 2.91.

**If this were the case, NML's premiums would be very sensitive to interest rates, since investment income would be the major source of reserves. It does not appear that NML's rates are any more volatile than ANI/P's (although data is scant), and it is not clear that a self-insurance pool with such unstable rates would be viable.

TABLE B-4

DERIVATION OF PROBABILITY ESTIMATES FROM REVENUE ACCUMULATION RATES*

Insurance Program	ANI/L	ANI/P	NML	NEIL
Revenue Accumulation Rate**	1/492 -1/277	1/571 -1/327	1/426	1/187
Components of A:				
investment income				
to year of first accident	nil	1.16-1.35	---	nil
to loss payment***	.76	.81	---	.82
refunds	1.04-1.52	---	5.10†††	1-5
retrospective**** premiums	---	---	.13-1.00	.37-1.0
reserve premiums	---	---	---	.98
Estimate of A†	.79-1.16	.94-1.09	.65-5.10	.34-4.05
Estimate of probability††	1/571 -1/219	1/622 -1/307	1/2173 -1/277	1/757 -1/64

* Not all of the adjustments are accurate to two decimals; trailing zeros are shown for consistency, not to indicate precision

** From Table B-3. For ANI/L, values are $P_j \cdot A$, and the highest probability in Table B-1 is discarded, as discussed in the text. For the other three programs, values are $P_m \cdot A$

*** From the beginning of the premium year to the average payment date of losses (in years with large losses) which is periods one and two as defined in the text.

TABLE B-4, Continued

**** The appropriate multiplier depends upon whether the pools intend to use retrospective premiums for all large losses, for some, or for none

† For ANI and NML, A is the product of the components listed. See text for details of calculation of effect of NEIL investment, reserve, and retrospective premiums

†† P_i is estimated for ANI/L, P_m is estimated for other programs; probability estimates equal revenue accumulation rate/A. Precision is not as great as implied; three or four digits are included for consistency, not to indicate significance

††† This value represents the total impact of the refund, investment income and limits growth considerations, as discussed in text

3. Estimating Probability from the Reactor Safety Study

The Reactor Safety Study estimates probabilities for several collections of events related to AIDEs. The RSS developed a set of categories to describe the degree of radioactive release separately for PWRs and BWRs, and then attempted to identify the sequences of accident events associated with each release category having non-negligible probability of occurrence. A nine-category scale was developed for PWRs. The seven categories corresponding to the largest amount of radioactive release, PWR 1 through PWR 7, all involved core melting to some degree. Similarly, a five-category scale was developed for BWRs. The four categories associated with the largest radioactive releases, BWR 1 through BWR 4, also involved some degree of core melting. The probability of a core-melt accident was estimated by the RSS as approximately 1/20,000 per reactor-year, and 90% confidence intervals were estimated to be a factor of five above and below this figure. The PWR 8 category involves a containment failure but no core meltdown; the RSS estimates the probability for this release category as 1/25,000. The least severe PWR category, PWR 9, involves no containment failure and no core meltdown; this probability was estimated as 1/2,500. The BWR 5 category, which also does not involve a core meltdown, was estimated to have a 1/10,000 probability of occurrence.

The RSS was not designed specifically to estimate insurance coverage costs, and thus the results are not strictly comparable to those derived in the preceding section. The RSS did intend to estimate the probability of accident events with large off-site impacts, which is similar to the probability of large ANI/L events. However, some large losses to ANI/L would result from factors which the RSS did not consider; the $25 million settlement in the TMI case may be an example of an ANI/L cost excluded from the RSS. Thus, the RSS results may be probability estimates either for large ANI/L events or for a subset of those events. The RSS does not attempt to estimate the probability of all events which would cause major property damage to the reactor, and assumes that such events are much more likely than the accidents it studied.

The RSS estimates appear to be very different from (but not necessarily inconsistent with) estimates obtained using methods discussed earlier. Even if every core melt were a maximum event, costing ANI/L $160M, the liability insurance premiums implied by the RSS core melt probability best estimate* are lower than actual premiums by a factor of 20 to 60.

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*From equation (B-4) and Table B-3, R = ($160M) · (1/20,000) / (.90 · (1-.3)), which is about $12,700 per reactor-year. This calculation assumes that the maximum event fraction for ANI/L is .90, and that A is 1.0. Using the average ANI/L premium of $0.380 million, and again assuming that A equals unity, the maximum event fraction, F_m, implied by using the RSS core-melt probability estimate is 0.03, which is extremely inconsistent with all other estimates for F_m.

Further, the RSS also predicts that most core melts will not be maximum events, causing less than one fatality and less than one injury, and causing less than $1 million (1975 dollars) in third-party property damage. These predictions make the RSS-implied liability premiums even lower than those discussed above.

Four possibilities exist which may explain the discrepancy between the RSS estimates and those obtained using the other methods, particularly estimates obtained from the existing pools. In light of these considerations the RSS figures were not employed in developing AIDE coverage cost estimates. First, the RSS estimates may be biased. This possibility has been discussed by at least one reviewer of the RSS.* Second, the RSS estimates may be valid for their intended use, but the set of events under study may differ from the set of events covered under existing insurance programs, or from the set of events defined as AIDEs. This could be attributable to the different focuses of the RSS and the insurance programs, or to possible incompleteness of the set of event sequences identified by the RSS as causing "significant" radioactive releases.** Third, the RSS probability and the existing pools' perceptions of probabilities may represent different opinions; for example, the pools may be founding their estimates on different sources of information than those used by the RSS. The existing pool's behavior would seem more relevant to estimating decommissioning costs, since the behavior and opinions of the planned AIDE pool would presumably follow that of the existing pools rather than the RSS. Fourth, the model for premiums discussed in the previous section may be incorrect in some respect; for example, a component may be missing from the model. In this case, the estimate derived would contain one or more factors in addition to the probability estimate. If these non-specified factors affected the AIDE insurance premiums and existing insurance premiums similarly, the factors would still be accounted for when expected coverage cost estimates were derived from the current pools' premiums. Using RSS estimates would preclude the possibility of accounting for such unspecified factors.

These considerations support the use of AIDE probability estimates developed from the existing insurance pools and historical experience over the use of the RSS estimates.

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*Union of Concerned Scientists (1977).

**The latter point was suggested by Lewis, et al. (1978) and the Union of Concerned Scientists (1977).

D. Estimates of Expected Coverage Cost for Accident-Initiated Decommissioning Events

Table B-5 presents the range of likely and reasonable expected coverage cost estimates for AIDE insurance, which were estimated by evaluating equation (B-4) using the following values.

1. Expense fraction. The expense fraction, N, is 15%. This is extrapolated from NML. The level of total pool operating expenses which would be covered by this expense loader is considered below; whether 15% turns out to be inadequate, appropriate, or excessive will depend in part upon the extent of the pool's commitment to differential rating of risks.

2. Maximum-event fraction. The maximum-event fraction, F_m, is 95% - 100%. Accident-initiated decommissioning would appear to be very close to a binary variable: either there is no loss, or the loss is very large. Nevertheless, there may be some chance, especially for the higher coverage limits, of a loss less than the maximum coverage level. If 10% of AIDEs are "small," costing less than the limit and averaging 50% of the full loss (after deductibles in both cases) limit, $F_m = 95\%$. This value of F_m is used for the $1 billion coverage; all AIDES are assumed to be maximum events for the $500 million coverage. The estimated coverage costs are not particularly sensitive to this split between large and small AIDEs, and there is no basis for projecting the distribution of AIDE costs. This factor is varied in this report primarily to remind the reader that both F_m and P_m would decline somewhat as the coverage limit is increased, since non-maximum events would be more likely, but that the change in F_m would partially offset the change in P_m, limiting the sensitivity of R to this effect.

3. Deductible. The deductible is the greater of 5% of maximum coverage or the accrued decommissioning reserve. As discussed, it appears to be prudent for the pool to require its members to reserve toward a decommissioning fund of $100 million to $250 million, depending on plant size. Currently, utilities appear to be reserving toward $50 million decommissioning funds. Assuming that average unit life projections are correct (the value of average life does not matter for this purpose, only that the estimates be accurate), that the decommissioning reserve is accrued linearly over time, and that AIDE probability is independent of unit age, the average deductible is almost exactly half the decommissioning fund target. The 5% minimum insures that the owner shares in any early loss.

TABLE B-5

ESTIMATES OF EXPECTED COVERAGE COST FOR ACCIDENT-INITIATED DECOMMISSIONING INSURANCE*

Nominal Coverage Limit	$500		$1000	
Decommissioning Reserve Target	$ 50	$250	$ 50	$250
Effective Coverage Limit**	$427.3	$337.5	$877.3	$787.5
Probability of AIDE***				
1/200	$2.51****	$1.99	$4.89	$4.39
1/400	1.26	0.99	2.44	2.19
1/600	0.84	0.66	1.63	1.46
1/800	0.63	0.50	1.22	1.10

* All values in millions of 1981 dollars; coverage period is assumed to be one reactor-year

** Net of average deductible and coinsurance; see text

*** The probability of an AIDE, P, is used to estimate the probability of a maximum avent, P_m, for the $500 million coverage; 90% of P is used to estimate P_m for the $1 billion coverage; see text

**** Estimates of expected coverage cost are obtained using equation (B-4) in text

Among the existing nuclear pools only ANI/P and NML use explicit deductibles and then only for very small amounts (generally less than 1% of coverage), and, in the case of ANI/P, only for turbine-generators and transformers. NEIL has a 26-week "deductible" in that no coverage is offered for the first 26 weeks of an outage.

4. Coinsurance. Coinsurance is 10% of the actual losses above the deductible and below the coverage limit. This value was selected judgmentally to provide some additional incentive for owner/operators to avoid decommissioning, and to limit somewhat the cost to the pool of decommissioning, if it occurs. The existing property and liability pools do not use co-insurance in this sense. However, NEIL's first year of coverage (i.e., months 7-18 of an outage) has at least a 10% co-insurance factor (based on expected, rather than actual, replacement power cost), and NEIL's second year of coverage (i.e., months 19-30 of an outage) has at least a 55% coinsurance factor. Since NEIL's maximum weekly indemnity ($2M) is much below the actual cost and value of replacement power in most areas of the U.S.,* the effective coinsurance factors for NEIL are actually higher than the minimum factors discussed above.

5. Coverage limits. Coverage limits are $500 million and $1 billion. The higher end of the range was chosen to correspond to current cost estimates for decontaminating TMI 2. The lower end of the range was arbitrarily chosen at half the high end value, for illustrative purposes. Due to the deductible and due to coinsurance, S_m is thus actually less than the nominal coverage limit; it is the effective coverage limit. This distinction does not arise in existing nuclear insurance programs, either because deductibles and coinsurance are non-existent (ANI/L) or insignificant (ANI/P), or because the maximum coverage is stated in terms net of deductibles and coinsurance (NEIL).

6. Constant dollars. Coverage and expected coverage costs are all stated in constant 1981 dollars, regardless of when the premiums or the losses are actually paid. Thus, inflation to payout date will roughly balance investment income between receipt of premium and payout for losses, so investment income is insignificant.

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*For example, replacement power from oil at $36/BBL and at 10,000 BTU/KWH would cost about 6¢/KWH = (6¢/KWH) x (1,000 KWH/MWH) x (168 hrs/wk.) x (.6) x 1100 MW) = $6.65 million per week for an 1100 MW reactor which normally has a 60% capacity factor.

7. Probability. The probability of a maximum event is estimated to fall in a range from 1/800 per reactor-year to 1/200 per reactor-year to correspond to the range of values derived in §II (C) of this Appendix, above.

As seen from Table B-5, for the highest coverage limit considered here, the annual cost of insurance would likely be in the two- to three-million dollar range.

Table B-6 examines the amount of expenses generated to run the pool, and the rate at which loss reserves would accumulate. The pool is assumed to include seventy-five reactors, roughly the number of commercial power reactors in the U.S. in 1982. The analysis in Table B-6 is only performed for the $1 billion coverage limit, but can be scaled up or down for other coverage limits. The 15% expense fraction seems to generate adequate operating funds for the pool, at least for the higher values of coverage limits and of P_m. However, the lower values of P_m generate rather low expense revenues for the pool, even at the billion-dollar coverage. Since ANI generated about $25 million in expenses in 1980, it seems unlikely that the AIDE pool could function effectively on an industry-wide basis with much less than $10 million in expenses. Expense loadings would probably have to exceed 15% for values of P_m under 1/800, for lower coverage limits, or combinations of low P_m and low limits.

At the most probable values of P_m (around 1/400), loss reserves accumulate fairly rapidly, reaching the maximum coverage in seven years.

From Tables B-5 and B-6, an approximate range for AIDE expected coverage costs can be inferred. The value of the probability for AIDEs seems unlikely to be much higher than 1/200, which implies that the expected coverage cost for $1 billion coverage is unlikely to exceed $5 million annually. At the other extreme, even extremely low values of P_m such as 1/2000 would produce expected coverage cost estimates for the $1 billion of about $0.5 million per reactor-year.* Thus, the expected coverage cost for a billion dollar AIDE coverage is most likely to be around $2 million, and is very unlikely to fall outside the $0.5 million to $5.0 million order-of-magnitude range.

This range of uncertainties can be placed in perspective by noting that:

a. Nuclear power reactors currently nearing completion will cost a billion dollars or more each. At typical carrying charges of 20%,** these plants will cost $200 million

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*As noted above, the expense fraction would probably also surpass 15% for low values of P_m.

**For investor-owned utilities; current carrying charges are somewhat higher than 20%, due to high interest rates.

TABLE B-6

EXPECTED COVERAGE COST
AND EXPENSE ANALYSIS
FOR BILLION-DOLLAR COVERAGE*

	Per Unit, Annually			Total Pool, Annually**		
Probability	Total Premium	Expense Portion	Loss Portion	Total Premium	Expense Portion	Loss Portion
1/200	4.39***	0.66	3.73	329	49	280
1/400	2.19	0.33	1.86	165	25	140
1/600	1.46	0.22	1.24	110	17	93
1/800	1.10	0.16	0.94	82	12	70

* $250 million decommissioning fund target is used; expected coverage cost estimates are taken from Table B-5

** Total pool is assumed to consist of 75 units

*** All values in millions of 1981 dollars annually just for return on investment and taxes.

b. Older, cheaper units must periodically update their safety systems; Connecticut Yankee plans to spend over \$94 million from 1980 to 1983 for this purpose.

c. Smaller retrofitting projects ("interim replacements") have increased the cost of existing plants by about 3% annually; for a billion dollar plant, that would be \$30 million.

   Interim replacements at New England nuclear units from 1968-1978 averaged about \$13,400/MW in early 1981 dollars (Chernick, 1980); for a 1150 MW plant, this would be over \$15 million annually.

d. Annual O&M costs for large commercial nuclear units are on the order of \$10 million to \$20 million 1981 dollars.

In addition, as noted in the Introduction to this Appendix, nuclear power costs in general are hard to estimate correctly and are highly variable. A million dollars annually (which is equivalent to less than 0.02¢/KWH for an 1150 MW unit operating at a 60% capacity factor) is a small cost and a small uncertainty by the standards of nuclear power costs.

Once again, it should be noted that the premiums charged by the pool need not necessarily equal the expected coverage cost estimated above. The actual premiums may fall outside the estimated range if the pool anticipates refunds or retroactive premiums.

III. ESTIMATION OF EXPECTED COVERAGE COST FOR NON-ACCIDENT-INITIATED DECOMMISSIONING EVENTS

A. Definition of Non-Accident Event

Accident-Initiated Decommissioning Events (AIDEs) are assumed to present major problems for the reactor operator for two reasons. First, the decommissioning/decontamination task is expected to be much more expensive than normal decommissioning, so the utility's accumulated reserves for normal decommissioning will probably be inadequate to pay for accident-initiated decommissioning. Second, accidents will often occur well before the end of the reactor's expected service life, so the utility will not generally have reserved sufficient funds even for normal decommissioning. Thus, all AIDEs are considered to be covered by the insurance pool.

Non-Accident-Initiated Decommissioning Events (NAIDEs) should not generally share the first problem raised by an AIDE. If a reactor is decommissioned on schedule due to anticipated problems (e.g., materials fatigue, corrosion, and embrittlement), the decommissioning cost should usually be close* to the decommissioning cost estimate obtained near the end of unit life, especially once decommissioning of large reactors has become a routine procedure. If unanticipated problems (e.g., discovery of design flaws or catastrophic failure of a major component, such as the turbine or steam generator) require shutting down the plant earlier than expected, the cost of decommissioning may be less than anticipated, due to the lower levels of contamination and activation. However, individual units may prove to be much more expensive to decommission than the average reactor, due to details of design or of operating history; these factors may not always be detected before retirement, and perhaps not until decommissioning is well under way.

The second factor which renders AIDEs problematic, the inadequacy of decommissioning reserves due to premature retirement, is probably a greater problem for NAIDEs than cost-overruns and other factors. Unless the owner/operator establishes a fully funded decommissioning reserve as soon as the reactor enters operation, there is some danger that decommissioning will occur before the reserve is adequate to pay even average decommissioning costs. Standard practice currently appears to favor straight-line depreciation for book purposes, and thus straight-line accrual of the decommissioning reserve; a unit retired at half its expected life would thus have only half a decommissioning reserve.

Thus, Non-Accident-Initiated Decommissioning Events (NAIDEs) may occur due to prematurity of decommissioning, cost-overruns, or a combination of those factors. If the difference between the decommissioning reserve and the

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*At least, this decommissioning cost should be closer to the estimates than would the cost of an AIDE.

cost of decommissioning is small, compared to the size and wealth of the owner/operator,* and if the NAIDE did not cause other serious financial impacts,** a NAIDE is a sort of mishap the owner/operator can take in stride. But if the reserve shortfall is very large compared to the financial resources of the owner/operator, and if the NAIDE removed the largest single item (the reactor) from the owner/operator's rate base, the owner/operator may be unable to proceed with decommissioning in a timely, safe, and efficient manner. It is these latter cases for which a NAIDE insurance program might potentially be structured, though we note below some difficult problems that may be inherent in such a program.

This Appendix treats NAIDE insurance as if it covered all NAIDEs, regardless of the extent of the owner/operator's financial hardship. Several approaches are possible to reduce the cost of the coverage by limiting it to the instances in which the utility would otherwise be unable to proceed with decommissioning. These possibilities include requiring explicit financial tests, structuring the self-insurance pool as a surety, and providing the decommissioning coverage as a contingency loan. These mechanisms, discussed further in Appendix E, would reduce the expected coverage cost to the pool by an indeterminate, but potentially quite large, factor. Thus, the coverage costs estimated in this section should be regarded as being near the upper end of a range, corresponding to various coverage designs.

*Relevant measures of size and wealth would be revenues, kilowatt hour sales, net worth, and earnings.

**Examples of such impacts are increased fuel and purchased power costs, and loss of revenues associated with the reactor, such as return, depreciation, O&M, and taxes.

B. Insurability of Non-Accident-Initiated Decommissioning

Non-Accident-Initiated Decommissioning Events possess some of the characteristics usually associated with "business risks" as that term is used in the fields of insurance and risk management. Since insurance against business risks is generally considered more problematic than insuring against physical hazards (e.g., fire or theft), it is useful to examine the concept of business risk and its applicability to non-accidental nuclear decommissioning insurance. Unfortunately, no systematic treatment of business risk appears to exist in the insurance literature, but the following quotation from Rodda (1978) touches on most of the relevant aspects:

> Production, marketing, and political activities which cause losses are what might be called business perils. While losses may result from them, gains may also be made. These perils are generally considered "speculative risks" rather than "pure risks," and are not suitable for insurance coverage. For instance, if a firm overproduces, it cannot buy insurance to cover the losses involved. If it could, there would be little incentive to control the level of production. Likewise, if a company enters a new market and fails, it cannot purchase insurance to cover the losses. If it could, the company could recklessly enter all types of new markets without fear of financial loss. The chance of production and marketing loss is largely in the hands of the insured. The moral hazard and adverse selection would be just too great to insure.

Three problems are identified in the quotation: business risks are speculative, insuring against business risks creates moral hazard, and insuring against business risks creates adverse selection. These three issues will be considered in turn below, along with factors which may limit their impact. It is important to remain aware of the distinction between problems which tend to decrease reactor lifetime (and hence increase the frequency of decommissioning) and those which tend to reduce the incentive for controlling decommissioning costs. Some of the issues discussed below may generate only (or primarily) one of these types of problems, while others may generate both types; the mitigating factors may similarly affect one or both types of problems.

1. Speculative Risks

Mehr and Hedges (1963) discuss speculative risks at some length. Of particular concern for NAIDE coverage are their observations that speculative risks are related to complementary gains, are inherently difficult to rate and involve dynamic, non-independent loss probabilities.

Business risks are generally associated with complementary gains, or corresponding opportunities for gains. This seems to be Rodda's primary concern: if a company could get coverage for the lowest risks within the range of risks possible ("downside" risks), while enjoying the benefits of windfalls and other good fortune, it would be very risk prone, the insurer's losses would be very high, and only the worst (most risk-prone) companies would want the insurance.*

The problems perceived with speculative gains are tempered considerably in the case of nuclear decommissioning insurance. Regulated utilities generally do not have an opportunity to "strike it rich" with nuclear plants. Nuclear investments may be desirable for utilities for a variety of reasons, but such investments cannot be expected to yield windfall profits much in excess of those allowed by the regulatory commissions. Publicly owned utilities might conceivably hope to earn some excess profits from nuclear plants; however, even for publicly owned utilities, the 10-15 year construction period (followed by perhaps several more years before the plant is competitive with other sources) and the multi-billion dollar investment required, render commercial nuclear power plants unsuitable as speculative investments, regardless of whether or not NAIDEs are insured.

The size of the investment and uncertainty as to construction cost, construction time, capacity factors, O&M expense, possible development of alternatives, financial capability and (for regulated utilities) allowed return and other rate treatment, obviously all encourage considerable caution on the part of utilities. To the extent that some portion of the risks is reduced by decommissioning insurance, utilities may be marginally more willing to undertake nuclear construction; on the other hand, internalization and quantification of nuclear risks in the form of an insurance premium might discourage utilities and their regulators from pursuing those nuclear investments which are least cost-effective.

If reasonably accurate rating were possible for each project, this problem of speculative investment in high-risk projects would be ameliorated; unfortunately, this is not generally possible for speculative risks.

Speculative losses arise from causes which are intrinsically difficult to rate, such as management decisions (in markets, financing, production technology, and innovation) and political events. Specifically, the insured often knows much more about the risks than the insurer.

The economic, technological, and institutional hazards of the nuclear industry are complex, suffer from imperfect information, and will certainly be difficult to rate well. Rating would be easier to the extent that in contrast to investments in other industries, nuclear plants were more uniform in design, their economics (on a current, as opposed to a projected, basis) were more straightforward to analyze, their construction and operation involved fewer trade secrets, they were subject to more inspection, and the factors which would render the plants obsolete (e.g., actions by the

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*This is one form of adverse selection, which is considered below. Many aspects of business risk are closely interrelated.

NRC and rate regulators, the economics of uranium and alternative energy sources) were more in the public realm. Can the pool design its rating program to reflect most voluntary activities which might substantially affect the pool's risk, and thus discourage excessive risk-taking by reactor operators? The degree to which the pool is successful in such differential rating will strongly influence its success in overcoming the problems of moral hazard, morale hazard and adverse selection (about which see further discussion below).

Nuclear risks, including those related to non-accidental decommissioning, are probably not constant over time, and the probabilities and population of reactors at risk are small, so estimating probabilities and forecasting losses are difficult. As we have noted above, these considerations prevent any aspect of uniquely nuclear insurance* from being rated on a highly precise basis. Due to the absence of many uniform events and of predictable total annual losses, Mehr and Hedges (1963) do not consider any of the nuclear insurance pools** to be offering true insurance, but rather "pooling and risk transfer."

Thus, the expected coverage costs estimated in this Report are acknowledged to have large uncertainties associated with them; these uncertainties may also encourage the use of retrospective premiums and reliance on a self-insurance pool (in which, if the risk is greater than estimated, then both the value of the insurance to the members and the average losses to the members are greater, in a counterbalancing fashion) rather than commercial insurance (in which the insureds and the insurers are different parties with distinctly different interests).

Traditional insurance schemes are based on some degree of independence of the insured events. An individual's chances of dying, being hospitalized, being in an automobile accident, losing property to fire, or whatever, are in part independent of whether or not other individuals suffer these fates in a particular policy year, and the insurance company will generally incur average losses in any year close to the true long-term expected average rates. Independence is only partial in these cases because, for example, low gas prices and good economic conditions can cause increased driving and hence increased accidents and poor economic conditions can increase arson rates. In addition, insurance companies will provide coverage*** for some non-independent losses resulting from catastrophic events, such as

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*As opposed to non-nuclear insurance (Workmen's Compensation, fire insurance) at nuclear facilities.

**This statement extends even to ANI. "That the atomic risk pooling is done by insurance companies does not of itself make it insurance, any more than something done by politicians is necessarily either politic or politics--or some particular thing done in classrooms by teachers is automatically instructive or educational." (Mehr & Hedges, 1963).

***Some authorities do not consider catastrophic insurance coverages to be true insurance (Mehr & Hedges, 1963).

hurricanes and earthquakes.

Some business risks involve events which are highly correlated, such as bankruptcy of small businesses, or obsolescence of equipment, especially in a narrowly defined field.* This concern applies to nuclear reactor decommissioning. Most of the premature decommissionings to date have resulted from plant-specific circumstances, such as Indian Point 1's cooling system or Humboldt's location. Dresden 1's problem with radiation accumulation may turn out to be unique or may turn out to be a generic problem with BWRs, but in any case the problem will not arise simultaneously for all BWRs. Rather, if it turns out that a contamination problem is common to BWRs in general, the pool would recognize, based on experience with Dresden and other early units, that BWR lifetimes are shorter than currently anticipated, and increase the required rate of reserve accumulation. The distribution of unit age will tend to prevent abrupt surprises regarding cumulative problems such as Dresden's.

Some other types of conceivable problems may be abrupt and systematic, however, resulting in a flood of decommissionings. For example, an error might be found in a generic design program, the NRC might tighten up on a set of rules, or a new technology might simultaneously make a generation of plants obsolete. Some of these events may be beyond the ability of the pool to handle; if one of these occurs, the retrospective premium limit may be exceeded, and the pool could go out of business. The possibility of non-independent decommissioning events thus limits the value of the pool, but does not cause doubt about the usefulness of its existence.

2. Moral Hazard

Three somewhat distinct phenomena are generally grouped as aspects of moral hazard:

(1) general laxity in loss prevention, which Mehr and Hedges (1963, p. 120) call the "loss-creating attitude of 'Oh, well, let it go; it's insured.'";

(2) laxity in cost control, once a loss has occurred; and

(3) intentional destruction of property.

The first two are sometimes also termed "morale hazard" to distinguish them from the more serious (and often illegal) acts of the third category.

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*Lloyd's of London's well-publicized problems with insuring computer-leasing operations resulted partly from failure to recognize the correlation in computer obsolescenses.

While some authors seem to regard any person who does not treat his insurance company's investment with the same care he would afford uninsured property as suffering from a serious moral deficiency, the economic literature on moral hazard (Arrow, 1963; Marshall, 1976; Forster and Steinmueller, 1978) treats this phenomenon as an inevitable aspect of economic behavior. While no one appears to doubt that moral hazard increases the number and/or cost of the insured events, the economic literature generally views moral hazard as a cost, rather than a barrier to insurance, and Forster and Steinmueller (1978) explicitly consider the conditions under which equilibrium exists despite moral hazard, and those in which moral hazard creates unstable conditions. The insurance literature is somewhat ambivalent concerning the impact of moral hazard on insurability:

> Intentional loss is not insurable for the obvious reason that if it were, people would deliberately destroy much of their property in order to be able to collect from the insurance company. Any time a business could not sell an old building or its inventory became obsolete, it could burn the inventory or building and collect from the insurance company. (Rodda, 1978, p. 15)

> There is no rate adequate for moral hazard. (Long and Gregg, 1965, p. 194)

> For the insurance mechanism to work the loss must not occur at the discretion of the insured... Even if such events are technically in his control (as in the case of fire losses under the personal property floater), he must not intentionally cause them to happen... The general idea behind fortuity is that the insured must be positively interested in the loss-producing event not occurring. This is not to say that when one insured ceases to be interested in preventing such event from occurring the whole insurance mechanism will collapse. The point is, rather, that insureds generally must have this interest or the mechanism will collapse in a hurry. (Long and Gregg, 1965, p. 36)

> Morale hazard can be and is amenable to the law of large numbers if about the same degree of morale hazard is in both the base experience from which the loss rate is computed and the situation for which a prediction is to be made. Since morale hazard is so widespread--a touch of the larcenous heart resides in so many breasts--comparability between groups in this regard tends to be high; consequently, this non-fortuitous cause of losses can be treated on a statistical basis and insured. (Mehr and Hedges, 1963, p. 120)

The applicability of moral hazard to nuclear decommissioning insurance has several features.

The extent to which insurance can result in laxity in cost control may possibly be more limited for nuclear power than for other technologies. The ability of plant owners to select cheaper-but-dirtier plants, or to skimp on maintenance and allow greater accumulation of radiation, is influenced by the NRC. If these choices avoid direct prior regulation, utilities face the risk that allowing radiation to accumulate will result in NRC orders restricting operation, increasing labor costs (by limiting individuals' exposure), requiring expensive decontamination, or forcing early retirement of the unit. If the contamination problem is more severe at the particular unit than in the industry as a whole, the utility might not receive regulatory approval to pass on to its customers the extraordinary costs of its errors in plant design, construction, or maintenance.* Nevertheless, moral hazard may dilute incentives for cost control over the costs of cleanup in the event of decommissioning. In this situation, financial incapacity tests, which are discussed in Appendix E, would have to be carefully designed to prevent potentially severe dilution of incentives for maintaining adequate reserves.

Utilities do have several strong incentives for avoiding early decommissioning in the first place, as distinct from their incentives once decommissioning is necessary. Retirement generally stops the flow-through to customers of O&M expenses, property taxes, insurance, return on investments, depreciation, and the decommissioning fund. Additionally, the utility loses the use of the accrued decommissioning reserve,** effectively paying another deductible, especially late in plant life. Above the reserve, the utility must pay the coinsurance on the decommissioning cost, which may be difficult to pass on to customers, especially if the plant is retired unusually early or due to management errors. The utility's future freedom of action (especially in terms of building new nuclear plants or other large high-technology generating facilities) may be restricted, its planning process may be subject to greater scrutiny, and it may receive a lower rate of return for any actual or apparent incompetence in maintaining its nuclear investment. Nuclear power reactors generally represent valuable investments which are lost when decommissioning occurs. The contribution of the unit to system reliability, the savings in operating costs compared to alternative sources of energy (KWH), the return and depreciation

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*A full analysis of the effects of regulation on utility behavior with respect to decommissioning occurrence and cost is beyond the scope of this Report. In general, however, rate regulation would appear to encourage utilities to prefer routine maintenance, the cost of which is relatively certain to be passed on to rate payers, to abnormal events (premature decommissioning, extensive decontamination, or cost overruns on decommissioning), for which compensation is less certain.

**The observation only holds true to the extent that the reserve is useful to the utilities. A utility with a fully segregated decommissioning fund might be expected to be more willing to retire its reactors.

on the plant (for regulated utilities), and the cost of replacement capacity (KW), all provide extremely large incentives to avoid decommissioning. These incentives are supplemented to a degree by the proposed deductibles and coinsurance. These incentives might be increased further by treating all or part of the coverage as a loan or surety, or by applying financial incapacity tests; these possibilities are discussed in Appendix E.

3. Adverse Selection

If the risk of the insurable event varies between potential buyers, if the buyers know their risk level better than the insurer, and if the coverage is not mandatory, then the worst risks will tend to buy the most insurance. As a result, the loss experience will tend to be higher than expected, premiums will increase, the best risks will leave the programs, and the process can cycle on itself until only the worst risks are left. This can be an expensive process for the insurer in traditional insurance, or for better risks in a self-insurance pool.

Three factors might possibly mitigate adverse selection in NAIDE insurance. First, the risk of premature or abnormally expensive decommissioning may be more uniform and information about the risk to individual units may be more readily available than for many other business risks. Second, to the extent that differential rating is possible, good risks and bad risks can be in the same pool with less penalties to the former. Third, depending on how strongly the NRC chooses to encourage reactor operators to obtain decommissioning insurance, coverage may in fact tend to be close to mandatory. Coverage will also probably be available at only one level for any particular reactor (although it may vary with reactor size and type). Thus, good risks may not be able to withdraw easily from the pool, and bad risks will not be able to expand their coverage, so the classic adverse selection cycle of excessive losses, higher premiums, and withdrawal of good risks could be impeded.

4. Conclusion on Insurability

The examination of the insurability aspect of NAIDE insurance performed in this report is rather cursory, and should be enlarged. While some of the utilities which reviewed this report expressed reservations about the business risk aspect of NAIDE insurance, this concern seemed to center more on the small size of current cost estimates for decommissioning, than on the basic insurability of NAIDEs, although the issue of insurability clearly concerned some. If the utility industry really expects decommissioning to cost only $50 million, then it will be hard to create much enthusiasm for NAIDE coverage. If the $250 million decommissioning cost suggested in this report is accepted, NAIDE insurance would be much more appealing.

In general, the available evidence suggests that some problems of insurability, especially moral hazard, could be serious for the NAIDE portion of the insurance. Other problems, including non-independence of losses, speculative gains, and adverse selection are less serious or surmountable. On the whole, the evidence is not strong enough to establish that any of the problems discussed would be sufficiently severe to prevent formation of the pool for AIDEs but further analysis and design would be required to be as confident for NAIDEs. The stability and efficiency of a decommissioning insurance pool for non-accident events remain open questions.

It is important to recall that utilities already operate under the influence of a number of inefficient incentives. These incentives generally arise from the differences in ratemaking and tax treatments of various kinds of costs (e.g., fuel expense, other operating expenses, capital costs, amortization of retired plants). Certain existing incentives discourage timely retirement and decommissioning, while others may encourage early retirement. Similarly, some incentives may shift the behavior of owner/operators towards preventive maintenance, while others shift the balance towards increased cleanup costs. Depending upon the relative strengths of the existing incentives, NAIDE insurance may either exacerbate or mitigate the existing net biases on retirement decisionmaking.

C. Frequency

As of 1981, 79 commercial LWRs had received operating licenses in the U.S. and 78 had been in operation for a year or more. Of the 78, three (Pathfinder, BONUS, and Elk River)* that were retired early (in one to four years) were small demonstration reactors of unusual design; these were the only reactors of the entire group meeting these criteria. Since their experience is believed to be anomalous for the population of reactors that is of current interest, they were excluded from our main summaries of analyses presented below. However, a footnote to Table B-8 below shows that inclusion or exclusion of the three early reactors has little effect on the estimates of reactor lifetimes.

Among the remaining LWRs, there has been one unequivocal NAIDE at Indian Point 1, which has been formally retired. Both Humboldt Bay and Dresden 1 appear to have suffered NAIDEs, although the utilities have not publicly announced their retirement. Humboldt Bay has not operated since July, 1976; Dresden 1 has been out of operation since October, 1978, and is not scheduled to restart until 1986. It seems likely that Humboldt Bay and Dresden 1 have experienced NAIDEs, and will not operate again. The operator of the LaCrosse plant has indicated plans for premature retirement of that unit as well, in the 1987-90 time frame, when it will be between 18 and 21 years of age. Thus the most relevant set of experience to date includes at least two, and at most three, NAIDEs.** Experience by 1990 will include four NAIDEs, if the LaCrosse plant is retired prematurely as planned, and possibly more.

Table B-7 shows the commercial operation date (COD), current age, and (where applicable) date and age at last operation, for all units starting commercial operation in 1970 or earlier, except the three BWRs discussed earlier which are excluded from analysis. The paucity of data on nuclear plant longevity is apparent from Table B-7. Only 12 plants have reached 10 years of age, and only 2 have reached 20 years.

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*BONUS and Elk River were very small reactors (16.5 MW and 22 MW, respectively), which were owned by the AEC and were never accepted by the utilities which operated them. Pathfinder was somewhat larger (58.6 MW), but was in full-power operation for only four months; in the fifteen months in which it was in operation, Pathfinder generated less than three months of full thermal power, and presumably even less electrical power. Both Pathfinder and Elk River were described as "small experimental prototype reactors" by the FPC (1968), which does not appear to have noted BONUS' demise at all.

**Other NAIDEs may have already occurred, but may not yet be evident. Any unit currently shut down might never restart, thus becoming (retroactively) a NAIDE as of the starting date of the final outage.

TABLE B-7

ALL LWRS OLDER THAN 10 YEARS, INCLUDING ALL NAIDES TO DATE*

PLANT	COMMERCIAL OPERATION DATE	LAST OPERATION DATE	LAST OPERATION AGE	CURRENT AGE (9/81)
Dresden 1	7/60	10/78	18.3	21.2
Yankee Rowe	7/61			20.2
Indian Point 1	10/62	10/74	12.0	18.9
Big Rock Point	3/63			18.5
Humboldt Bay	8/63	7/76	12.9	18.1
Connecticut Yankee	1/68			13.7
San Onofre 1	1/68			13.7
La Crosse	9/69			12.0
Oyster Creek	12/69			11.8
Nine Mile Point	12/69			11.8
Ginna	7/70			11.2
Point Beach 1	12/70			10.8

* See text for explanation regarding the determination of a NAIDE

TABLE B-8

PRODUCT-LIMIT ESTIMATES OF LWR CUMULATIVE SURVIVORSHIP RATES

Plant*	Observed Service Life	Number of Units Surviving To Each Age	Number of Units Experiencing A NAIDE in Each Interval**	Fraction of Units Surviving To Each Age Which Did Not Experience a NAIDE In Each Interval	Cumulative Survivorship Rates***
Point Beach 1	10.8+	12	0	1	1
Ginna	11.2+	11	0	1	1
Nine Mile Point	11.8+	10	0	1	1
Oyster Creek	11.8+	10	0	1	1
Indian Point 1	12.0	8	1	7/8	.875
La Crosse	12.0+	7	0	1	.875
Humboldt Bay	12.9	6	1	5/6	.729
Connecticut Yankee	13.7+	5	0	1	.729
San Onofre 1	13.7+	5	0	1	.729
Dresden 1	18.3	3	1	2/3	.486
Big Rock Point	18.5+	2	0	1	.486
Yankee Rowe	20.2+	1	0	1	.486

*All figures calculated as of September, 1981. A '+' indicates that unit is still in service.

**An interval is defined as the period from the observed service life of each plant, inclusive, to the next service life, exclusive.

***This column is obtained by multiplying the entries in column 5 from the first censored age to the current censored age. Including the reactors Pathfinder, BONUS, and Elk River changes the results slightly. Assuming that the equivalent of commercial operation followed first electric generation by six months, Pathfinder was in operation 8 months, BONUS for 40 months, and Elk River for 47 months. As of 9/81, 72 LWRs had survived over 8 months, 66 over 40 months, and 63 over 47 months. Thus, the cumulative survivorship to 47 months is (71/72) (65/66) (62/63)= .956. Including these three plants would thus multiply all survivorship estimates over four years by .956; the 20-year survivorship would be .465. This is not very different from .486, the survivorship estimate obtained when excluding these three reactors.

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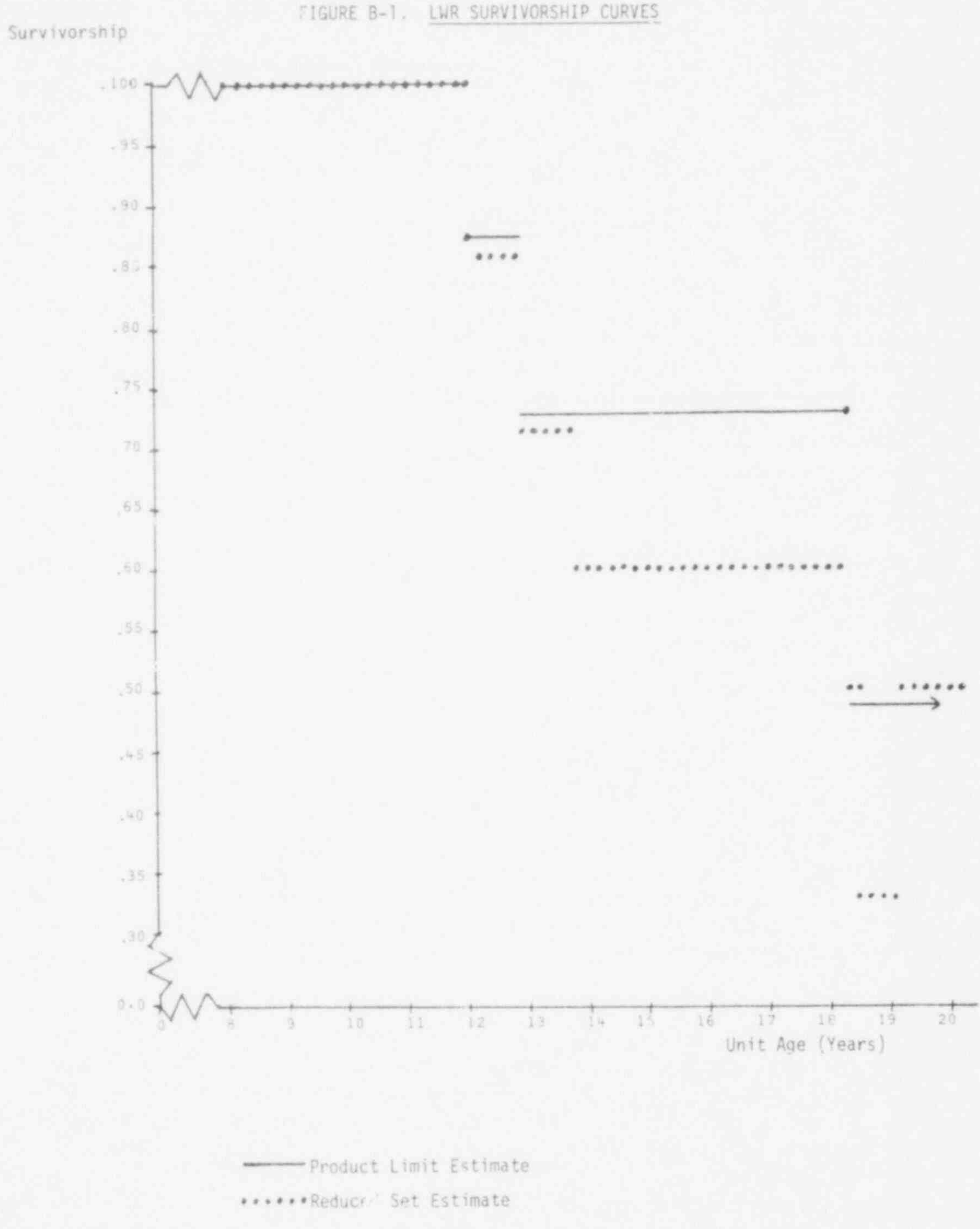
TABLE B-9:

REDUCED-SET ESTIMATES OF LWR SURVIVORSHIP RATES

Plant	Plant Age in Years* From: 0 To:** 12.0	12.0 12.1	12.1 12.9	12.9 13.8	13.8 18.2	18.2 18.3	18.3 18.5	18.5 18.9	18.9+
Dresden	0***	0	0	0	0	0	●	●	●
Yankee Rowe	0	0	0	0	0	0	0	0	0
Indian Point 1	0	●	●	●	●	●	●	●	
Big Rock Point	0	0	0	0	0	0	0		
Humboldt Bay	0	0	0	●	●				
Conn. Yankee	0	0	0	0					
San Onofre 1	0	0	0	0					
La Crosse	0	0							
No. of Units Reaching this age	8†	8	7	7	5	4	4	3	2
No. of Units Surviving	8	7	6	5	3	3	2	1	1
Survivorship	1.00	.875	.857	.714	.600	.750	.500	.333	.500

NOTES: *Data to September, 1981
**Second endpoint not included in interval
***0 = Plant survived this age; ● = Plant did not survive this age
†Or more

FIGURE B-1. LWR SURVIVORSHIP CURVES



This limited data can be converted to a survivorship function either by the product-limit method or by the reduced-set method. Discussion of these methods can be found in Lee (1980). These are the continuous analogues of, respectively, the annual-rate method and the composite original group method traditionally used in utility depreciation studies (Winfrey, 1935). The results of these methods are presented in Tables B-8 and B-9, and in Figure B-1. Note that the data aggregate all vintages, sizes, and types of LWRs, and that LaCrosse's retirement is not included in these figures, because its retirement is still well in the future, whether it is retired prematurely or not.

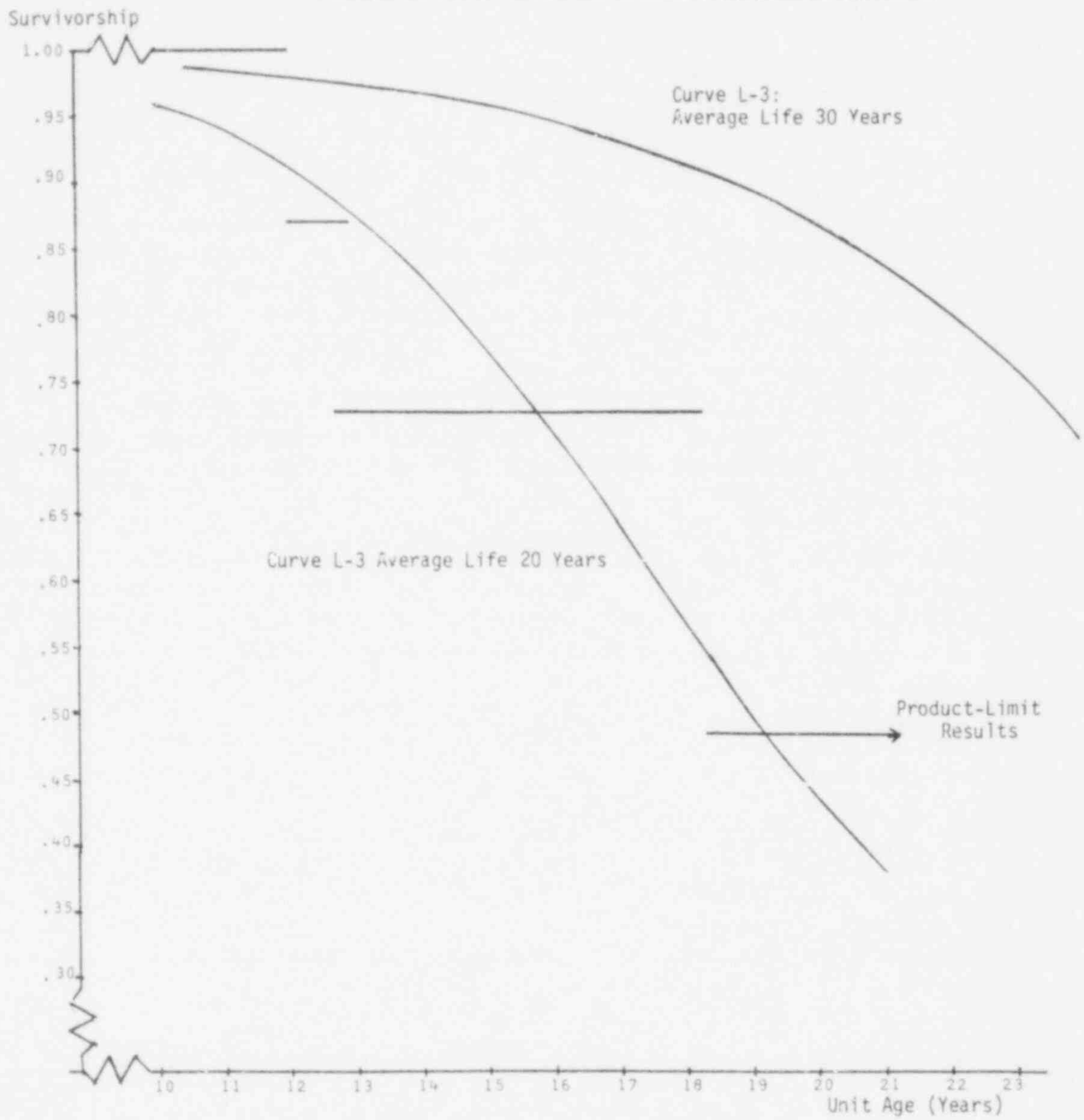
The product-limit survivorship estimate makes more efficient use of the data than the reduced-set estimate. In obtaining a survivorship estimate after a number of years, say X years, the product-limit method uses data from all reactors which operated less than and including X years, while the reduced set method only considers reactors which operated a full X years, and reactors which suffered a NAIDE within the X-year period. The product-limit estimate would seem to be more appropriate for use here.

The experience to date has been quite scanty, and the experience with early small units, built at least partially for demonstration purposes, may not be representative of future experience with more recent large units, which are built as more nearly routine construction projects. It is not even clear whether future experience can be expected to be better than past experience. For example, the larger size of new units increases both the difficulty of correcting problems and the reward for doing so. Increased regulatory involvement in unit construction may decrease the frequencies of such errors as Humboldt's location, or Indian Point 1's cooling system design, but it may also introduce new systems to wear out and to complicate retrofit and repair. The rate of addition of regulatory standards may continue its historic acceleration, or it may stabilize, decrease, or even become negative; it could do each of these sequentially over the next twenty years. The very fact that nuclear construction has become routine might produce better plants due to increased experience, or worse plants due to decreased care and excessive demand for limited quantities of skilled labor.

In addition to the problems of extrapolation of data, it must be recognized that the data are exceedingly sparse. Even assuming the comparability of all reactors, there are only three retirements. As a result, any inferences drawn from this data are necessarily quite weak. For example, the product-limit estimate of survivorship after age 18.3 is .486, and an estimate of its standard deviation is 0.216.

For the purposes of this report, two alternative distributions of non-accident premature decommissioning are used. The retirement curve presented by Winfrey (1935) which appears to be most similar to the data is Curve L-3 with approximately a twenty-year average life. For sensitivity purposes, the same curve is used with the commonly assumed thirty-year average life, for which the data set provides no real support, but which cannot be rejected on the basis of the current data. These curves are compared to the product-limit results in Figure B-2.

FIGURE B-2: COMPARISON OF PRODUCT-LIMIT RESULTS TO WINFREY CURVE L-3



D. Average Cost of Decommissioning

In order to estimate the pool's expected losses and hence the pool's expected coverage costs, both the probability and the expected cost of the insured event must be estimated. The easiest way to determine the average cost is to define it as a fixed indemnity, as NEIL does, rather than actual cost to the insured.* The estimation problem may also be simplified by providing for only a small portion of the possible loss, in order to restrict the range over which the pool's loss on each event may vary. Unfortunately, neither of these approaches is really suitable for decommissioning/decontamination insurance, if the objective of such insurance is to provide a high level of assurance that funds will be available to pay the actual cost of the decommissioning, so that the process may proceed in an orderly and safe fashion.

Engineering estimates of the cost of decommissioning nuclear reactors are available, but there are reasons to suspect that they are not appropriate for directly estimating insurance premiums, without first making certain adjustments. It is well known that engineering cost estimates for other activities related to nuclear power, such as plant construction and operation, have been unreliable and consistently understated, and that costs have increased rapidly over time in real (inflation-adjusted) terms.** Since engineering estimates have not been accurate in predicting other nuclear power costs, there is some reason to believe that a decommissioning/decontamination expense insurance pool neither should nor would accept unadjusted engineering cost or time estimates for nuclear power plant decommissioning.

The similarities between the cost estimation problems of nuclear power plant construction and nuclear power plant decommissioning extend beyond the common association with reactors and the handling of radioactive materials.***

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*Of course, even NEIL must estimate the actual cost in order to apply the indemnity limit of 90% of actual cost. NEIL presumably requires this coinsurance to limit premium costs and to avoid moral hazard.

**Some of these problems are discussed in the Introduction to this Appendix.

***Of course, the construction of nuclear power plants occurs before the radioactive inventory is put in place, while decommissioning is primarily concerned with removing the by-products of fission. The very rapid (and apparently unanticipated) real increases in nuclear reactor operations and maintenance (O&M) expense (on the order of 10% per year in the 1970's) illustrate that the costs of handling radioactive systems can be as volatile as the costs of preparing for them in original construction.

Decommissioning seems to share at least two of the problems frequently cited as contributing to nuclear construction cost overruns (see, for example, Perl, 1978, p. 9; Blake, et al., 1976, p. 28; Bergstrom and Brandfon, 1979, p. 3; Crowley, 1978; ORNL, 1980). First, the scope of the decommissioning project is not yet entirely clear, and is subject to change both before the start of the project and during its course. Second, as a result of such phenomena as continuing changes in the definition and scope of the decommissioning process, productivity misestimation, variability in decisionmaking schedules by regulators and owner/operators, and others, the schedules and durations of various decommissioning activities are subject to substantial change. Some major impacts of delay, such as inflation and the inflation-related portion of interest charges, are eliminated by defining costs in constant dollar terms. However, delay has other effects which are quite real, such as decreased productivity, the costs of maintaining (or repeatedly mobilizing and demobilizing) crews and equipment during slack periods, and the costs of continuing maintenance and security. Technical advance, though, could reduce costs.

In some ways, decommissioning may be more vulnerable to changes in scope and schedule than is nuclear construction. Nuclear power plant construction has been a continuing, ongoing process at least since 1963, so engineers have had an opportunity to observe construction progress and problems in further-advanced plants when they plan and construct later plants. While regulatory requirements have changed over time, there have been active construction permits (and hence, plant designs with at least preliminary and temporary approval) for over 18 years. There was also a rather steady stream of operating licenses issued from 1968 to 1979, providing engineers with continuing signals regarding the acceptability of designs.

The experience in dismantling power reactors, on the other hand, is essentially limited to the Elk River reactor, a very small (22 MW) BWR which operated for only 4.4 years and which was decommissioned between 1971 and 1974. The Elk River experience may prove to be of limited value in estimating the costs of decommissioning reactors 50 times as large, which will have operated perhaps 7 times as long, and which will be decommissioned perhaps 20 years after Elk River. This lack of actual decommissioning experience contrasts to the steady stream of contemporary data for similar-sized plants available for nuclear construction cost estimation.

Based on the preceding discussion, it seems imprudent to make use of unadjusted engineering cost estimates of decommissioning expense in calculating decommissioning coverage costs. Unfortunately, there is no independent alternative cost estimation procedure; the same lack of experience which contributes to decommissioning cost uncertainty prevents the use of the regression techniques, which have been applied to nuclear construction costs and to nuclear O&M costs (Perl, 1978; Mooz, 1978; Chernick, 1980). Thus, the best course of action seems to be adjusting the existing engineering cost estimates. Short of repeating the engineering estimation work with more specific knowledge of future conditions (which is probably not available currently), the most reasonable approach seems to be an extrapolation of past levels of nuclear cost mis-estimation.

The historic experience from which nuclear cost underestimation may be extrapolated consists of construction costs, and operations and maintenance (O&M) expense. The former seems more applicable to decommissioning cost estimation for two reasons. First, construction cost estimates are available for several operating units, and several estimates are often available for the construction of a single unit. O&M cost estimates appear to be much less common; in general, nuclear O&M expense increases have received less attention than nuclear construction cost increases. Second, O&M is a small, ongoing expense which, despite recent increases, remains a relatively small percentage of total generation costs once a plant is on line; by contrast, initial construction cost (like decommissioning) is a single large discrete event, with a fairly well-defined conclusion. Therefore, this analysis will extrapolate decommissioning costs by using nuclear reactor construction cost experience.

The term myopia refers to shortsightedness in planning ahead. Myopia factor, in the context of this Report, describes the phenomenon of mis-estimating the nuclear reactor construction costs under discussion. Estimates for the myopia factor are derived in this section. In modeling these mis-estimates in nuclear construction cost estimation, it seems reasonable to expect that:

a. Despite the inherent uniqueness of each project, there has been some systematic, industry-wide tendency to underestimate nuclear construction costs.

b. Errors are apt to be larger for long-term projections than for short-term projections; the closer a project is to completion, the more accurate the cost estimate should be.

c. Since it is easier to predict changes in conditions in the short-term than in the long-term, changes in the first year after an estimate are more likely to be accurately predicted than changes in the second year after the estimate, and so on. Hence, incremental errors will tend to increase as the time span (from the estimate date to the completion date) increases, and an increase in the time span covered will be associated with an increase in the total error of the estimate.

Also, in order to be useful in estimating the cost of projects whose actual completion dates and durations are not yet known, we would expect a model to have a fourth characteristic as well:

d. The relevant time span for calibrating models of future cost is the period from the date of the estimate to the estimated date of completion, rather than to the actual completion date.

To check these expectations, all readily available* cost estimates for nuclear units which have now been completed were assembled. All cost estimates which included the following were used:

a. estimate date (month and year);
b. estimated completion date (month and year), and cost;
c. actual completion date (month and year), and cost; and
d. more than one year to estimated completion.

Twenty-one such estimates were available; they were estimates for seven different units. For each estimate, the following data were derived:

E = estimated cost of the unit, in 1965 dollars,** as of the time of this estimate;

A = actual cost of the unit when completed, in 1965 dollars; and

t = estimated time to completion (time from estimate date to projected completion date).

Figure B-3 plots the ratio of A to E, which is a measure of engineer overconfidence, versus t for the twenty-one cost estimates. While the data is somewhat scattered, it is certainly consistent with the prior expectations (a) to (d), above. Note that any function constructed from these estimates must logically pass through the point $t=0$, $A/E = 1$, which corresponds to the final cost report.

Four models were fitted to the data in Figure B-3. These were the unity-intercept linear

$$A/E = 1+mt + \epsilon, \qquad \text{(B-6)}$$

the unconstrained linear

$$A/E = a+mt + \epsilon, \qquad \text{(B-7)}$$

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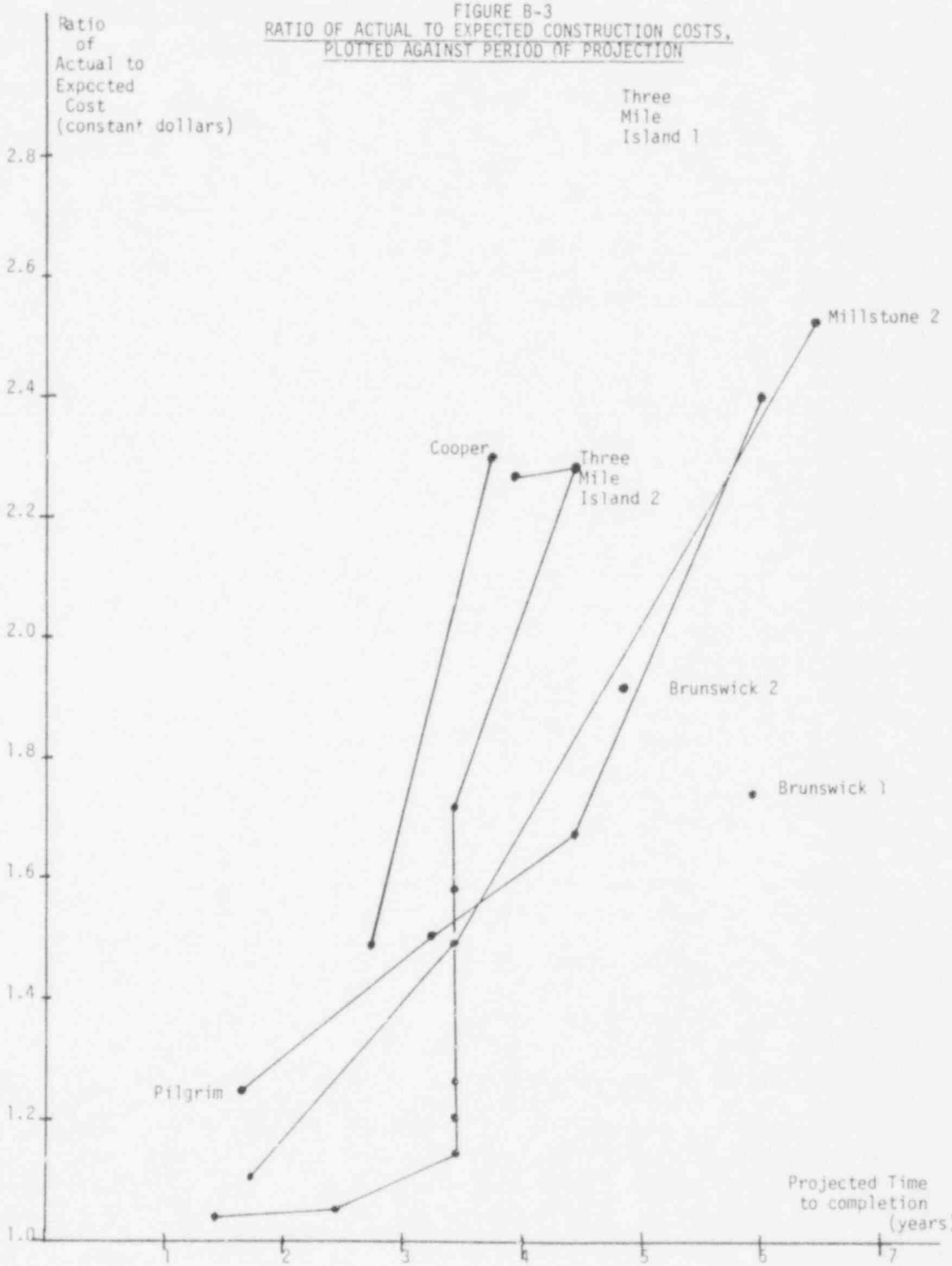
*Other estimates would presumably be available from an exhaustive search of administrative dockets in various jurisdictions.

**The Handy-Whitman Total Nuclear Production Plant deflator for the appropriate region was used.

FIGURE B-3
RATIO OF ACTUAL TO EXPECTED CONSTRUCTION COSTS,
PLOTTED AGAINST PERIOD OF PROJECTION



NOTE: Lines are drawn connecting estimates for the same reactors in chronological order of estimate date.

the unity-intercept exponential

$$A/E = (1+m)^t_\gamma, \text{ and} \tag{B-8}$$

the unconstrained exponential*

$$A/E = a\ (1+m)^t_\gamma. \tag{B-9}$$

The m in equations (B-6) through (B-9) represents the myopia factor.

The variables a and m in equations (B-6) through (B-9) were estimated using ordinary least squares regression; the regression equations obtained were:

$$\widehat{A/E} = 1 + .204t \tag{B-6a}$$

$$\widehat{A/E} = .598 + .300t \tag{B-7a}$$

$$\widehat{A/E} = (1 + .147)^t \tag{B-8a}$$

$$\widehat{A/E} = .844\ (1 + .195)^t \tag{B-9a}$$

where equation (B-6a) is the regression equation corresponding to the model in equation (B-6), and so forth. Thus, the estimates of the myopia factor m are 0.204 (equation B-6); 0.300 (equation B-7); 0.147 (equation B-8); and 0.195 (equation B-9).

It is important to determine whether substantial portions of the estimated myopia factors represent engineering underestimates of inflation to the expected commercial operation date (COD), as opposed to errors in estimating real (inflation-adjusted, constant dollar) costs. The distinction is critical for the current application. In estimating decommissioning costs, errors in projecting inflation are of little importance, since the investment income earned on decommissioning reserves (whether held by the owner/operator or by the pool), and hence the value of the reserves, will generally tend to rise with inflation, as will revenues, earnings, net plants in service, and other measures of owner/operators' ability to pay retroactive premiums. By contrast, errors in projecting real costs will not be offset by equivalent compensating changes in reserves and resources.

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*ε in equations (B-6) and (B-7) is an additive error term which has an expected value of zero. The γ term in equations (B-8) and (B-9) is a multiplicative error term with an expected value of one. These error terms are necessary because the true functional form of the A/E ratios will not be fit exactly by equations (B-6) through (B-9) above.

Since actual inflation between the expected COD and the actual COD is a component of m, underestimates of inflation can only overstate m in equations (B-6) through (B-9) by:

$$m = m' (1+a)/(1+e) \qquad \text{(B-10)}$$

where m' = true myopia factor

a = actual annual inflation rate from estimate date to estimated COD (actual escalation rate)

e = inflation rate used in estimate (projected escalation rate)

To determine whether the observed values of m might be due to engineers' underestimates of inflation to the expected COD, the inflation or escalation rates used in five specific estimates and one generic estimate were compared to the actual inflation experience to date. This information was obtained from the available Plant Capital Investment Summaries. The results of that analysis are presented in Table B-10. The unanticipated inflation which would show up in the m values, as measured by the factor (1+a)/(1+e) in equation (B-10), varies from less than .1% to about 2.3%.* Further, WASH-1150 indicates that at least some architect/engineers were predicting inflation to within 1.8 points of actual inflation as early as mid-1969. Thus, it appears that at most only about one or two percentage points of the m value can be attributed to underestimates in inflation rates, at least for the cost estimates for which specific inflation rates are available.

As a further check on the influence of inflation estimates on the myopia factors, a myopia analysis was performed for the one early cost estimate which was available with all inflation removed; the estimate of $134/kw in constant 1967 dollars, from WASH-1082 (AEC, 1968). The reference unit used in WASH-1082 was a 1000 MW, privately financed first unit. This estimate was then compared to the actual costs of twenty-one units for which a construction permit application was filed in 1967, and/or a construction permit was received in 1968, the time frames of WASH-1082. (Of the other five units which met the timing criteria, two were covered by fixed-cost turnkey contracts, the costs for two are not reported separately,** and one is not yet in operation.) When discounted to 1967 dollars

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*This value obtained using data from Seabrook 1, where the projected escalation rate employed is the average of materials and labor rates.

**These units are Peach Bottom 2 and 3, both of which entered service in 1974. Inclusion of both units in the regression by assigning each half their combined cost and counting Unit 3 as a second unit produces substantially similar results.

TABLE B-10

COMPARISON OF ACTUAL NUCLEAR COST INDEX ESCALATION RATES WITH ENGINEERING PROJECTIONS FROM PROJECT COST ESTIMATES

Unit	Estimate Date	Apparent Escalation Period	Projected Escalation Rate*	Actual Escalation Rate and Period**
Seabrook 1	8/73	?/74 - 11/79	6% material	9.44% (1/74 - 1/80)
2	8/73	?/74 - 8/81	8% labor	9.41% (1/74 - 1/81)
Seabrook 1	2/75	?/75 - 11/80	8%	8.08% (1/75 - 1/81)
Seabrook 1	5/79	7/76 - 4/83	8% simple	9.26% simple (7/76 - 1/81) 8.05% compound
Pilgrim 2	10/74	?/75 - 8/80	6.8%	7.92% (1/75 - 7/80)
Generic***	6/69	6/69 - 6/75	7.5%	9.4%

* All rates in table compound, except as noted

** Actual rates from Handy-Whitman

*** AEC, 1970

and normalized to the 1000 MW size used in WASH-1082, the costs for privately financed first units ranged from \$160 to \$371 per kw, with an average of \$244/kw.* Since the estimate from WASH-1082 was intended for reactors entering commercial operation within 5.5 years, applying the range of actual costs above and the WASH-1082 estimate to equation (B-8) yields an estimated myopia range of 3.3% to 20.3%; the average yields a myopia estimate of 11.5%. Using the linear myopia model, equation (B-6), the myopia factors implied by these ratios of actual to expected cost range from 3.5% to 32.2%, and the average value above yields an estimate of 14.9%. The unit which is not yet in service (Diablo Canyon 1) will almost certainly be more expensive than the twenty-one unit average, so the actual average myopia factors for the cohort will almost certainly be somewhat higher than the estimates based on the available data, and thus consistent with the results of the earlier analysis.

A myopia phenomenon similar to that found in nuclear construction can be observed in the current engineering estimates of decommissioning cost. Oak, et al. (1980) report that staff labor costs for BWR dismantlement,** estimated at \$17.6*** million, would have been \$7 million lower if calculated by the method used in the PWR estimates (Smith, et al., 1978), which

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*A multiple regression was run on the twenty-one units, using the logarithm of the cost per KW as the dependent variable. The independent variables were indicators for private financing and for first units, and the logarithm of size in MW. The average value discussed is the predicted cost per KW, for a unit with the characteristics of the reference unit in WASH-1082. Normalization was done by multiplying the actual cost per KW by the term (MW/1000), raised to the coefficient of the size variable in the regression equation. The estimated regression coefficients can be interpreted to indicate that unit cost is proportional to capacity raised to the .96 power, for reactors of similar unit type (first or second) and financing; that public ownership is associated with a lower unit cost of 14%, for reactors of similar size and unit type; and that second units are 29% cheaper than first units, for reactors of similar size and financing.

**Prompt dismantlement is the only type of decommissioning for which cost estimates are discussed in this Report. Lead times for mothballing and entombment, the other suggested decommissioning alternatives, are so long as to render cost estimation by myopia correction highly speculative. In addition, NRC policy seems to favor prompt dismantlement.

***Except as noted, all costs are before contingency and in 1978 dollars.

neglected some constraints on staff radiation exposure. Assuming that the percentage change in staff labor costs due to the change in methodology also applies to PWR dismantlement, the PWR cost estimate would be about $6 million greater under the revised methodology. Total cost estimates, before contingency, were $24.8 million for the PWR and $34.8 million for the BWR; the estimates were completed in May, 1978, and October, 1979, respectively. Expected changes due to methodology revisions would produce an estimated total cost of $30.8M for PWRs in October, 1979, and of $27.8M for BWRs in May, 1978. Thus, methodological refinements over a period of 1.4 years increased the cost estimates by 24% for the PWR and 25% for the BWR. If these increases are considered typical of increases to completion, they can be used to estimate myopia factors of .16 to .17 using equation (B-8) or of .17 to .18 using equation (B-6).

The importance of the myopia adjustments is a function of the time (t) into the future for which costs are being estimated. For decommissioning costs, this period is considerable. If rates are being set for 1983, for example, the decommissioning cost estimates from 1979 (Oak, et al., 1980) would be four years old. If a premature decommissioning event occurs in 1983, and is promptly recognized as such, current estimates (e.g., Oak, et al., 1980) suggest that prompt decommissioning would require about six years. However, past premature decommissionings have not been promptly recognized. For example, Indian Point 1 was shut down for about six years before it was even retired, while Dresden and Humboldt have not yet been officially retired by their owners. (Humboldt has been retired for rate making purposes.) No plans for dismantling Indian Point 1 have yet been announced, and of the eight* other retired commercial power reactors, only one (Elk River) has yet been dismantled. Thus, t may be as low as 10 years and/or high as 15 years or more at the present, for premature decommissionings.

Annual re-estimation of decommissioning cost, combined with NRC commitments to recognize premature retirements quickly and to require planning for decommissioning to start as soon as possible after shutdown (or before, if the reactor is a likely candidate for early retirement), could lower future values of t for premature decommissioning** to the five- to eleven-year range. This estimated range is based on assumptions that approximately one year elapses between the cost estimate date and the date the plant shuts down, that projected dismantlement duration is four years (if planning is completed before shutdown) to six years, and that the period

*Three of the eight are reactors eliminated from analysis for reasons discussed in §III (C); the other five are not LWRs.

**This value of t would apply to any unexpected decommissioning, whether the plant had reached the end of its originally projected life or not.

between shutdown and recognition of premature decommissioning can be limited to the zero to four year range. The value of t for retirements which take place on schedule and which promptly lead to decommissioning, would be five years. However, utilities are often reluctant to dismantle plants which can be kept in a deactivated state as insurance against higher-than-anticipated load growth, construction delays on new plants, or poor performance by existing or new capacity. Thus, dismantlement may be delayed even for scheduled retirements unless physical or regulatory conditions clearly preclude restart or recommissioning, or unless the NRC takes a very aggressive position in forcing prompt dismantlement. Scheduled retirements are not currently relevant, since the first candidate for scheduled retirement seems to be La Crosse, sometime after 1987.

By combining the currently reasonable range of values for t, 10 to 15 years, with the equations (B-6a) through (B-9a), a range of A/E ratios can be derived. Table B-11 presents this range of A/E estimates, or cost multipliers, which vary from 3.0 to 12.2. The median value of this distribution of A/E ratio estimates is close to five and the mean to six, with a range of plausible values from about three to twelve. Note that t = 10 is an absolute minimum, but that t = 15 is by no means a maximum; on the other hand, Table B-11 does not correct for the small inflation-prediction error in the historic price projections. The A/E ratios from Table B-11 are used in Table B-12 to derive a range of corrected cost estimates for decommissioning various size plants.

Table B-11 presents decommissioning cost estimates for PWRs using a range of plant capacities and of A/E ratios. The estimates of decommissioning costs as a function of size in Table B-12 are taken from the sensitivity analyses of Smith and Polentz (1979) and Oak, et al. (1980), and are scaled using the Overall Scale Factor (OSF) function they developed for each reactor type. Despite the problems in predicting reactor construction costs, engineers have been fairly accurate in predicting the extent of economies of scale in reactor construction. For example, if s is defined as the scaling factor in the traditional economies of scale equation (deNeufville and Stafford, 1971):

$$\frac{\text{cost of unit 1}}{\text{cost of unit 2}} = \left[\frac{\text{size of unit 1}}{\text{size of unit 2}}\right]^{s} \qquad \text{(B-11)}$$

then the economies of scale claimed in the studies reviewed and presented in ORNL (1980) are equivalent to scaling factors of about 0.49 to 0.55. The New England Power Pool (NEPOOL, 1976) assumed economies of scale for nuclear construction equivalent to about s = 0.78. These engineering assumptions are generally consistent with the results of econometric studies. Per (1978) found that s = 0.4, but most of the large plants in his data set were still under construction, and as much as seven years from estimated completion. Therefore, those plants were represented by estimated costs, which would tend to bias the time and size coefficients downwards. Mooz (1978) used only a few short-range estimates for plants with operating licenses, and derived economies of scale equivalent to s = 0.7 over

TABLE B-11

RATIO OF ACTUAL COST TO ENGINEERING ESTIMATES OF COST FROM MYOPIA ANALYSIS

Myopia Equation Form	Equation Number	Projected Years to Completion of Decommissioning (t) 10	15
unity-intercept linear	(B-6a)	3.0	4.1
unconstrained linear	(B-7a)	3.6	5.1
unity-intercept exponential	(B-8a)	3.9	7.8
unconstrained exponential	(B-9a)	5.0	12.2

TABLE B-12

CORRECTED DECOMMISSIONING COST ESTIMATES FOR PWRS

	Plant Size Category		
	Small	Medium	Large
Capacity (MW)	175	500	1175
Current Cost Estimates (1978 dollars)*	14.8**	25.1	38.5
Currest Cost Estimates (1981 dollars)***	19.6	33.1	50.8
Ratio of Actual to Estimated Cost (1981 dollars)			
3.0	58.8****	99.3	152.4
5.0	98.0	165.5	254.0
8.0	156.8	264.8	406.4
12.0	235.2	397.2	609.6

* Estimates for the small and medium size plants were obtained using the traditional economies of scale equation, a scaling factor of 0.5 and available data on large size reactors. See text. Costs are for PWRs (Smith, et al., 1978); costs for BWRs appear to be about 12% higher (Oak, et al., 1980). Labor constraints of Oak, et al., (1980) assumed. See text.

** All costs in millions of dollars, expressed to the nearest 0.1 million.

*** 1981 costs are assumed to be 32% greater than 1978 costs; Handy-Whitman regional cost indices for nuclear production plant are 29.7% to 34.6% higher in 1/81 than for 1/78.

**** The Decommissioning Cost Estimates are obtained by multiplying the Current Cost Estimates by the Ratio of Actual to Estimated Costs.

the range of his data.* Hence, it seems reasonable to adopt the engineering estimates for decommissioning OSF, which are equivalent to scaling factors of s = 0.55 for PWRs and s = 0.46 for BWRs in the 500 MW(t) to 3500 MW(t) range.

*The 21 units compared to the WASH-1082 projection showed much weaker economies of scale, with s estimated to be 0.96. Thus, it would appear that the costs of reactors in this data set appeared to keep pace with increases in size. However, the standard error of this coefficient was 0.21; in light of this, 0.96 is not very different from the results above.

E. Estimation of Expected Coverage Cost for Non-Accident-Initiated Decommissioning Events

From equation (B-3) and the previous observation that neither risk aversion nor investment income should significantly affect the decommissioning pool premiums,

$$R(t) = E\left[L(t)\right] / (1-N) + \varepsilon \qquad \text{(B-12)}$$

where

$R(t)$ = expected coverage cost at age t

$L(t)$ = expected losses due to a NAIDE at age t

N = expense fraction

and ε = term representing factors not accounted for, which are assumed to have little or no effect on expected coverage cost.

For NAIDE coverage

$$E\,[L(t)] = p(t) \cdot S(t) \qquad \text{(B-13)}$$

where $p(t)$ = probability of retirement at age t, given that the plant has not been retired before age t

$S(t)$ = average loss at age t, given that a loss occurs.

If the deductible is equal to an accrued decommissioning reserve which accumulates linearly to the expected life of the plant (T), and the cost of decommissioning is a known quantity (C), then:

$$S(t) = \begin{cases} C(1-d) \cdot (T-t)/T & \text{for } t \le T \\ 0 & \text{otherwise} \end{cases} \qquad \text{(B-14)}$$

where S = loss to the pool
T = assumed plant life for depreciation reserve
t = age at last generation of electricity
C = cost of decommissioning
d = coinsurance rate,

The decommissioning cost, C, need not necessarily be the correct cost of decommissioning at the end of the unit's anticipated life; the model assumes that it is the current target for the decommissioning reserve and the actual cost of decommissioning a unit which experiences a premature decommissioning event in the average year.* This model also assumes that cost overruns do not occur and that all units have accumulated adequate decommissioning reserves at the end of their anticipated life, so no coverage is provided for scheduled retirements.

While it is reasonable for the pool to establish a deductible tied to current estimates of decommissioning costs, it is not reasonable to assume that these costs are perfectly known, as demonstrated in §III (D) of this Appendix, above.

If the actual decommissioning cost, c, is a random variable with mean C, then the average value of S will be larger than in the deterministic cost case considered above.

For example, if the actual decommissioning cost is random variable c, with a range of .5C to 1.5C, then the pool's loss in the event of a NAIDE is also random:

$$\tilde{S}(t,c) = \begin{cases} (1-d)\cdot\left(c - \frac{Ct}{T}\right) & \text{for } 0 \le t < T/2 \\ (1-d)\cdot\left(c - \frac{Ct}{T}\right) & \text{for } T/2 \le t < T \text{ and } c > \frac{Ct}{T} \\ (1-d)\cdot(c-C) & \text{for } T \le t \quad, c > C \\ 0 & \text{otherwise} \end{cases} \qquad \text{(B-15)}$$

Averaging over the possible values of c yields

$$E_c\,\tilde{S}(t,c) = \begin{cases} C(1-d)\,(T-t)/T & \text{for } 0 \le t < T/2 \\ C(1-d)\,\left(9/8 - \frac{3t}{2T} + t^2/2T^2\right) & \text{for } T/2 \le t < T \\ C(1-d)/8 & \text{for } T \le t \end{cases} \qquad \text{(B-16)}$$

Table B-13 presents p(t) for Winfrey's Curve Type L-3 (Winfrey, 1935), the average loss defined in terms of general C and d for each of the models derived above (equations (B-14) and (B-16)), and the resulting premium with C = 250 million, d = 10%, and N = 15%. The average decommissioning cost C estimate was derived in §III (D). The time scale is given in percentage of average life, and data is given for 5% intervals. If average life is twenty years, the probabilities and premiums are annual rates. If average life is thirty years, the results are for eighteen-month periods; annual rates would be two-thirds as large.

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*All costs and coverages are assumed to be in the same year's dollars and in constant dollars, so that a covered unit will be covered for the same amount of work, regardless of when it is performed. Given the long time scale of decommissioning, and the possible delay in recognizing premature decommissioning, this provision seems appropriate, as well as convenient.

TABLE B-13

ESTIMATION OF NAIDE EXPECTED COVERAGE COSTS

		Deterministic Model (Equation B-14)		Stochastic Model (Equation B-16)	
t/T*	p(t)**	Average*** Loss	Premium****	Average Loss	Premium
20%	.0007	.0006 C(1-d)	0.16	.0006 C(1-d)	0.16
50%	.0143	.0072	1.91	.0072	1.91
95%	.1197	.0060	1.59	.0181	4.79
150%	.1744	--†	--	.0218	5.77
200%	.3914	--	--	.0489	12.94
Averages††					
0-100%	--	.0070	1.85	.0092	2.42
100% - 240%†††	--	--	--	.0436	11.55

* in % of average life

** From Winfrey (1935); probability p(t) refers to the probability of an NAIDE occurring during the period which is 5% of the expected life in length and which ends at the stated value of t/T

*** Average loss for both models is expressed as a fraction of a general C and d

**** in millions of dollars; Assumes 15% expenses, 10% coinsurance, average decommissioning cost of $250 million

† In deterministic model, all values = 0 after 100% of average life

†† Average probabilities are weighted mean probability estimates, weighted by average loss figures

††† Curve assumed for p(t) retires all units by 240% of average life

While expected coverage costs are higher in the later years of unit life in equation (B-16) compared to equation (B-14), this effect is exactly counterbalanced by an expected decommissioning reserve surplus which just equals the differences between S(t) in equation (B-14) and $E_C \left[\hat{S}(t,c) \right]$ in equation (B-16) (except for the coinsurance factor).

Table B-14 restates the expected coverage costs on an annual basis for a thirty-year average life, two basic coverage levels, and two rate design models (deterministic and stochastic).

The deterministic model may be conceptualized either as an indemnity coverage or as a truly deterministic cost model. The stochastic model assumes both that the cost of decommissioning varies (between 0.5 and 1.5 times the expected value) and that the coverage is for the entire cost of the decommissioning.

The uncertainties in these expected coverage cost estimates are considerable, and at least as large as those for the AIDE coverage. For example, if the appropriate ratio of actual to estimated cost in Table B-12 is 12.0, rather than 5.0, and if average plant life is 20 years rather than 30 years, the expected coverage costs in Table B-14 would be 3.6 times larger.* Unfortunately, there is very little data from which reliable ranges for reactor survivor curves and average decommissioning costs can be calculated. Nonetheless, the order-of-magnitude uncertainty range appears to be approximately correct: average unit lives much greater than 40 years or much less than 20 years seem quite unlikely, as do average decommissioning costs for a large reactor of much less than $150 million or much more than $600 million. For the stochastic coverage, this would result in expected coverage costs in the one- to six-million-dollar range for a large reactor during its anticipated life. For unusually long-lived reactors, the life-time average of annual NAIDE expected coverage costs could be as large as $18 million.

If decommissioning costs prove to be very high and very variable or if reactors prove to be very short-lived, the attractiveness of the cost-control mechanisms discussed in Appendix E would be increased.

As in the estimation of coverage costs for AIDEs, premiums charged by the pools will not necessarily be the same as the coverage costs estimation, for reasons discussed in the Introduction to this Appendix. Differences in coverage design, pricing behavior of the pool and uncertainty in the estimates usedcould all cause actual premiums to vary from the expected coverage costs estimated within.

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*Assuming that time scales and coverages are adjusted accordingly. The appropriate C value would then appear to be $600M rather than $250M; the 3.6 figure is obtained by multiplying 600/250 · 30/20 equals 3.6.

TABLE B-14

TOTAL NAIDE EXPECTED COVERAGE COSTS, IN MILLIONS OF 1981 DOLLARS PER REACTOR YEAR*

	Deterministic		Stochastic	
Year**	$100M Coverage	$250M*** Coverage	$100M**** Coverage	$250M Coverage
10	0.23	0.58	0.23	0.58
20	1.12	2.81	1.19	2.98
30	0.22	0.56	1.12	2.81
60	--†	--	3.45	8.63
Average 0-30††	0.49	1.24	0.65	1.61
Average 30-72	--	--	3.08	7.70

* Assumes 15% expenses, 10% coinsurance

** Thirty-year average life assumed. See text for discussion of effect on expected costs of assuming a 20 year average life

*** $250M would be approximately the appropriate coverage for a large PWR (about 1150 MW), as estimated in the myopia analysis. Appropriate coverages would be about $280M for a large BWR, with 12% larger premiums than those shown above, and about $100M for the smallest LWRs. Lower decommissioning cost estimates would justify lower coverage amounts and proportionately lower premiums

**** Maximum decommissioning costs and coverages would be 50% greater than these average cost levels for the stochastic cases

† Deterministic coverage cost estimate = 0 for $t \geq 30$

†† Average probabilities are weighted mean probability estimates, weighted by average loss figures

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APPENDIX C:

ACCEPTABILITY OF A SELF-INSURANCE POOL TO THE ELECTRIC UTILITY INDUSTRY

I. SELECTION OF JUDGMENT SAMPLE OF OWNER/OPERATORS

One of the main objectives of this project was to obtain a general picture of the attitudes of the electric utility industry, as reflected by a sample of owner/operators of nuclear power plants, towards the acceptability of a self-insurance pool for nuclear power plant decommissioning expense. Previous studies (Wood, 1980) have noted the difficulty of evaluating the attractiveness of the self-insurance option for assuring the adequacy of funds for decommissioning expense without some expression of interest in the concept by the electric utility industry. Accordingly, it was decided that some effort should be devoted to eliciting responses from owner/operators to an early draft version of this report in order to obtain criticism and comment upon some of the features of the proposed self-insurance pool and in order to test the acceptability of the concept of a self-insurance pool.

The first problem encountered involved selecting a reasonable sample of owner/operators. An external constraint was imposed upon the number of owner/operators contacted with a survey instrument by regulations of the U.S. Office of Management and Budget, which require previous approval by OMB for questionnaires sent to 10 or more respondents by any Federal agency. Accordingly, we were limited to a sample of nine or less owner/operators. Beyond this constraint, two other criteria were identified as important in selecting the sample: (1) the sample should be in some defined sense representative of the universe of all U.S. owner/operators; and (2) the sample should provide as much information as possible. Note that these two criteria could conceivably conflict to some extent.

Given these two criteria, it made sense to proceed in a three-step process: first, to draw up a list of the variables with respect to which it was desirable to have the sample of nine owner/operators be "representative" of the population as a whole, and to order this list of variables from most important to least important; second, to draw up a list of any additional factors which might make the inclusion of a particular owner/operator attractive; and third, to invite participation of the nine selected owner/operators in stages, so that it would be possible to "re-balance" the sample, if necessary, in light of any refusals to participate.

In the first step, selecting and ordering the variables with respect to which the sample of nine owner/operators should be "representative" of the universe of all U.S. owner/operators, the following list was developed and ordered:

1. size of owner/operator in \$ annual revenues or \$ of assets

2. apparent "riskiness" of owner/operators' nuclear plant(s), as measured by lifetime capacity factors

3. whether owner/operator's nuclear plant(s) is (are) PWR(s) or BWR(s)

4. manufacturer of owner/operator's nuclear plant(s)

5. amount of nuclear MW owned by owner/operator

6. amount of total MW owned by owner/operator

7. size of owner/operator's nuclear plant(s) in MW

8. vintage of owner/operator's nuclear plant(s)

9. reserving practices to date of owner/operator

10. ownership form used by owner/operator for nuclear plant(s)

11. area of country served by owner/operator

12. whether owner/operator investor-owned or publicly owned

The variables are listed above in approximate order of importance, with most important variables listed first.

Beyond these twelve variables, three additional criteria were identified which, if present in an owner/operator, would tend to make that owner/operator's responses more informative. These three additional criteria were:

1. presence of special expertise in the area, possibly as indicated by a leadership role in forming NML or NEIL

2. presence of experience with specific problems, such as having a nuclear plant prematurely ready for decommissioning

3. presence of an ownership structure which might cause one owner/operator's responses to represent the combined opinions of several additional utilities

In sum, we attempted to select a group of nine owner/operators which were "representative" of the universe of all U.S. owner/operators with respect to the twelve variables listed above, and which also included some owner/operators with the three additional desirable criteria listed above.

Given this objective, we produced by trial and error (that is, by repeatedly modifying proposed lists to remove apparent "unbalances") the following list of nine owner/operators:

1. Boston Edison
2. Northeast Utilities
3. Yankee Atomic

4. General Public Utilities
5. Duke Power
6. Commonwealth Edison
7. Sacramento Municipal Utility District
8. Pacific Gas and Electric
9. Soutnern California Edison

This proposed sample was discussed with NRC staff, who suggested two changes: (1) the replacement of Sacramento Municipal Utility District with the Tennessee Valley Authority, in order to decrease the number of California utilities; and (2) the replacement of Duke Power with Consolidated Edison, to improve general diversity, as it was hypothesized that Duke Power and Commonwealth Edison might be similarly situated in many respects. These two suggested modifications were agreed to as reasonable, in that both sets of nine appeared to have (roughly speaking) about the same distributions of the 12 variables listed previously as the universe of U.S. owner/operators, and that both sets of nine also appeared likely to be highly informative in light of the three additional criteria listed above. This produced the final sample of nine owner/operators as follows:

1. Boston Edison
2. Northeast Utilities
3. Yankee Atomic
4. General Public Utilities
5. Consolidated Edison
6. Commonwealth Edison
7. Tennessee Valley Authority
8. Pacific Gas and Electric
9. Southern California Edison

Invitations to participate in the study were sent out in two stages, so that it would be possible to "re-balance" the sample, if necessary, in light of any refusals to participate. This became unnecessary as all nine of the owner/operators invited to participate in the project accepted the invitation. An early draft version of this report dated August 14, 1981, was sent out, along with a cover letter and a questionnaire, to the nine owner/operators, and responses were received from six owner/operators between late August and the cut-off date for responses of November 6, 1981.

II. COPY OF LETTER INVITING PARTICIPATION OF OWNER/OPERATORS

Essentially identical letters inviting participation in the project were sent out to the nine owner/operators. A copy of the letter sent to Pacific Gas and Electric Company is reproduced on the next page of this Appendix.

ANALYSIS AND INFERENCE, INC. RESEARCH AND CONSULTING

10 POST OFFICE SQUARE, SUITE 970 – BOSTON, MASSACHUSETTS 02109 – (617) 542-0611

June 24, 1981

Barton W. Shackelford
President and Chief Operating Officer
Pacific Gas and Electric Company
77 Beale Street
San Francisco, CA 94106

Dear Mr. Shackelford:

Analysis and Inference, Inc. has been given a contract by the U.S. Nuclear Regulatory Commission to study the costs, feasibility and acceptability of a utility self-insurance pool as the means of assuring the availability of funds for nuclear power plant decommissioning. The Request for Proposals was No. RS-OSD-81-001 and the Contract is No. NRC-01-81-001. The purpose of this letter is to inquire as to whether Pacific Gas and Electric Company, as an owner/operator of a nuclear power plant, would like to participate in this work.

Briefly, the work requires us to produce a tentative design for such a self-insurance pool, to estimate the costs of such a pool, and to determine the acceptability of the pool to the electric utility industry. We plan on circulating preliminary drafts of our work to about nine owner/operators in late July, 1981, along with a short list of questions designed to elicit opinions on the proposed pool and criticisms of the work at that stage. I would guess that a response by an owner/operator might take 1 to 2 person-days of work. All comments and criticisms by the individual owner/operators would be held confidential, and only would appear in the final report in aggregated, unattributed form.

We would like Pacific Gas and Electric Company to be one of the nine owner/operators, if you are interested. Please call me if you have any questions whatsoever about the project or the proposed participation by the owner/operators. Thank you very much for your attention to this matter.

Very truly yours,

Michael B. Meyer

MBM:EAW

III. COPY OF COVER LETTER AND QUESTIONNAIRE SENT TO OWNER/OPERATORS

An earlier draft version of this report, dated August 14, 1981, was sent to the nine owner/operators in the sample, together with a cover letter and a questionnaire. Copies of the cover letter and the questionnaire are reproduced starting with the next page of this Appendix.

ANALYSIS AND INFERENCE, INC. RESEARCH AND CONSULTING

10 POST OFFICE SQUARE, SUITE 970 – BOSTON, MASSACHUSETTS 02109 – (617) 542-0611

August 14, 1981

Bill Noone
Manager, Insurance Department
Pacific Gas and Electric Company
77 Beale Street, Room 851
San Francisco, CA 94106

Dear Mr. Noone:

Enclosed please find one copy each of two documents:

(1) Draft Report, entitled "Design and Costs of an Electric Utility Self-Insurance Pool for Assuring the Adequacy of Funds for Nuclear Power Plant Decommissioning Expense," dated August 14, 1981.

(2) Questionnaire, dated August 14, 1981.

Instructions for filling out and returning the questionnaire are contained on Page 1 of the questionnaire.

I would like to take this opportunity to thank you and your organization for participating in this project, and for providing your comments and criticisms on this work in progress. If you have any questions whatsoever, please do not hesitate to write or call me at (617) 542-0611.

Very truly yours,

Michael B Meyer

Michael B. Meyer

MBM:EAW

Enclosures

QUESTIONNAIRE

This Questionnaire was prepared for the Office of State Programs, U.S. Nuclear Regulatory Commission, pursuant to Contract No. NRL-01-81-001, by Analysis and Inference, Inc. It is being circulated to nine owner/operators of nuclear power plants in order to solicit criticism and comment upon a companion document, a Draft Report entitled "Design and Costs of an Electric Utility Self-Insurance Pool For Assuring the Adequacy of Funds for Nuclear Power Plant Decommissioning Expense," dated August 14, 1981.

Michael B. Meyer

August 14, 1981

TABLE OF CONTENTS

I. INSTRUCTIONS

A. Confidentiality

All information provided by owner/operators in responding to this questionnaire will be kept confidential by Analysis and Inference, Inc. No portion of these questionnaire responses will be forwarded to the U.S. Nuclear Regulatory Commission. A section of the final report to the NRC on this project will contain a discussion of the comments of the owner/operators, in aggregated form, without attributing positions or comments to individual owner/operators.

B. How to Respond to the Questionnaire

The questionnaire is designed to elicit your opinions on certain key features of the draft report. It seems likely that the most efficient way to respond to the questionnaire would be to first read the entire draft report quickly, and then to focus on the portions of the draft report referred to by each question when answering each question. Every question contains a specific reference to a page of the draft report, in order to make responses easier. Please feel free to attach additional pages if the space provided is inadequate for your response.

C. Time and Address For Returning Questionnaire

Please return the completed questionnaire by Friday, September 4, 1981. Please mail the questionnaire to:

Michael B. Meyer
Analysis and Inference, Inc.
10 Post Office Square, Suite 970
Boston, Mass. 02109

D. If You Have Questions

If you have any questions whatsoever, please call Michael B. Meyer at (617) 542-0611.

II. QUESTIONS

A. Design of Rates and Membership in the Pool

The Draft Report states that it would be desirable from the point of view of assurance to have the pool accept any owner/operator that applied for membership (pp. 4-5), and recommends that risk classification be used to compensate for differences in risk (p. 5).

1. Do you think requiring the pool to accept any U.S. owner/operator makes sense? Please circle one response:

Mandatory acceptance of risks is:

HIGHLY DESIRABLE

ACCEPTABLE

SOMEWHAT UNACCEPTABLE

COMPLETELY UNACCEPTABLE

Comments:

2. What type of risk classification variables make sense to you for use in setting premium rates?

Please circle acceptable risk classification variables:

Reactor type (PWR, BWR)

Reactor size in MWe

Reactor Manufacturer

Age of Reactor

Whether multiple units on site

Reserving practices of owner/operator

Capacity factor to date of reactor

Availability factor to date of reactor

Please add any other acceptable risk classification variables:

Comments:

B. Premium Design

The Draft Report points out that self-insurance pools need not necessarily set ordinary premiums at the expected cost of losses plus expenses, due to the possibility of using retroactive premium assessments (pp. 12-13).

3. Should the pool be allowed to charge retroactive premiums?

Please circle the acceptability level of retroactive premiums:

HIGHLY DESIRABLE

ACCEPTABLE

SOMEWHAT UNACCEPTABLE

COMPLETELY UNACCEPTABLE

Comments:

4. Should ordinary premiums be set at, above, or below the expected cost of losses plus expenses?

Please circle whether ordinary premiums should be:

ABOVE EXPECTED COST

EQUAL TO EXPECTED COST

BELOW EXPECTED COST

Comments:

C. Coverage Levels

The Draft Report estimated the costs for accident-initiated decommissioning coverage at coverage levels of $100 million, $500 million, and $1 billion, and for non-accident-initiated decommissioning coverage at coverage levels of $90 million (small PWR), $125 million (small BWR), $250 million (large PWR), and $350 million (large BWR). See Appendix B, p. B-44.

5. What do you think the maximum coverage levels should be for PWR's and for BWR's, for both accident-initiated and non-accident-initiated decommissioning coverages? Please fill in the amount of coverage you think should be offered. in 1981 dollars:

a. large PWR, accident-initiated coverage:_______________

b. large BWR, accident-initiated coverage:_______________

c. large PWR, non-accident-initiated coverage:___________

d. large BWR, non-accident-initiated coverage:___________

Comments:

The Draft Report recommends deductible levels and coinsurance levels as follows:

Accident-initiated coverages:	5% (of maximum coverage level) deductible; 10% coinsurance above deductible and below maximum coverage level
Non-accident-initiated coverages:	(unit age in years÷30 years) X (average cost) deductible; 10% coinsurance above deductible and below maximum coverage level

6. Are these levels of deductibles and coinsurance high enough to provide proper incentives for safe operation and for efficient management of decommissioning costs? Please circle one answer:

YES

NO

NO OPINION

Comments:

7. Are these levels of deductibles and coinsurance too high for an owner/operator to absorb? Please circle one answer:

YES

NO

NO OPINION

Comments:

8. Should the non-accident-initiated coverage cover only the shortfall in decommissioning reserves due to prematurity of decommissioning (as assumed by the deterministic model, see p. B-38 of Appendix B), or should it also be designed to cover shortfalls in the reserves due to higher-than-expected decommissioning costs (as assumed by the stochastic model, see p. B-40 of Appendix B)? Please circle one answer:

SHORTFALL DUE TO PREMATURITY ONLY

SHORTFALL ALSO DUE TO HIGHER-THAN-EXPECTED COSTS

NO OPINION

Comment:

D. Premium Cost Estimation

The Draft Report suggests that the ratio of the loss portion of total premium to the maximum coverage would be on the order of 1/250 to 1/600 for accident-initiated decommissioning (see Appendix B, pp. B-4 to B-12) and on the order of 1/100 to 1/150 for the non-accident-initiated decommissioning (see Appendix B, pp. B-38 to B-43).

9. Do these ratios seem too optimistic or too pessimistic to you, for each type of coverage? Please circle one answer:

Accident-initiated decommissioning: TOO OPTIMISTIC (TOO LOW)

TOO PESSIMISTIC (TOO HIGH)

NO OPINION

Comments:

Non-accident-initiated decommissioning: TOO OPTIMISTIC (TOO LOW)

TOO PESSIMISTIC (TOO HIGH)

NO OPINION

Comments:

10. Are you aware of any alternative data sources or event frequency models for either the accident-initiated or the non-accident-initiated decommissioning coverages which could be used in premium cost estimation? Please circle one answer:

YES

NO

If you answered YES, please describe the data source and/or model:

11. Is there a more appropriate basis for estimating the cost of non-accident-initiated decommissioning than by extrapolating past levels of nuclear power plant construction cost underestimation to present decommissioning cost estimates? Please circle one answer:

YES

NO

NO OPINION

If you answered YES, please describe the cost estimation method:

E. Over-All Acceptability

12. Is the concept of an electric utility self-insurance pool for accident-initiated decommissioning acceptable or not? Please circle one answer:

HIGHLY DESIRABLE

ACCEPTABLE

SOMEWHAT UNACCEPTABLE

COMPLETELY UNACCEPTABLE

NO OPINION

Comments:

13. Is the concept of an electric utility self-insurance pool for non-accident-initiated decommissioning acceptable or not? Please circle one answer:

HIGHLY DESIRABLE

ACCEPTABLE

SOMEWHAT UNACCEPTABLE

COMPLETELY UNACCEPTABLE

NO OPINION

Comments:

F. Identity of Respondent

14. Name of Person Making Responses:______________________________

Telephone Number of Respondent:______________________________

Owner/Operator Making Response:______________________________

IF YOU HAVE ANY OTHER COMMENTS WHATSOEVER, PLEASE NOTE THEM BELOW:

Please return this questionnaire to:

Michael B. Meyer
Analysis and Inference, Inc.
10 Post Office Square, Suite 970
Boston, Massachusetts 02109

by Friday, September 4, 1981. Thank you for your assistance.

IV. SUMMARY OF RESPONSES OF OWNER/OPERATORS

This section of Appendix C summarizes the responses to the questionnaire included above of the six owner/operators who responded by November 6, 1981.

Question 1: Do you think requiring the pool to accept any U.S. owner/operator makes sense?

Response: Of the six responses received, four stated mandatory acceptance was "highly desirable" and two stated it was "acceptable." When coupled with some level of risk classification, or of minimum engineering qualifications, mandatory acceptance of risks does not seem to pose a problem.

Question 2: What type of risk classification variables make sense for use in setting premium rates?

Response: The six responses varied substantially. One owner/operator indicated all eight suggested variables were acceptable, while one owner/operator only agreed one variable (multiple units on site) was acceptable. The other four responses were in between: one agreed with three variables (reactor type, reactor size, and reactor age), one agreed with four (reactor type, reactor size, reactor age, and multiple units on site), one agreed with five (reactor type, reactor size, reactor manufacturer, reactor age, and multiple units on site), and one agreed with three (unit type, size and age), while pointing out that these variables could be related to amount of potential loss, but that they were not necessarily linked to probability of loss.

Question 2: Should the pool be allowed to charge retroactive premiums?

Response: Four respondents of six stated that retroactive premiums were "highly desirable," while the other two stated that they "acceptable." There appears to be no serious problem with allowing for retroactive premiums; indeed, they may be a necessity in the early years of the pool's operation. One respondent did point out, however, that the proliferation of different nuclear insurance programs, each with retroactive premium provisions, could begin to cause difficulties for some owner/operators.

Question 4: Should ordinary premiums be set at, above, or below the expected cost of losses plus expenses?

Response: Three respondents answered "below expected cost," two answered "equal to expected cost," and one answered "above expected cost."

Question 5: What do you think the maximum coverage levels should be for PWR's and BWR's, for both accident-initiated and non-accident-initiated decommissioning coverages (1981 dollars)?

Response: Responses varied, as summarized below:

Coverage	Respondent 1	2	3	4	5	6
large PWR, accident	\$1 B	\$1 B	\$1 B	**	\$2 B	\$1 B
large BWR, accident	\$1 B	\$1 B	\$1 B	**	\$2 B	\$1 B
large PWR, non-accident	\$250 M	*	*	**	\$42 M	\$100-150 M***
large BWR, non-accident	\$350 M	*	*	**	\$55 M	\$100-150 M***

NOTES:

* Did not respond, as disagreed with the provision of non-accident coverage.

** Responded that the amount of coverage should be site-specific.

*** These responses included a caveat that the respondent was not sure that non-accident coverage was appropriate.

Question 6: Are the levels of deductibles and coinsurance high enough to provide proper incentives for safe operation and for efficient management of decommissioning costs?

Response: Four respondents said "yes," one said "no," and one said "no opinion"; however, the "no" and the "no opinion" answers were followed by a statement that the incentives for safe operation and for efficient management of decommissioning costs were already adequate, and would not be affected by a 100% deductible (i.e., no coverage). Four of the six respondents made specific, additional statements to the effect that incentives were completely adequate, with or without this coverage.

Question 7: Are the levels of deductibles and co-insurance too high for an owner/operator to absorb?

Response: Four answered "no," and two answered "no opinion." There does not seem to be any problem with the proposed deductible and co-insurance levels.

Question 8: Should the non-accident-initiated coverage cover only the shortfall in decommissioning reserves due to prematurity in decommissioning (as assumed by the deterministic model), or should it also be designed to cover shortfalls in reserves due to higher-than-expected decommissioning costs (as assumed by the stochastic model)?

Response: Three respondents had no opinion, citing their opposition to or their uncertainty about non-accident coverage in general. One responded "shortfall due to prematurity only," and two others responded "shortfall also due to higher-than-expected costs."

Question 9: Do these ratios (referring to the "perceived probabilities") seem too optimistic or too pessimistic to you, for each type of coverage?

Response: The responses were distributed as follows:

		Distribution of Answers		
		Too Optimistic	Too Pessimistic	No Opinion
Coverage	Accident	0	1	5
	Non-Accident	0	0	6

Question 10: Are you aware of any alternative data sources or event frequency models for either the accident-initiated or the non-accident-initiated decommissioning coverages which could be used in premium cost estimation?

Response: Four respondents answered "no," while one answered "yes," citing the TMI-2 cost study as a relevant additional data source, and one answered "yes," citing various utilities' failure mode and effects analyses, published individually in various Final Safety Analysis Reports, and citing various Probability Risk Assessment studies done by individual utilities and the NRC since the RSS.

Question 11: Is there a more appropriate basis for eliminating the cost of non-accident-initiated decommissioning than by extrapolating past levels of nuclear power plant construction cost underestimation to present decommissioning cost estimates?

Response: Three respondents answered "yes," both stating that site-specific estimates should be used in place of generic estimates; one respondent said "no," and the other two answered "no opinion."

Question 12: Is the concept of an electric utility self-insurance pool for accident-initiated decommissioning acceptable or not?

Response: Two respondents answered "highly desirable," three answered "acceptable," and one answered "somewhat unacceptable." Four stated their opinion that there would be a decreasing need for separate decommissioning coverage as first-party property damage coverage increases come into effect in late 1981 and early 1982.

Question 13: Is the concept of an electric utility self-insurance pool for non-accident-initiated decommissioning acceptable or not?

Response: Two respondents answered "acceptable," one answered "somewhat unacceptable," two answered "completely unacceptable," and one answered "no opinion" while expressing some reservations about non-accident coverage.

References

Kish, L., Survey Sampling (New York: John Wiley and Sons, 1965), §1.5, p. 19 (discussion of judgment samples).

Wood, R.S., "Assuring the Availability of Funds for Decommissioning Nuclear Facilities," U.S. Nuclear Regulatory Commission, NUREG-0584, Rev. 2, 1980, pp. 47-51.

APPENDIX D:

COLLECTIBILITY IN BASE RATES OF SELF-INSURANCE PREMIUMS

The degree to which owner/operators will find the proposed self-insurance pool acceptable should be affected in part by whether or not the premium charges would be collectible from the ratepayers in the owner/operators' base rates. The purpose of this Appendix is to provide a brief analysis of whether or not such premiums are likely to be collectible in base rates.

Although no one can predict with certainty exactly what rate regulators will do in the future, past rate case decisions do provide some guidance in this area. Accordingly, a search of one standard reporter for public utility decisions (Public Utilities Reports, abbreviated PUR) was conducted covering the years 1933 to 1977 and a search of another standard reporter (Commerce Clearing House's Utilities Law Reporter, abbreviated ULR) was conducted for the years 1974 to date to determine rate regulators' attitudes towards insurance premiums in general and nuclear insurance premiums specifically. (For the purposes of this discussion, "rate regulators" includes both the Federal Energy Regulatory Commission, which regulates wholesale rates, and state public service commissions, which regulate retail rates.)

In general (subject to five exceptions discussed below) rate regulators have ruled that insurance premiums and true self-insurance reserve payments are properly included in test year expenses. Three cases exemplify this general rule: Pennsylvania Public Utility Commission v. Duquesne Light Co., 88 PUR 3d 1 (1977) (Penn.); Re Northwestern Bell Telephone Co., 2 PUR 4th 312 (1974) (Neb.); and Re California-Pacific Utilities Co., 20 PUR 4th 479 (1977) (Ore.).

The exceptions to this general rule (insurance premiums and self-insurance reserve payments are properly expensed in rates by including them in the test year cost of service) relate more to general rules of ratemaking than to any particular aversion of regulators to insurance premiums. Cases were found which carved out five exceptions to this general rule, as discussed below.

(a) Self-insurance premiums (i.e., reserve payments) may be excluded (like other unproven but claimed expense increases) if the increase claimed in the reserved amounts is not justified by any corresponding increase in claims, losses, nature of risks, etc. For an example of this exception, see Westwood Lake, Inc. v. Metropolitan Dade County Water and Sewer Board, 71 PUR 3d 260, 203 So. 2d 363 (1967) (Fla.).

(b) An increased cost of insurance premiums, where that increase is attributable to poor claims experience and thus to poor management by the utility, may not be allowed, like other expenses associated with poor management. For an example of this exception, see Re Cody Gas Co., 90 PUR 3d 239 (1971) (Wyo.).

(c) Insurance premiums (like any other expense) will not be allowed if they are out-of-test-period expenses. For examples of this exception, see Re Peoples Gas System, Inc., 1 PUR 4th 464 (1973) (Fla.); Re Ohio Valley Gas Co., Case No. 72-1014-Y (1975) (Ohio).

(d) Prepaid insurance premiums will be disallowed (like other prepayments) if it cannot be shown that the prepayment of the expense benefitted the ratepayer. For an example of this exception, see Re Narragansett Electric Co., 1 PUR 4th 60 (1973) (R.I.).

(e) Insurance premiums paid for insurance on non-utility businesses (like other non-utility expenses) may be disallowed. For an example of this exception, see Re Public Service Co. of North Carolina, Inc., 19 PUR 4th 1[illegible]9 (1977) (N.C.).

The main conclusion one can draw from the reported cases on insurance premiums in general is that rate regulators allow insurance premium payments and self-insurance premium (reserve) payments to be expensed by including them in test year expenses. The five exceptions which could be found in this general rule do not reflect any antipathy by rate regulators to insurance payments, but merely reflect the application of other well-accepted principles of ratemaking in areas which happened to involve insurance payments.

With respect to regulators' attitudes towards nuclear insurance premiums specifically, no reported case was found which discussed the subject directly. Due to two problems with the case law reporters examined (they do not publish every decided case, and their indexing systems are imperfect), this should not be taken as proof that no decided case has discussed nuclear insurance premiums. (Indeed, two unreported cases were found which did discuss, and allow, NEIL premiums for expense purposes in rate cases. See Re Western Massachusetts Electric Company, D.P.U. 20279-A (Mass., October 29, 1980); Re Boston Edison Company, D.P.U. 160 (Mass., September 30, 1980).) Moreover, the fact that no mention appears in reported cases of nuclear insurance premiums does not mean that there is no information upon which to base predictions of regulators' attitudes towards such premiums.

Four reasons can be given to support the prediction that such premiums would probably be allowed as a proper expense for rate-making purposes. First, utilities currently routinely include nuclear insurance premiums as proper elements of the two standard accounts for insurance premiums and thus routinely report these premiums to ratemakers as components of accounts that are generally permitted for rate-making purposes. For example, first-party property damage insurance premiums (which would include ANI/P and NML premiums) are included in Account 924 and third-party property damage and bodily injury liability insurance premiums (which would include ANI/L premiums) are included in Account 925. See Federal Power Commission (1970). Thus, these premium expenses are reported in aggregate fashion with other expenses which are allowable. Second, because of the way in which rate cases are tried and decided (only expenses which are specifically challenged by some party to the proceeding are usually discussed and then accepted or rejected explicitly, while expenses which are not challenged are allowed sub silentio), the lack of mention of nuclear insurance premiums in reported cases in fact probably indicates that these expenses have been allowed implicitly because they have not been challenged. Third, as stated previously, two unreported cases were found which did allow NEIL premiums. Fourth and finally, the general rule that it is proper to allow insurance premiums as expenses for rate-making purposes (assuming no specific impropriety in the premium is found, as discussed previously) should apply to nuclear insurance premiums as well as any other type of insurance premiums.

No case could be discovered which discussed the relative merits (with respect to collectibility) of different types of premiums such as reserve premiums or retroactive premiums. Thus the speculation concerning the relative degrees of collectibility among different types of premiums contained in §III (C) (2) (b) of the text above, cannot be improved upon by reference to decided cases.

In conclusion, it seems reasonable for planning purposes to assume that these premiums will be allowed for rate-making purposes and that the degree of assurance that they will be allowed can be substantially increased by obtaining regulatory approval to join the pool prior to operation. Specifically, ordinary premiums should be collectible, as ordinary and necessary business expenses, in base rates. Reserve premiums should be collectible, either by being amortized or by being capitalized as additions to rate base. Retroactive premiums should be collectible, either by being expensed or by being amortized.

References:

Federal Power Commission, Uniform System of Accounts Prescribed for Public Utilities and Licenses (Wash., D.C., U.S.G.P.O., Jan., 1970).

APPENDIX E:

ALTERNATIVE FINANCIAL ASSURANCE MECHANISMS

FOR NON-ACCIDENT PREMATURE DECOMMISSIONING

The insurance mechanism described in the text and in Appendix B, above, for non-accident premature decommissioning is not the only possible financial assurance mechanism that a utility self-insurance pool might provide to owner/operators. This Appendix will briefly describe three alternative and less traditional financial assurance mechanisms that might possibly be provided for non-accident premature decommissioning by a utility self-insurance pool that provided traditional insurance coverage for accident-initiated premature decommissioning.

It should be emphasized that all three of these financial assurance mechanisms discussed here as possible alternatives to traditional insurance coverage have not been analyzed in depth by this project. Rather, these alternatives are put forth as worthy subjects of further study, should the traditional insurance mechanism for non-accident premature decommissioning, discussed in the text above, be considered too expensive or unacceptable for any other reason.

These three alternative financial assurance mechanisms are: (1) insurance for non-accident premature decommissioning where financial instability or incapacity of the owner/operator was required, as part of the definition of the insurable event, as a condition precedent for payment by the pool for the losses; (2) a contingency loan agreement, in which the pool would make loans to the owner/operator faced with non-accident premature decommissioning if the decommissioning could not be financed by the usual means; and (3) a surety agreement in which the self-insurance pool became a surety for the owner/operator's obligation to decommission the plant, with the NRC being the obligee and the owner/operator being the principal, and with the self-insurance pool being empowered to recover from the owner/operator costs incurred by the pool in discharging the owner/operator's obligations. Note that the common element of these three alternative mechanisms is that each would be offered as an additional coverage by a utility self-insurance pool that offered traditional insurance coverage for accident-initiated premature decommissioning. These three alternative financial assurance mechanisms will be described briefly in order below.

First, the insurance mechanism could be modified by the inclusion of a financial instability or incapacity test as part of the definition of the insurable event. This would mean that the mere occurrence of a non-accident premature decommissioning would not trigger coverage by the self-insurance pool. Instead, coverage would only be offered for cases in which a nuclear plant suffered from a non-accident premature decommissioning and in which the owner/operator was financially incapable of decommissioning the plant. This financial incapacity or instability could either be measured by some pre-specified test (say, a bond rating on mortgage bonds or other long-term debt, or a fixed-charge coverage ratio) or by an after-the-fact determination by an NRC hearing officer. This type of conditional insurance coverage would have the advantage (over the unconditional coverage discussed in the text) of having lower expected losses and thus lower premium costs, as it is reasonable to expect that some or most non-accident premature decommissionings will not be accompanied by financial instability or incapacity of the owner/operator. On the other hand, this type of conditional insurance coverage might be harder to price (by the pool) and harder to evaluate (by an owner/operator) in that another level of uncertainty and complexity would be added to the insurance agreement. Additionally, the untraditional nature of this type of conditional coverage might tend to make its acceptance more difficult. Indeed, the lack of examples of financial instability tests in insurable event definitions in current insurance arrangements may very well indicate problems with this approach. Finally, the possibility of moral hazard exists with the use of such a test. Two examples of sources of moral hazard can be described. First, an owner/operator is in control of its own accounting data to some extent, and thus could conceivably control to some extent the outcome of the test. Second, the existence of such a financial instability test in an insurable event definition might create an additional incentive to create single-asset utilities as owner/operators of new plants.

Second, the self-insurance pool could provide contingency loans to members faced with a non-accident premature decommissioning that could not be financed by the usual means. Contingency loan agreements do not appear to be widely used in the United States today, despite their possibly attractive features and their use elsewhere, notably in Great Britain. Doherty (1978) notes the lower premium costs for contingency loan agreements (as compared to regular insurance) with respect to certain types of corporate business losses, and concludes that contingency loan agreements provide a practical method of securing businesses from several types of corporate losses, including what might be termed "business risks". Again, like the addition of a financial instability or incapacity test to a traditional insurance agreement, the use of a contingency loan agreement would seem to result in a trade-off, with lower costs, lower value of the coverage to the owner/operator, and greater uncertainty about the value of the coverage provided to the owner/operator all resulting from the contingency loan agreement than for traditional insurance. Finally, also like the addition of a financial instability test to a traditional insurance agreement, the lack of examples of contingency loans in the United States may indicate problems with this approach.

Third, the self-insurance pool could become a surety, guaranteeing to the NRC (as the obligee) that the owner/operator (as the principal) would in fact discharge its duties to the NRC to decommission the plant. If the owner/operator defaulted, the pool would assume responsibility for the decommissioning, and would then have the right to attempt to recover from the owner/operator the costs of decommissioning. For a general discussion of the surety arrangement and of the relationships created by surety bonds, see Denenberg (1965). This surety arrangement should also be more inexpensive than the traditional insurance coverage described in the text, above, as some or most non-accident premature decommissionings would not cause default by the owner/operator, and even where such default did occur, the pool would have some expectation of later recoveries from the owner/operator. It is known that surety bonds from surety bonding companies would not be available in the amount and for the term needed for decommissioning bonds. See Wood (1979), pp. 11-13.

Among these three alternative financial assurance mechanisms, it would appear likely that the second and third alternatives (the contingency loan agreement and the surety agreement) should have lower costs than the first alternative, the insurance agreement with the financial instability or incapacity test as a condition of coverage. This is the case because both the contingency loan agreement and the surety agreement would provide the pool with some substantial expectation that at least some of the pool's loss costs could be recovered from the owner/operator. Additionally, it would appear that the contingency loan agreement and the surety agreement would therefore provide somewhat better incentives to the owner/operator than the insurance agreement with the financial instability or incapacity condition, although this improvement in incentives might be quite marginal.

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Glossary

a	Actual escalation rate
A	Product of all factors, other than expected losses and expenses, which affect the level of the premium (§ II)
A	Actual project cost (§ III)
c	Decommissioning cost (random)
C	Decommissioning cost (fixed)
d	Coinsurance fraction
e	Projected escalation rate
E	Engineering estimate of project cost
$E[x]$	Expectation of X
$F_m(F_j)$	Ratio of expected value of losses due to maximum (major) events to the expected value of total losses
L	Losses in a reactor-year
$L_m(L_j)$	Losses due to maximum (major) events
m	Myopia factor (§ III)
m'	"True" myopia factor
N	Expenses as a fraction of premium
$p_m(p_j)$	Probability of occurrence of a maximum (major) event
$p(t)$	Probability of retirement at age t, given that the plant has not been retired before age t
R	Premium
$R(t)$	Expected coverage cost at age t
s	Scaling factor
$S(t)$	Average loss at age t, given that a loss occurs
t	Time
T	Assumed plant life for depreciation reserve

Abbreviations

AIDE	Accident-Initiated Decommissioning Event
AEC	Atomic Energy Commission
ANI	American Nuclear Insurers, and its reinsurers
ANI/L	Liability insurance from ANI
ANI/P	Property Insurance from ANI
BWR	Boiling Water Reactor (type of LWR)
COD	Commercial Operation Date
HTGR	High Temperature Gas-cooled Reactor
KW, Kw	Kilowatt
KWH	Kilowatt hours
LWR	Light Water Reactor
MAELU	Mutual Atomic Energy Liability Underwriters
MAERP	Mutual Atomic Energy Reinsurance Pool
MW, MW(e)	Megawatt(s) electric
MW(t)	Megawatt(s) thermal
NAIDE	Non-Accident-Initiated Decommissioning Event
NEIL	Nuclear Electric Insurance Limited
O&M	Operation and Maintenance
OSF	Overall Scale Factor
NML	Nuclear Mutual Limited
NSSS	Nuclear Steam Supply System
PNL	Pacific Northwest Laboratory
PWR	Pressurized Water Reactor (type of LWR)
RSS	Reactor Safety Study (WASH-1400)
UE & C	United Engineers and Constructors
WNP2	Washington Nuclear Project 2

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16. ABSTRACT (200 words or less) This Report summarizes a feasibility study of an electric utility self-insurance pool for assuring the adequacy of funds for nuclear power plant decommissioning expense. The feasibility study was comprised of three components: (1) the design of such a self-insurance pool; (2) the estimation of the expected costs of coverage for such a pool; and (3) the testing of the acceptability of such a pool to the electric utility study. First, a self-insurance pool is an appropriate method of assuring the adequacy of funds for decommissioning. Second, the expected costs of coverage for decommissioning insurance are non-trivial in absolute terms, but are a small percentage of total nuclear power generation costs. Third, the concept of a self-insurance pool for decommissioning expense is generally acceptable to the electric utility industry, while the actual use of such a pool for accident related coverages seems more acceptable than for non-accident related coverages. Fourth, the degree of assurance that funds would be available for decommissioning seems to be good. Fifth, the use of any type of insurance arrangement, including a self-insurance pool, for non-accident related coverages seems to raise problems of insurability which, while not necessarily insurmountable, require careful attention if non-accident coverages are to be offered.

17. KEY WORDS AND DOCUMENT ANALYSIS

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