NUREG/CR-6617

The Price-Anderson Act - Crossing the Bridge to the Next Century: A Report to Congress

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Prepared for
U.S. Nuclear Regulatory Commission

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Manuscript Completed: June 1998
Date Published: October 1998

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ABSTRACT

This report fulfills the mandate of Subsection 170p. of the Atomic Energy Act of 1954, as amended, which requires that the Commission submit to the Congress by August 1, 1998, a detailed report on the need for continuation or modification of Section 170 of the Act, the Price-Anderson provisions. Part 1 presents an overview of the Price-Anderson system. Part 2 examines the issues that the Commission is required by statute to study (i.e., condition of the nuclear industry, state of knowledge of nuclear safety, and availability of private insurance). Part 3 covers other issues of interest and importance to the Congress and to the public, such as proof of causation and international agreements relevant to Price-Anderson. Part 4 of the report contains conclusions and recommendations. Part 5 is the list of references. Appendix A is an evaluation of the affordability of certain Price-Anderson assessments.

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EXECUTIVE SUMMARY

The "Price-Anderson" provisions[1] of the Atomic Energy Act of 1954, as amended, have proven to be a remarkably successful piece of legislation. Price-Anderson embodies two core values of the United States that remain essential as the nation crosses into the next century. These twin values are the development of technology to improve living standards for all and the compensation of those who may suffer from the consequences of deploying or testing advanced technologies. With negligible cost to the public, the Price-Anderson Act has facilitated the utilization of nuclear power technology for peaceful uses and has assured that, in the unlikely event of an accident, the public will be compensated for any resulting liabilities. The Price-Anderson system has grown in depth of coverage over the years and proved its viability in the aftermath of the Three Mile Island incident. Especially considering that the federal government no longer stands as the indemnifier for large commercial nuclear power reactors, except in certain scenarios, continuing Price-Anderson further into the next century appears today to be prudent public policy. *Because the Act has benefitted from extensive public discussion and legislative modification over the years, only modest changes, if any, need be contemplated in connection with its renewal.*

Purpose and Organization of the Report

Section 170p of the Atomic Energy Act of 1954, as amended in 1988, requires the Commission to submit to the Congress [2] by August 1, 1998, "a detailed report concerning the need for continuation or modification of the provisions of [the Price-Anderson Act], taking into account the condition of the nuclear industry, availability of private insurance, and the state of knowledge concerning nuclear safety at that time, among other relevant factors, and [which] shall include recommendations as to the repeal or modification of any of the provisions of [the Price-Anderson Act]." The report, which has been extensively reviewed by the Commission, is submitted in response to that Congressional requirement. The report pertains only to issues for which the U.S. Nuclear Regulatory Commission (NRC) is responsible.[3] The NRC submitted a comparable report to Congress on Price-Anderson in 1983.[4]

Part 1 of the report provides an overview of the Price-Anderson Act and its amendments through the 1988 extension and an update on legal issues pertaining to nuclear insurance and indemnity.

Part 2 of the report addresses those issues identified in subsection 170p relating to the need for continuation or modification of the Act.

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[1] Public Law 85-256, 71 Stat. 576 amending the Atomic Energy Act to include Section 170 and related definitions in Section 11.

[2] The Price-Anderson Amendments Act of 1988, Pub.L. No. 100-108, 102 Stat. 1066 (1988), amending Sections 170 and 11 of the Atomic Energy Act.

[3] This report does not include any discussion of issues relating to Department of Energy (DOE) contractor activities indemnified under subsection 170d of the Atomic Energy Act, which are the subject of a separate report by DOE and outside the scope of this report.

[4] U.S. Nuclear Regulatory Commission, *The Price-Anderson Act – The Third Decade*, NUREG-0957 (1983).

Part 3 of the report considers other relevant issues, such as scientific and legal proof of causality and international agreements.

Part 4 contains the Commission's conclusions and recommendations.

Part 5 is the list of references.

Appendix A contains an update of affordability studies of retrospective premiums conducted for the Commission.

Part 1. Overview of Price-Anderson System

The Price-Anderson Act was enacted into law on September 2, 1957, as Section 170 of the Atomic Energy Act, to meet two basic objectives:

(1) Remove the deterrent to private sector participation in atomic energy presented by the threat of potentially enormous liability claims in the event of a catastrophic nuclear accident.

(2) Ensure that adequate funds are available to the public to satisfy liability claims if such an accident were to occur.

Congress designed the Price-Anderson Act to equitably balance the public's needs with the industry's. Specifically, Congress decided to require that licensees provide financial protection[5] for risks of liability for nuclear damage, to indemnify the nuclear power industry as necessary, and to cap total liability in the event of an incident.

The Price-Anderson Act has been successful in removing impediments for firms to enter, and then remain, as participants in the civilian nuclear sector. Companies representing both utilities and support service and equipment suppliers indicated they would likely not participate in the nuclear industry without some method of liability limitation, such as that provided under the Price-Anderson Act. Public testimony submitted during its initial enactment and its subsequent renewals supported this viewpoint.

The Act requires licensees to provide financial protection. Financial protection under the Act means the ability to respond in damages for public liability (including costs of incident response or precautionary evacuation) and to meet the costs of investigating and defending claims and settling suits for such damages. The scope of Price-Anderson coverage includes any nuclear incident in the course of transportation of nuclear fuel to a reactor site, the storage of nuclear fuel at a site, the operation of reactors including discharges of radioactive emissions or effluents, the storage of nuclear wastes at reactor sites, and the transportation of radioactive material from reactors.

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[5] Although Price-Anderson offers optional methods of providing financial protection, licensees have always used one or more forms of nuclear liability insurance to meet the requirement for financial protection.

The Price-Anderson system channels to the operator the obligation to pay compensation for damages and provides "omnibus" coverage. This means that the same protection available for a covered facility extends through indemnification to any person who may be legally liable, regardless of the identity of the person liable or his relationship to the licensed activity. Thus, those who are injured are assured of the availability of funds to pay their claims, and firms that contribute in some manner to the construction (including design), operation, and/or maintenance of covered licensees are all protected. For example, each defendant company that, at the time of the accident, was an owner or operator of the Three Mile Island facility, together with each company that supplied design, engineering, or maintenance services, or that was a vendor of systems or equipment incorporated in the facility, was indemnified through the Price-Anderson financial protection system. Because Price-Anderson channels the obligation to pay compensation for damages, a claimant need not sue all of these parties but can bring its claim to the reactor licensee.

Key parameters of Price-Anderson include: which licensees and what costs are covered, and how much coverage is provided. Each of these parameters is discussed in the report.

Covered licensees include production and utilization facilities, with commercial nuclear power reactors being the main concern of Price-Anderson and the focus of the report to Congress. The report recommends, however, that Price-Anderson implications of any new regulatory responsibilities for DOE activities or facilities that Congress may assign to the Commission be addressed when each such assignment is made. With respect to what costs are covered by the Act, the report recommends that Congress may want to make clarifying technical amendments regarding coverage of defense costs and punitive damages under Price-Anderson.

The amount of coverage provided may be the most important issue covered in the report. This is especially true because the total coverage provided by the Act determines the limit of liability. The total coverage includes both the required financial protection and the federal indemnity, if any.[6]

Since its enactment, the Price-Anderson Act has required as financial protection that commercial nuclear reactor units be insured to the maximum available level of primary insurance. As the private insurance market increased its maximum available level of primary insurance, each nuclear reactor unit needed to increase its coverage level. Although initially based solely on available commercial insurance, the required amount of financial protection currently is the sum of both the commercial primary insurance layer and a secondary retrospective assessment layer, first mandated by the 1975 Amendments. The retrospective premium layer is supported by licensee obligations to pay a pro-rated share of damages in excess of the primary insurance amount up to a specified limit per reactor per incident. For commercial power reactors, the federal indemnification was superceded in November 1982 by the substantial amount of required financial protection provided by the increased number of licensees who were obligated to contribute retrospective premiums under the Act.

In order to make an even larger pool of funds available to pay public liability claims, the 1988 Amendments increased maximum secondary insurance assessments from the $5 million established in 1975 to $63 million per reactor unit per incident, to be adjusted for inflation at five year increments. With the increase of the maximum available level of primary insurance to $200 million from $160 million, combined maximum primary and secondary insurance coverage totaled $7.34 billion for all active reactor units in 1988, of which

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[6] Federal indemnification cannot exceed $500 million. For licensees with financial protection requirements of less than $560 million, the Act mandates that NRC provide indemnity protection in the amount of $500 million for each nuclear incident less the amount by which the required financial protection exceeds $60 million.

$7.14 billion came from the secondary insurance program. This larger pool of funds was expected to make the compensation system more equitable, reliable, and efficient. Congress did not identify the rationale for the particular number chosen (i.e., $63 million) nor a target for the aggregate limit on liability.

As of August 20, 1998, the nuclear power industry will be insured to a maximum per incident dollar level of $9.43 billion (i.e., maximum available primary insurance coverage of $200 million plus maximum available secondary insurance of $9.23 billion [i.e., 110 units multiplied by $83.9 million each]). If the number of participating nuclear power reactor units decreases faster than the rate of inflation, this dollar figure will almost certainly represent the industry's highest level of insurance funding, absent further changes to Price-Anderson. Nonetheless, even with a future reduction in participants, the aggregate amount of coverage will remain a large sum for years to come.

Congress has long recognized that a nuclear incident might involve damages in excess of the limit of liability. In 1975, Congress explicitly committed to protect the public from the consequences of a disaster of such magnitude. Congress enacted statutory provisions in 1988 committing to provide full and prompt compensation to the public for all public liability claims resulting from such a disaster and establishing a process for the preparation of compensation plans after any nuclear incident involving damages that are likely to exceed the applicable limit on liability. A review of issues associated with Price-Anderson litigation reveals that no legal problems in the current text require remedial legislation. Several clarifications that might prove useful, particularly a clarification on the prohibition of punitive damages, are indicated in the report.

Part 2: Principal Issues Bearing on the Need to Continue Price-Anderson

The Price-Anderson Act requires NRC to consider in reporting on the need to continue or modify its provisions, the condition of the nuclear industry, availability of private insurance for handling claims, and the state of knowledge concerning nuclear safety. The report addresses each of these three considerations in turn.

2.1 Condition of the Nuclear Industry

At the time of the last Report to Congress on the Price-Anderson Act in 1983, the nuclear power industry was undergoing substantial change. Mandatory backfits were increasing the costs of reactor unit construction and operation. No new units had been ordered, and existing orders were being canceled. Since then, the pace of backfits has slowed, operating costs have decreased, and reactor units have steadily increased electricity generation. Nevertheless, the current cohort of reactor units is expected to decrease over time, thereby lessening the size of the available secondary retrospective assessment layer for power reactors relative to what it would be if the number of participating reactors remained constant.

Issues both specific to the nuclear power industry and some also relevant to the entire electric utility industry may affect the Price-Anderson system by reducing the number of nuclear reactors participating in the system. These issues include the following:

(1) Lack of new reactor units;
(2) Operating license renewal;
(3) Aging of reactor unit components;
(4) The economics of reactor units; and
(5) Introducing competition into the electrical power industry.

Lack of New Reactor Units

The economics of nuclear energy was premised on its providing baseload power, not augmenting peakload power needs. Until demand growth outstrips current additions to the U.S. electrical grid, few opportunities will exist for new nuclear reactor units. No construction permit applications are under review at the NRC and no construction permit applications are identifiable in the foreseeable future, although applications for standardized design approvals that could be used for future plants have been processed. Those utilities that might build nuclear power plants are subject to powerful financial, load growth, political, regulatory, and other restraints on their decisions to develop more nuclear facilities.

License Renewal

The Atomic Energy Act and NRC regulations limit commercial power reactor licenses to 40 years, but also permit the renewal of such licenses. The 40-year term was originally selected on the basis of economic and antitrust considerations, not technical limitations, but once selected, individual plant designs may have been engineered based on an expected 40-year service life. The Commission in 1995 established by rule (10 CFR Part 54) a framework for the issuance of renewed operating licenses for up to twenty years for nuclear power plants. The rule focuses on effects of aging on plant safety. Extensive work has been completed by NRC staff in reviewing technical reports from industry on aging management issues. Earlier this year the first license renewal applications were submitted (Baltimore Gas and Electric for the two Calvert Cliffs units and Duke Power for the three Oconee units) and additional applications are expected within the next two years. License renewal appears to be a very attractive option financially compared to building new fossil capacity and the Commission has committed the resources necessary to promptly review the initial applications.

Aging

Aging degradation may affect a broad range of plant systems, structures, and components. When the first units were constructed, some reactor unit components' were expected to last over 60 years but major components were expected to last at least 40 years. However, operating experience indicates that the expectation was unrealistic in some cases, such as for steam generators, due to aging degradation. Decisions to minimize aging degradation will reflect economic factors. An aggressive maintenance program, including capital expenditures to replace major components, may significantly retard the effects of aging but the associated costs for such a maintenance program may not allow some utilities to earn an acceptable return.

Economics

Utilities are continuing to seek further cost reductions from existing reactor units. Future cost reductions will result from: (1) smaller labor pools, (2) reduced total capital expenditures, and (3) more efficient reactor unit electrical generation. Reactor units that are not economic may be closed down.

Deregulation and Restructuring

The electric utility industry has entered a period of economic deregulation and restructuring that is intended to lead to increased competition in the industry. The NRC believes that economic deregulation does not preclude adequate protection of public health and safety.[7] Apart from potential safety concerns, deregulation may lead to more premature closures of power generating assets than would otherwise have occurred in the absence of competition, if an operating reactor is not cost-competitive. Restructuring may have another effect relevant for Price-Anderson: some licensees may become less able to afford retrospective premiums (see Appendix A of the report).

2.1.1 Impacts of Reactor Retirement on Price-Anderson System

More than one-third of current U.S. nuclear capacity will reach the end of the initial license period by 2013. While only 5 reactor units will reach the end of their initial licenses by 2008, in the following five years, between 2008 and 2013, an additional 29 reactor units (i.e., a total of 34 reactor units by 2013) will reach the end of their 40-year initial licenses.

Due to reactor economics, the costs of aging and license renewal, and competition, some level of *early* retirement prior to license expiration is now expected. Since the 1983 Report to Congress, eleven units have been retired early. Experts currently project between 5 and 25 additional early reactor unit retirements, depending on assumptions.

The number of reactors participating in the Price-Anderson system is important because most of the total financial coverage derives from the secondary insurance layer. The greater the number of participating reactors, the greater the coverage and the higher the liability limit. As the number of reactors decreases due to retirement without replacement, the amount of coverage, along with the liability limit, will decline until federal indemnification is triggered again. The return of federal indemnification is not likely to occur until sometime after 2020, unless many reactors retire early without replacement.

Legislative options to address the decline in coverage include (1) maintaining in real dollars the current $9.43 billion of coverage, (2) letting the aggregate amount of coverage decline as reactor units retire, or (3) setting the aggregate coverage at another (perhaps risk-related) value.[8]

To maintain in real dollars the 1998 level of $9.43 billion per incident in insurance coverage, each remaining reactor unit would need to increase its individual coverage level to offset each retirement. By 2008, maximum secondary assessments would need to increase by between 10 and 28 percent in real terms to maintain current aggregate levels of coverage, assuming the maximum level of primary insurance remains at the $200 million level.[9] By 2013, the maximum secondary assessment would need to increase by between 58 and 120 percent to maintain the current aggregate level of coverage. Therefore, a doubling of the amount of the secondary layer of coverage (and corresponding doubling of the current annual retrospective assessment) by 2013 may be required to maintain current funding levels in real dollars. NRC staff believes that most utilities should be able to handle a doubling of the current $10 million level of annual retrospective assessment payments to $20 million with

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[7] See "Final Policy Statement on the Restructuring and Economic Deregulation of the Electric Utility Industry," 10 CFR Part 50, Volume 62, *Federal Register*, pp. 44071-44078 (August 19, 1997).

[8] The report does not speculate as to what an appropriate "risk-based level" would be.

[9] Increasing the primary level of coverage will mitigate only to a small degree initially the need to increase the maximum levels of secondary assessments.

little distress (see Appendix A of the report). However, the Commission also notes that the current deregulatory environment, which may lead to restructuring within the nuclear utility industry, may also impact the ability of some utilities to handle a $20 million annual retrospective premium assessment.

Alternatively, holding the current $200 million primary insurance and the current $83.9 million maximum assessment levels constant in real terms, by 2008 maximum available insurance funds in real terms will decline to $7.58 billion and by 2013 will amount to $4.48 billion, assuming a high early retirement scenario occurs (i.e., only 88 and 51 reactor units operating in 2008 and 2013, respectively). These are large sums of money, much greater than the levels of claims payments incurred to date. Funding levels between $4.5 and $6 billion (low early retirement scenario) by 2013 should be ample, based on experience to date. However, accidents with greater off-site consequences than any so far in our experience are conceivable, with higher amounts of potential public liability claims.

Summing up, in the near-term, the threat posed to the Price-Anderson system by reactor retirement without replacement is not critical. In the long-run, reactor retirement without replacement may seriously erode the financial protection available and/or require retrospective payment levels that may be difficult for utilities to afford.

2.2 State of Knowledge of Nuclear Safety

2.2.1 Safety Performance of Nuclear Power Reactors

In terms of public health consequences, the safety record of the U.S. nuclear power industry has been excellent. The only incident in United States reactor history (approximately 2,000 reactor-years) that may result in injury to the public is the 1979 accident at Three Mile Island. A study reported in 1990 found no concrete evidence that the Three Mile Island accident affected cancer rates in the area immediately surrounding the plant.[10] The principal study of the effects of environmental radiation from nuclear facilities, performed by the National Cancer Institute, found "no suggestion that nuclear facilities may be linked causally with deaths from leukemia or other cancers."[11]

The NRC monitors the performance of the 110 commercial nuclear power plants currently licensed for operation in the United States. Tools currently used in monitoring licensee performance include a set of eight Performance Indicators (PIs), the Systematic Assessment of Licensee Performance (SALP), and the Senior Management Meeting (SMM) ("Watch List" and "Declining Trends List"). These tools generally document improving trends and high levels of measured safety performance.

2.2.2 Potential for Occurrence of Accidents

The state of knowledge of nuclear safety requires consideration of various types of possible accidents that may pose a public risk. Probabilistic risk assessment (PRA) is an analytical process that can estimate

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[10] Maureen C. Hatch, *Cancer Near the Three Mile Island Nuclear Plant: Radiation Emissions*. Columbia University School of Public Health, September, 1990.

[11] Jablon, Seymour, Hrubec Zdenek, John D. Boise, and B.S. Stone, *Cancer in Populations Living Near Nuclear Facilities*, National Institutes of Health Publication 90-874, July 1990.

quantitatively the potential public risk, considering the design and the operational and maintenance practices of a plant. In 1975, the NRC completed the first study of design basis accidents postulated for commercial nuclear power plants -- WASH-1400, the Reactor Safety Study. WASH-1400 evaluated for two nuclear power plants the probability of postulated accident sequences that could lead to core damage. WASH-1400 found that accident probabilities were higher than previously believed but that the offsite consequences (to the public and the environment) were significantly lower.

In NUREG-1150, the 1990 update of the Reactor Safety Study, the NRC used improved PRA techniques to assess the risk associated with five nuclear power plants, including the two plants originally evaluated in WASH-1400. In general, the central estimates (means, medians) of the distributions reported in NUREG-1150 are lower in magnitude than those predicted in earlier studies, such as WASH-1400, but the uncertainty ranges remain large.

At this point, the interaction between nuclear accident risk and Price-Anderson can still be summarized as follows: Although the two layers of insurance should provide ample liability protection for most postulated nuclear power plant accidents, there remains a very low probability of a very high-consequence accident that could result in public liability claims well in excess of the present and projected amounts of nuclear liability insurance.

2.3 Availability of Private Nuclear Liability Insurance in the U.S.

The Price-Anderson Act motivated the private insurance industry to develop a means by which nuclear power plant operators could meet their financial protection responsibilities. The insurance industry chose the "pooling" technique. Pooling provides a way to secure large amounts of insurance capacity by spreading the risk of a small number of exposure units (i.e., reactors and other nuclear-related risks) over a large number of insurance companies. American Nuclear Insurers (ANI), an insurance industry pool, currently writes all nuclear liability policy limits up to $200 million. In 1998, ANI's members retained 31.1% of the liability exposure under each policy and ceded 68.9% to reinsurers around the world. This approach allows ANI to marshal the resources of the worldwide insurance community and spread the uncertainties of the risk over a very large financial base.[12]

Insurers and other observers believe that the Price-Anderson Act has been an important element in enabling insurers to provide stable, high quality capacity for nuclear risks. The Price-Anderson Act has encouraged maximum levels of insurance for the nuclear risk in the face of normally overwhelming obstacles for insurers - i.e., catastrophic loss potential, lack of credible predictability, very small spread of risk, and limited premium volume. This has been accomplished over more than forty years without interruption and without the "ups and downs" (or market cycles) that have affected nearly all other lines of insurance business.

The amount of available primary coverage has not risen since 1988, when Congress vastly increased the amount of funding available under the retrospective assessment layer; however, ANI has stated that it could more than likely increase the available primary coverage. There reportedly is little demand from within the nuclear industry to increase the primary insurance limits. Although such increases would contribute only marginally to

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[12] A portion of the reinsurance ceded by ANI is currently being ceded to Nuclear Electric Insurance Limited (NEIL), a nuclear utility mutual (or "captive") insurance company incorporated with limited liability under the laws of Bermuda.

the total aggregate coverage, given the greater size of the retrospective assessment layer, an increase to about $350 million (to account for inflation since 1957) would provide a substantial cushion for accidents comparable to TMI. Moreover, the costs to utilities of increasing the size of the primary layer would be mitigated by the industry's involvement as a reinsurer and the insurers' program for making premium refunds after 10 years on the basis of industry-wide loss experience. ANI does not need Commission approval or Congressional legislation to increase the primary insurance level. The Commission believes , however, that Congress may wish to consider investigating with the nuclear insurance industry an increase in the primary insurance layer.

Claims History Under Price-Anderson

From 1957 to December 1997, claims for 195 alleged incidents involving nuclear material under various liability policies were filed. Most, but not all, of the reported claims experience is related to indemnified nuclear facilities. The insured losses and expenses paid through this period total approximately $131 million. Of this amount, about $70 million ($42 million in indemnity and $28 million in expenses) arose out of the Three Mile Island Unit 2 (TMI-2) accident that began on March 28, 1979.

Part 3: Other Relevant Price-Anderson Issues

3.1 State of Scientific Knowledge of Causality And Legal Issues as to Proof of Causation

Because the evidence of harm generally is not contemporaneous with the exposure, a recurring issue related to compensating victims of radiation exposure is how to determine who in fact has been harmed when releases or exposure levels are low. The report reviews the current state of scientific knowledge for identifying radiation-induced harm and those exposed as well as current legal issues relevant to compensation.

3.1.1 State of Scientific Knowledge

Since the last NRC Report to Congress on the Price-Anderson Act, the knowledge base for identifying biological effects and other indicators of radiation exposure has expanded. A significant change that has occurred is the overall increase in the estimate of lifetime cancer risk attributable to a given radiation dose in the high dose, high dose rate regime. This increase is due primarily to reassessments of radiation dosimetry at the Hiroshima and Nagasaki atomic bomb sites. Another significant change—attributable both to new studies of the atomic bomb survivors and to advances in biological science—is the ability now to generate better estimates of the effects of radiation on the mental development of the fetus. Notwithstanding these gains in the knowledge base, however, much still is unknown about the biological effects of radiation, particularly at low dose and low dose rates. Additional studies, which are underway, may provide additional insights into the health effects of low level radiation exposure.

3.1.2 Legal Issues Relating to Proof of Causation and Damages

The 1988 Amendments committed Congress to providing "full compensation" to those injured as a result of a nuclear accident or precautionary evacuation. However, the Amendments left the resolution of the extent of proof required to establish compensable injury to state law. As it may often not be possible to establish by a preponderance of the evidence that later appearing health effects were caused by exposure during the accident (as opposed to other environmental or genetic factors), state tort law governing the degree of proof of causation required to establish entitlement to compensation may result in the denial of compensation to individuals with latent health effects. This issue was reviewed in detail by the Presidential Commission on Catastrophic Nuclear Accidents, which was established by the 1988 Price-Anderson Amendments "to study means of fully compensating victims of a catastrophic nuclear accident that exceeds the amount of aggregate public liability." The *Report to the Congress of the Presidential Commission on Catastrophic Nuclear Accidents* was published in August, 1990. Following submission of its report, the study commission terminated, as specified by Congress.

The system as it exists today is well able to provide ample and prompt compensation for public injuries and other economic losses directly connected to a serious nuclear accident. The NRC expects that, if a serious accident should occur where latent effects are scientifically shown to be probable, the courts would do their best to satisfy statutory requirements that funds be allocated for latent injury claims. However, to sustain a claim, there may be difficulties in establishing sufficient proof that latent injuries are, in fact, caused by the nuclear accident. Despite these concerns, the Commission believes that it is premature to modify the causation and proof of damages provisions of the Price-Anderson Act.

3.2 Issues Raised by the Convention on Supplementary Compensation for Nuclear Damage

The Convention on Supplementary Compensation for Nuclear Damage signed by the United States is a new international convention on civil nuclear liability that in large part is modeled after the Paris and Vienna Conventions on Nuclear Liability, which were in turn rooted in the earlier Price-Anderson Act. The new Convention overlaps and replicates many provisions in Price-Anderson and does not conflict with Price-Anderson provisions in any significant way. A "grandfather" provision permits the U.S. to become a Party without amending the Price-Anderson Act's idiosyncratic provisions, designed principally to accommodate our federal system. Thus, virtually no changes in the Price-Anderson Act are required for the U.S. to join the Convention. Any modifications to the Price-Anderson Act would necessarily take into account potential U.S. obligations under the Convention. Failure to extend the Price-Anderson Act to cover future as well as existing plants would be inconsistent with ratification and disturbing to other signatories and the interested international community.

Part 4: Conclusions and Recommendations

The structured payment system (currently billions of dollars) created to meet the two objectives stated in the Price-Anderson Act has been successful. It has operated for over 40 years with minimal cost to the taxpayer. As discussed in detail in the report, the Price-Anderson system has functioned well in connection with the payment of claims arising out of the Three Mile Island accident in 1979, the only major accident situation where it was called upon. Many nuclear suppliers express the view that without Price-Anderson coverage, they would not participate in the nuclear industry. Regardless of the degree of early retirement of nuclear reactors, Price-Anderson will continue to make a large sum of funds available to victims of nuclear incidents for at least the next decade.

In considering the future direction of the Price-Anderson Act, the Congress has before it a range of possible actions from termination of the Act (which would not terminate Price-Anderson coverage in connection with currently licensed facilities) to its extension unchanged. The Commission believes that in view of the strong public policy benefits in ensuring the prompt availability and equitable distribution of funds to pay public liability claims, the Price-Anderson Act should be extended to cover future as well as existing nuclear power reactors.

The Commission believes that the same amount, type, and terms of public liability protection should be provided for future and existing plants.

Recommendations

(1) The Commission recommends renewal of the Price-Anderson Act because the Act provides a valuable public benefit by establishing a system for the prompt and equitable settlement of public liability claims resulting from a nuclear accident. The Commission further recommends extending the Act for only 10 years to allow Congress to be better able to take account of substantial changes that have begun and will continue within the nuclear power industry. While existing nuclear power plants would remain covered in any event, the Act should be extended to cover future nuclear power plants, and the existing limit of liability provisions should be maintained. Any changes in the Act should also apply to existing nuclear power plants.

(2) The Commission recommends that the Congress consider amending the Price-Anderson Act to raise the maximum annual retrospective premium that can be charged from the present $10 million per reactor per incident to $20 million per reactor per incident per year. An increase in the size of the annual retrospective premiums to $20 million would substantially increase the amount of funds available shortly after a nuclear accident to pay public liability claims but should not jeopardize the financial viability of the participating utilities. However, deregulation and restructuring within the utility industry may have some impact on certain licensees' ability to cover such assessments. The current statutory provisions to determine the maximum total retrospective premium per reactor per incident should remain the same (currently $83.9 million).

(3) The Commission does not recommend changes to the causation and proof of damages provisions of the Price-Anderson Act at this time.

(4) The Commission recommends that the Congress consider investigating with nuclear liability insurers the potential for increasing the private insurance capacity made available through the insurance pools for the basic layer of insurance. The Commission notes that this capacity has not kept pace in recent years with inflation.

(5) The Commission recommends that the Congress clarify its intent on the following issues that have been or can be sources of uncertainty in implementing Price-Anderson. The clarification should ensure that:

    (a) A nonprofit NRC licensee may not be indemnified for legal costs incurred in connection with the settlement of a claim

    (b) The prohibition on payment of punitive damages extends to every case where a defendant is indemnified under Price-Anderson not just where damages would exceed financial protection and would actually involve the government paying for punitive damages.

(6) The Commission recommends that the Congress should determine whether a public liability lawsuit arising or resulting from a nuclear incident may be filed in a tribal court. Further judicial developments relating to this issue may suggest consideration in connection with Price-Anderson renewal legislation.

(7) The Commission recommends that any modifications to the Price-Anderson Act should take into account any potential U.S. obligations under the Convention on Supplementary Compensation for Nuclear Damage.

(8) The Commission recommends that Price-Anderson implications of any new regulatory responsibility for DOE activities or facilities which Congress may assign to the Commission be addressed by a provision in the enactment creating the Commission's specific authority for that regulation.

FOREWORD

The Atomic Age began in December 1942, when Enrico Fermi and others achieved the first controlled nuclear chain reaction at the University of Chicago. Among other things, that success led to both the atomic bomb and commercial nuclear power. The great potential which nuclear power held for society was recognized early on, as was the need for vigilance to ensure safety. The U.S. Congress also recognized that a careful balancing of societal interests to protect accident victims and to advance development of what was then a fledgling technology would be needed. The Congressional hearings on this issue took place in the aftermath of legislation enacted by Congress to compensate the innocent victims of the Texas City disaster. In that incident, a ship being loaded with fertilizer for export by the government under the Marshall Plan exploded by accident, leveling the city and killing and injuring thousands. After many years of litigation, culminating in Supreme Court review, it was ruled that neither the government nor any other party was liable, and no claims were paid. Ultimately, Congress stepped in to make some funds available. In drafting legislation on nuclear power reactors, Congress responded not only to the nuclear industry's fears of being wiped out by uninsurable liability claims, but also to the lesson learned from Texas City to ensure that some mechanism would be in place to pay the innocent victims of a nuclear accident, regardless of what or who caused it.

The resulting "Price-Anderson" provisions of the Atomic Energy Act of 1954, as amended, have proven to be a remarkably successful piece of legislation. Enacted in 1957, Price-Anderson embodies two core values of the United States that remain essential as the nation crosses into the next century. These values include the desire to foster the development of technology to improve living standards for all Americans and a commitment to compensate those who may suffer from the consequences of deploying or testing advanced technologies. With negligible cost to the public, the Price-Anderson Act has facilitated the development of innovative nuclear power technology for peaceful uses and has assured that, in the unlikely event of an accident, the public will be compensated for any resulting liabilities. The Price-Anderson system as applicable for commercial reactors, which is paid for by private industry, has grown in depth of coverage over the years and proved its viability in the aftermath of the unfortunate Three Mile Island incident. Especially considering that the federal government no longer stands as the indemnifier for large, commercial nuclear power reactors, except in certain scenarios, continuing Price-Anderson further into the next century appears today to be prudent public policy. Because the Act has benefitted from extensive public discussion and legislative modification over the years, only modest changes need be contemplated in connection with its renewal.

In 1975, when Congress extended the Price-Anderson Act for ten years from August 1, 1977 to August 1, 1987, it added a new subsection 170p. that read as follows:

> p. The Commission shall submit to the Congress by August 1, 1983, a detailed report concerning the need for continuation or modification of the provisions of this section, taking into account the condition of the nuclear industry, availability of private insurance, and the state of knowledge concerning nuclear safety at that time, among other relevant factors, and shall include recommendations as to the repeal or modification of any of the provisions of this section.

The 1988 Price-Anderson Amendments[13] retained this requirement, changing the date of the required report to August 1, 1998. Under the current Price-Anderson provisions, the Commission does not have the authority to enter into new indemnity agreements with its licensees after August 1, 2002. The Nuclear Regulatory Commission is submitting this report, which has been extensively reviewed by the Commission, in response to that Congressional requirement. This report pertains only to issues for which the U.S. Nuclear Regulatory Commission (NRC) is responsible.[14]

Part 1 of this report provides an overview of the Price-Anderson system of nuclear liability insurance and indemnity. Included in this overview are a concise history of the Price-Anderson Act and its amendments through the 1988 extension and an update on legal developments and events pertaining to nuclear insurance and indemnity since the 1988 extension.

Part 2 of the report addresses those issues identified in subsection 170p. relating to the need for continuation or modification of the Act. These include the following:

- the condition of the nuclear industry
- the state of knowledge of nuclear safety
- availability of private insurance

Although these issues alone were specifically identified by Congress as related to the need for continuation or modification of the Act, Congress invited NRC to consider other relevant factors. Other issues pertaining to protection of the public have arisen in recent years through legislative proposals, academic studies, or suggestions by members of the public, States, or public interest groups. In preparing this report, which is likely to be one of several analyses on the future of Price-Anderson that will be undertaken by different groups, NRC believes it is responsive to the spirit as well as the letter of the Congressional report requirement to apply its expertise to a number of these other issues. Therefore, Part 3 of the report considers other issues that are relevant to the Act such as scientific and legal proof of causality and an international agreement relevant to Price Anderson.

Part 4 contains the Commission's conclusions and recommendations.

Part 5 is the list of references.

Appendix A presents an evaluation of the affordability of certain Price-Anderson assessments.

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[13] The Price-Anderson Amendments Act of 1988, Pub.L. No. 100-108, 102 Stat. 1066 (1988), amending Sections 11 and 170 of the Atomic Energy Act.

[14] This report does not include any discussion of issues relating to Department of Energy (DOE) contractor activities indemnified under subsection 170d of the Atomic Energy Act, which are the subject of a separate report by DOE and outside the scope of this report.

ACKNOWLEDGMENTS

The overall responsibility for the preparation of this report was assigned to the Generic Issues and Environmental Projects Branch, Division of Reactor Program Management, Office of Nuclear Reactor Regulation, Nuclear Regulatory Commission. Ira P. Dinitz, Senior Insurance and Indemnity Specialist, had primary responsibility for providing technical input to and review of the preparation of the report. Marjorie S. Nordlinger, Senior Attorney, Office of General Counsel, also made substantial contributions to the report. Many other members of the NRC assisted in the review of drafts of this report.

This report was prepared under Task Order 8 of Contract Number NRC-04-95-065; Joe Mate of the Office of Nuclear Reactor Regulation served as NRC Project Officer, and Sid Feld of the Office of Nuclear Reactor Regulation was the NRC Technical Monitor. The ICF contractor team was led by Paul Bailey with the support of Kevin Blake, Margo Brown, Peter Duback, Stephen Krill, James Laurenson, and Jerome Saltzman, former Executive Director, Presidential Commission on Catastrophic Nuclear Accidents. Consultants to ICF included Dr. John Long, former Chair, Insurance Department, Indiana University, and Laurie Rockett, Esquire, partner Hollyer Brady Smith Troxell Barrett Rockett Hines and Mone, LLP. Finally, John Quattrochi, Senior Vice President, American Nuclear Insurers, provided insurance input to this report.

PART 1: OVERVIEW OF PRICE-ANDERSON SYSTEM

1.1 History, Major Provisions, and Scope

The Atomic Energy Act of 1954[15] removed the restrictions placed by the Atomic Energy Act of 1946 on the possession and use of substantial quantities of fissionable materials by private persons and organizations and authorized a comprehensive regulatory program. In the period immediately following the enactment of the 1954 legislation, attention focused on a significant impediment to the development of peaceful uses of atomic energy by the private sector of the economy: the lack of adequate available insurance. Despite its remote possibility, if a major nuclear accident were to occur, its consequences could result in liability claims that would exhaust the levels of insurance that were then available and impose on the nuclear industry large, potential losses for which no insurance was available. In response to this situation, the Price-Anderson Act[16] was enacted into law on September 2, 1957, as Section 170 of the Atomic Energy Act.

The Price-Anderson Act was enacted to meet two basic objectives:

(1) Remove the deterrent to private sector participation in atomic energy presented by the threat of potentially enormous liability claims in the event of a catastrophic nuclear accident.

(2) Ensure that adequate funds are available to the public to satisfy liability claims if such an accident were to occur.

Congress designed the Price-Anderson Act to equitably balance the public's needs with industry's. Specifically, Congress decided to require that licensees provide financial protection[17] for risks of liability for nuclear damage, to indemnify the nuclear power industry as necessary, and to cap total liability in the event of an incident.

The Price-Anderson Act has been successful in removing impediments for firms to enter, and then remain, as participants in the civilian nuclear sector. The Act accomplished this with its indemnification program and liability limits. Companies representing both utilities and support service and equipment suppliers indicated they would likely not participate in the nuclear industry without some method of liability limitation, such as that provided under the Price-Anderson Act. Public testimony submitted during initial enactment of the Price-Anderson Act in 1957 and its subsequent renewals (most notably, in 1965, 1966, 1975 and 1988) supported this viewpoint.

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[15] 42 U.S.C. §§ 2011-2284 (1994 and 1997 Supp.).

[16] Public Law 85-256, 71 Stat. 576, amending the Atomic Energy Act to include Section 170 and related definitions in Section 11.

[17] Although Price-Anderson offers optional methods of providing financial protection, licensees have always purchased nuclear liability insurance to meet the requirement for financial protection.

The original Price-Anderson Act limited liability for any single nuclear incident to $560 million.[18] This was the sum of $500 million per reactor unit in government indemnification plus the maximum level of private insurance (i.e., $60 million) available at the time. In the event of an incident, the unit's owners were responsible for the first $60 million in payments with the federal government responsible for the next $500 million. The maximum amount for each nuclear incident remained $560 million until 1975.

The private insurance just described ($60 million in 1957), whereby utilities pay a premium each year for liability coverage of a fixed amount, is referred to in this report as "primary insurance" or "primary coverage." The obligation by the government to provide funds for a nuclear accident once the private insurance for that accident has been exhausted is referred to as "government indemnity."

1.1.1 Major Revisions of Price-Anderson

The Price-Anderson Act has had several major revisions. In 1965, the Act was extended through August 1, 1977. In recognition of the intention of the insurance industry to raise its liability capacity above $60 million, the 1965 Amendments stipulated that government indemnity would be reduced to the degree that financial protection was provided above $60 million.

The 1966 Amendments introduced the related concepts of extraordinary nuclear occurrence (ENO) and waiver of defenses. When the Commission determines that a nuclear incident is an ENO in accordance with the Commission's regulations, a recovery scheme referred to as "waiver of defenses" is activated whereby claimants would need to show only (1) personal injury or damage, (2) monetary amount of loss, and (3) causal link between the loss and the radioactive material released. Claimants would not need to show the fault of any party in order to pursue their claims. These provisions were needed because, at the time, many States did not have strict liability laws applicable to claims from nuclear accidents.

The Act was again amended on December 31, 1975 to provide for an additional 10-year extension through August 1, 1987. The 1975 Amendments directed the Commission to require that licensees maintaining the maximum amount of financial protection (i.e., large commercial nuclear power reactors) participate in a retrospective premium insurance plan. Under the plan, licensees would be required to pay a pro-rated share of the damages in excess of the primary insurance amount up to $5 million per reactor per incident in retrospective premiums (also called "deferred premiums") in the event of a nuclear incident resulting in damages exceeding the amount of primary insurance coverage. The private insurance just described, based on retrospective premiums, is referred to in this report as "secondary insurance" or "secondary coverage."

Because the limit of liability remained at $560 million under the 1975 Amendments, the effect of the secondary layer of insurance was to reduce the indemnity obligation of the government. In November 1982, when the 80th large nuclear power reactor was licensed, the total retrospective coverage became $400 million (80 reactors times $5 million). The $400 million, when added to the $160 million primary insurance layer then available, resulted in a total of $560 million -- equal to the existing limit of liability -- so that the government indemnity under the Act was essentially eliminated. Congress also provided that the limitation of liability, which equalled the total financial protection of the primary and secondary layers of insurance, would grow in $5 million

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[18] All dollar amounts used in this report are nominal (i.e., non-deflated, own-year) dollars unless otherwise stated in the text.

increments as each new power reactor was licensed to operate. Finally, in recognition of concerns about the adequacy of the limit of liability at the time, the 1975 Amendments explicitly provided that "in the event of a nuclear incident involving damages in excess of [the] amount of aggregate liability, the Congress will thoroughly review the particular incident and will take whatever action is deemed necessary and appropriate to protect the public from the consequences of a disaster of such magnitude."

In the 1988 Amendments, Congress extended Price-Anderson, made a larger pool of funds available to pay public liability claims by increasing the maximum secondary layer to $63 million per reactor unit per incident, to be adjusted for inflation, raised the maximum annual retrospective premium to $10 million from $5 million, retained the existing statutory language for the finding of an ENO, eliminated the 20-year statute of limitations, commissioned a study of administrative systems for compensating latent injury claims, left causation and proof of damages provisions unchanged, extended waiver of defenses provisions, and excluded the payment of defense costs from the insurance layers under certain conditions when the public liability from an accident may exceed the limit of liability. Congress did not, however, eliminate the limit on liability.

The 1988 Price-Anderson Amendments also mandated the establishment of the Presidential Commission on Catastrophic Nuclear Accidents "to study means of fully compensating victims of a catastrophic nuclear accident that exceeds the amount of aggregate public liability." The *Report to the Congress of the Presidential Commission on Catastrophic Nuclear Accidents*, (the "*Presidential Commission Report*") was published in August, 1990. Following submission of its report, the study commission terminated, as specified by Congress.

1.1.2 Scope and Implementation of Price-Anderson

The key parameters of Price-Anderson include: which licensees are covered, how much coverage is provided, what costs are covered, and the compensation process. Each of these parameters is discussed in the following sections.

1.1.2.1 Licensees Subject to Price-Anderson Indemnity

The first major Price-Anderson parameter concerns which licensees it covers. The Price-Anderson system channels to the operator the obligation to pay compensation for damages and provides "omnibus" coverage; i.e., the same protection available for the operator of a covered facility extends through indemnification to any person who may be legally liable, regardless of the identity of the person liable or his relationship to the licensed activity. Thus, those who are injured are assured of the availability of funds to pay their claims, and firms that contribute in some manner to the construction (including design), operation, and/or maintenance of covered licensees are all protected. For example, each defendant company that at the time of the accident was an owner and operator of the Three Mile Island facility, together with each company that supplied design, engineering, or maintenance services, or that was a vendor of systems or equipment incorporated in the facility, was indemnified through the Price-Anderson financial protection system. Because Price-Anderson channels to the party licensed to operate the nuclear reactor the obligation to pay compensation for damages, a claimant need not sue all of these parties but can bring its claim to the reactor licensee.

Price-Anderson's primary focus is on "production and utilization facilities." Included within this term are all nuclear reactors ranging from the largest power reactors to the smallest research and test reactors, as well as fuel reprocessing plants and enrichment facilities. The Commission is required to apply the provisions of the

Act to production and utilization facilities.[19] The NRC is also given discretionary authority to apply the provisions to other types of licensees not involved in the operation of production or utilization facilities, such as those possessing radioactive materials. Price-Anderson currently applies to the categories of licensees as described below:

- Large Commercial Reactors. Licensees of nuclear power plants having a rated capacity of 100 MW(e) or more must provide proof to NRC that they have financial protection in an amount equal to the maximum amount of liability insurance available at reasonable cost and on reasonable terms from private sources. These licensees also must participate in the secondary insurance retrospective premium program described below.

- Reactors Under 100 MW(e). Licensees authorized to operate nuclear reactors of less than 10 MW(t) capacity are required by NRC to have and maintain financial protection in amounts ranging from $1 million to $2.5 million depending on their power levels. Financial protection requirements for power reactors authorized to operate above 10 MW(t) and below 100 MW(e) are established in accordance with a formula designed to take into account the population in a reasonably sized area around the reactor. Under the formula, population is weighted roughly in inverse proportion to the square of the distance of the population from the reactor site.

  -- Federal Licensees. Federal agencies licensed to operate nuclear reactors are not required to provide financial protection and receive government indemnity coverage from the first dollar up to $500 million. (DOE facilities are not licensees.)

  -- Nonprofit Educational Institutions. A number of state-owned educational institutions are unable to comply with subsection 170a of the Act (the requirement to provide financial protection which includes coverage of the legal costs of defending against suits) because of sovereign immunity from public liability and lack of authority to waive immunity or pay insurance premiums. Congress enacted remedial legislation in 1958 (P.L. 85-744, 72 Stat. 837), which became subsection 170k of the Act. As a result, licensees found by the NRC to be nonprofit educational institutions are granted a waivable exemption from the financial protection requirements of Price-Anderson. NRC is required to indemnify such licensees from *public liability* arising out of a nuclear incident in excess of $250,000 up to the statutory maximum of $500 million and to make payments without regard to immunity that the institution may have. Some of the licensed non-profit educational institutions have chosen to purchase nuclear liability insurance to cover the unindemnified $250,000.

- Plutonium Processing and Fuel Fabrication Facilities. Subsequent to the renewal of the Price-Anderson Act of 1975, the NRC considered whether its discretionary authority to extend Price-Anderson coverage should be applied to persons using plutonium in plants defined in NRC regulations as "plutonium processing and fuel fabrication facilities."

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[19] Public Law 1010-575, 104 Stat. 2835 (1990) added to Section 193 of the Atomic Energy Act subsection (e) stating that Section 170 of the Atomic Energy Act shall not apply to any license under Part 53 or 63 for a uranium enrichment facility constructed after the date of enactment of this subsection.

The NRC decided after study to exercise its discretionary authority and require as of August 1, 1977, that plutonium processors having authorized plutonium possession limits of five kilograms or more must provide the maximum financial protection available.

- Other Materials Licensees. Subsequent to 1977, NRC also evaluated whether it should exercise its discretionary authority and require financial protection for materials licensees other than those possessing plutonium. Based on work performed for NRC by the Oak Ridge National Laboratory (see NUREG/CR-0222 "Economic Consequences of Accidental Release from Fuel Fabrication and Radioisotope Processing Plants"), NRC staff refinement of that report, and an in-house study of this question, NRC decided that no apparent need existed to extend Price-Anderson to other classes of materials licensees.[20]

- Radiopharmaceutical Licensees. The 1988 Amendments directed NRC to initiate a proceeding to determine whether radiopharmaceutical licensees should be indemnified under Price-Anderson. Following a negotiated rulemaking process, the arbitrator decided that the NRC should not extend the Price-Anderson Act to these licensees.

Price-Anderson implications of any new regulatory responsibilities for Department of Energy activities or facilities that Congress may assign to the NRC should be addressed when each such assignment is made.

1.1.2.2 Total Amount of Funds to Cover Price-Anderson Claims

The total amount of coverage provided is one of the key parameters of Price-Anderson. The total coverage, which determines the limit of liability, includes both the required financial protection, if any, and the federal indemnity, if any. The sum of any required financial protection and any federal indemnity equals the aggregate limit on liability.

When NRC requires financial protection, subsection 170b of the Act provides that the amount required of licensees will be the amount of liability insurance available from private sources, except that the NRC may establish a lesser amount on the basis of written criteria (which it may revise from time to time) that take into consideration such factors as (1) the cost and terms of private insurance; (2) the type, sizes, and location of the licensed activity and other factors pertaining to the hazard; and (3) the nature and purpose of the licensed activity. Utilities operating large power reactors (with a power level of 100 electrical megawatts (MWe) or more) are required to purchase the maximum available amount of privately underwritten public liability insurance. Initially, federal indemnification filled the gap (up to $500 million)[21] between required amounts of financial protection and the aggregate limit of liability. As the required amounts of financial protection have increased for commercial power reactors, the gap has disappeared, along with federal indemnity. Currently, the required amount of

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[20] The only other instances in which NRC has exercised its discretionary authority involved spent fuel produced at one reactor and stored at the site of another reactor owned by the same licensee. The two licensees involved were Carolina Power and Light Company and Duke Power Company.

[21] Federal indemnification cannot exceed $500 million. For licensees with financial protection requirements of less than $560 million, the Act mandates that NRC provide indemnity protection, in the amount of $500 million for each nuclear incident less the amount by which the required financial protection exceeds $60 million.

financial protection and aggregate limit of liability is the sum of both the primary insurance and the retrospective premium layer.

Since its enactment, the Price-Anderson Act has maintained its requirement that commercial nuclear reactor units be insured to the maximum available primary insurance level. As the private insurance market increased its maximum available level of primary insurance, each nuclear reactor unit needed to increase its coverage level. In turn, federal indemnification was reduced, because of the liability cap. Increases to maximum primary insurance levels since 1957 are shown in Exhibit 1.

Exhibit 1 Growth in maximum available primary insurance

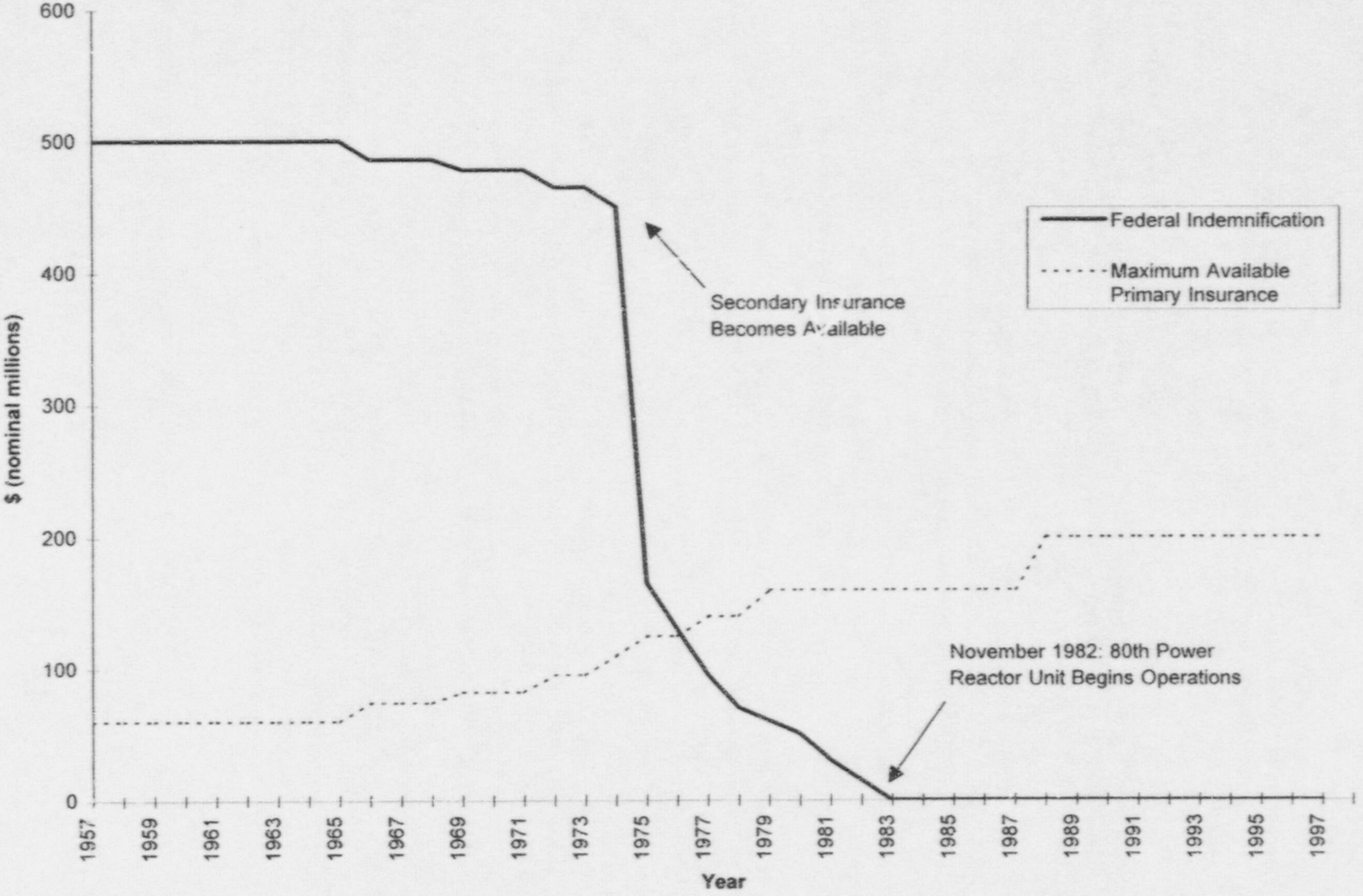
Year	$ (millions)
1957	60
1966	74
1969	82
1972	95
1974	110
1975	125
1977	140
1979	160
1988	200

The 1975 Amendments, as previously noted, created a second insurance program for the commercial nuclear power industry, using what is known as "retrospective premiums." The industry was thereafter required to provide retrospective insurance for a pooled fund in addition to the primary insurance. (The retrospective insurance coverage initially was to make available a pool of funds in a sum equal to a maximum assessment of $5 million per incident for each power reactor.) If an incident occurs, then the licensees -- industry-wide -- are responsible for paying for those damages exceeding the maximum available primary insurance level, up to the maximum secondary assessment level. Exhibit 2 shows the effect of retrospective insurance on federal indemnification, with the dramatic decrease caused by the creation of the secondary insurance program.

After November 1982, with 80 reactor units operational, the maximum available insurance funds totaled $560 million, which was the sum of the maximum retrospective premium assessments (i.e., $5 million per unit per incident multiplied by 80 equals $400 million) and the maximum then available level of primary insurance (i.e., $160 million). Thus federal indemnification for large power reactors was eliminated.

In order to make an even larger pool of funds available to pay public liability claims, as mentioned above, the 1988 Amendments increased maximum secondary insurance assessments to $63 million per reactor unit per incident, with the provision that secondary insurance premiums would thereafter be inflation adjusted at five

Exhibit 2 Decline in federal indemnification



year increments.[22] With the increase in 1988 of the maximum available level of primary insurance to $200 million from $160 million, combined maximum primary and secondary insurance coverage totaled $7.34 billion for all active reactor units in 1988, of which $7.14 billion came from the secondary insurance program. This larger pool of funds was expected to make the compensation system more equitable, reliable, and efficient. Congress did not identify the rationale for the particular number chosen (i.e., $63 million) nor a target for the aggregate limit on liability.

The first adjustment to the maximum secondary insurance premium in 1993 used the difference between the September 1988 and the March 1993 CPI index for urban consumers. This difference equaled 19.9 percent and increased the maximum secondary insurance payment, as of 20 August 1993, to $75.5 million per incident. The NRC updated the maximum secondary insurance premium to $83.9 million as of August 20, 1998.

Thus, as of August 20, 1998, the nuclear power industry will be insured to a maximum per incident dollar level of $9.43 billion. This dollar figure results from adding maximum available primary insurance coverage of $200 million to maximum available secondary insurance of $9.23 billion (i.e., 110 units in 1998 multiplied by $83.9 million). Exhibit 3 highlights these changes by presenting total available insurance funds. The almost vertical rise subsequent to increasing the maximum available secondary insurance level from $5 million to $63 million is one clear effect of the 1988 changes to the Price-Anderson Act. Exhibit 3 shows that the $9.43 billion represents the highest total available insurance level since enactment of the Price-Anderson Act. If the number of participating nuclear power reactor units decreases faster than the rate of inflation, this dollar figure will almost certainly represent the industry's peak in insurance funding, absent further changes to Price-Anderson. Nonetheless, even with a future reduction in participants, the aggregate amount of coverage will remain a large sum for years to come.

1.1.2.3 Covered Costs

In addition to the licensees covered and the amount of coverage, another key parameter of Price-Anderson is the definition of covered costs. That definition must be derived from a series of statutory definitions and provisions. "Financial protection" under Section 11k of the Atomic Energy Act means "the ability to respond in damages for public liability and to meet the costs of investigating and defending claims and settling suits for such damages." Public liability is defined in Section 11w of that Act as follows:

> "any legal liability arising out of or resulting from a nuclear incident or precautionary evacuation (including all reasonable additional costs incurred by a State, or a political subdivision of a State, in the course of responding to a nuclear incident or precautionary evacuation)" except for claims covered by workmen's compensation, claims arising out of an act of war, or claims for loss of or damage to or loss of use of property located at the site of and used in connection with the activity where the nuclear incident occurs.

Section 11q defines the term "nuclear incident" to mean any occurrence within the United States causing bodily injury, sickness, disease, or death, or loss of or damage to property, or loss of use of property, arising out of or

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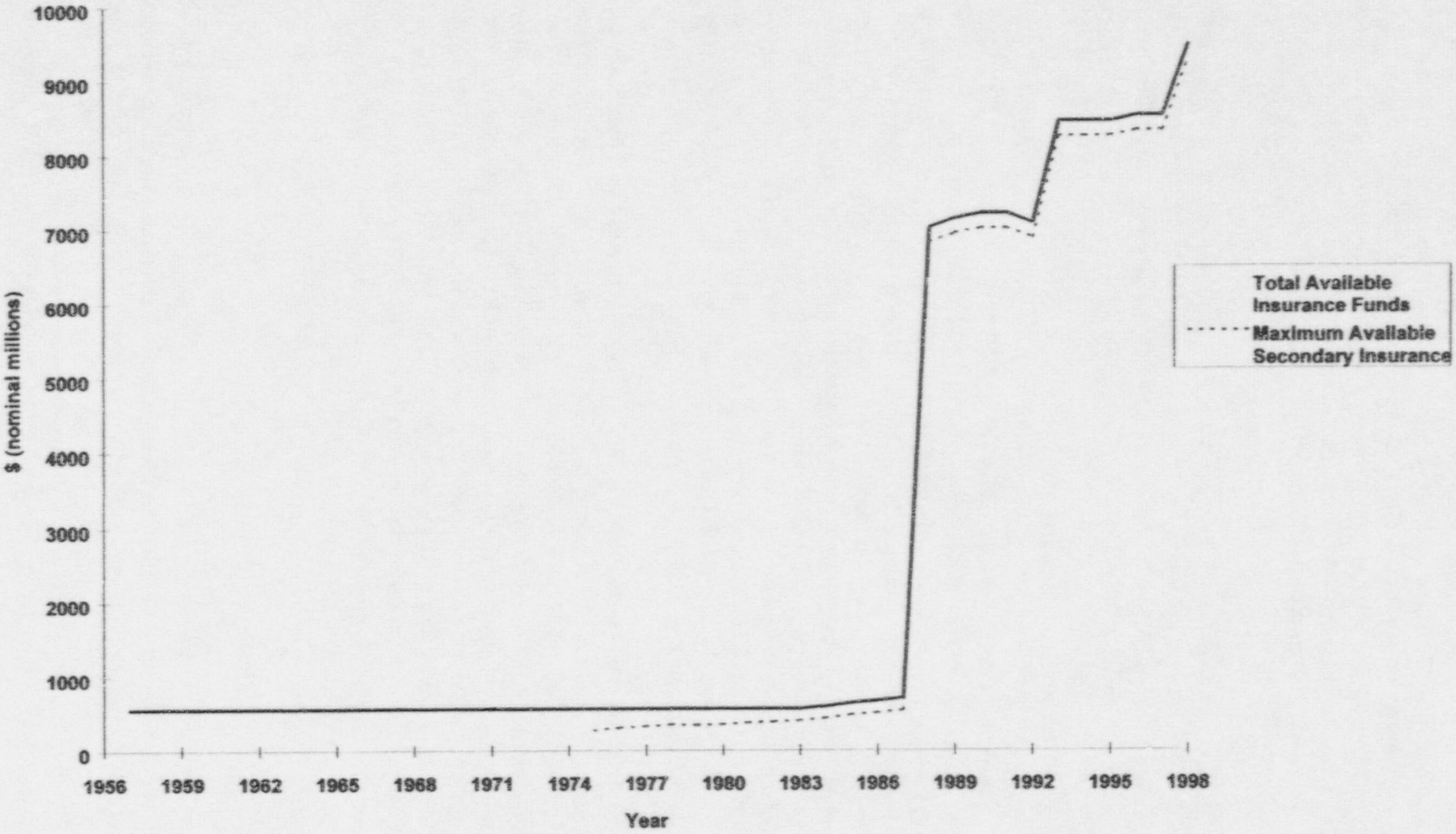
[22] These adjustments are to be made using the aggregate change in the Consumer Price Index (CPI) for urban consumers from the base period.

Exhibit 3 Growth in total available insurance funds (nominal $)



resulting from the radioactive, toxic, explosive, or other hazardous properties of source, special nuclear, or byproduct material. Accordingly, the scope of Price-Anderson coverage includes any nuclear incident in the course of transportation of nuclear fuel to a reactor site, the storage of nuclear fuel at a site, the operation of a reactor including discharges of radioactive emissions or effluents, the storage of nuclear wastes at a reactor site, and the transportation of radioactive material from a reactor. Required "financial protection" covers defense costs and "public liability." Government indemnity also covers "public liability" and covers additional costs as specified in the Act.

Which costs are recoverable under the rubric of public liability may differ across state jurisdictions and has evolved over time.[23] All States allow recovery for bodily injury and property damage, but other types of costs may be more problematic. Specific types of costs have proven to be issues under Price-Anderson, as described below and in Section 1.2 of this chapter.

Coverage for Precautionary Evacuation

A report of the General Accounting Office (GAO) dated September 14, 1981 (EMD-81-111), examined the question whether the Price-Anderson Act covered public liability claims in potential nuclear accident situations, even when there was no radioactive release. Although that report focused primarily on the Price-Anderson Act's applicability to Department of Energy nuclear operations,[24] GAO examined the question of whether the definition of "nuclear incident" in the Act was broad enough to cover liability resulting from a nuclear incident in which a radiation release appeared imminent but did not occur and yet a precautionary evacuation was ordered. This question may have had less significance for reactors licensed and indemnified by NRC because the terms of the primary and secondary insurance provided by these licensees insure payment "for loss of use of property while evacuated or withdrawn from use because ... of imminent danger of such contamination." However, it remains to be seen how the insurers will interpret coverage (e.g., personal injury claims) under this provision in specific circumstances.

Until 1988, neither the Price-Anderson Act nor its legislative history specifically addressed the question whether costs arising from a precautionary evacuation are covered. The 1988 Amendments enlarged the Section 11w definition of "public liability" to include liability resulting from a "precautionary evacuation" and added new sections 11gg and 170q. Section 11gg defines "precautionary evacuation." Section 170(q) precludes any court from awarding costs of a precautionary evacuation unless such costs constitute "public liability." The import of this requirement is that the event must have presented an imminent danger of radiological harm and have been ordered by an authorized state official to protect public health and safety. The determination of whether the costs of precautionary evacuations, as all costs resulting from an actual nuclear incident, are allowable under Price-Anderson will be made by an appropriate court.

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[23] For example, States may differ on whether claims for emotional distress, chromosomal injury, medical monitoring, increased risk, stillbirth, and public response costs following nuclear accidents are recoverable.

[24] DOE contractors are not required to maintain nuclear insurance for their activities but are indemnified by DOE under Price-Anderson for any claims up to the liability limit of power reactor licensees.

1.1.2.4 Compensation Process

Price-Anderson addresses several aspects of the process of compensation. For example, Section 170(g) directs the Commission to use, to the maximum extent practicable, the abilities and services of private insurance organizations. Similarly, Section 170(m) authorizes the Commission to enter into agreements with other indemnitors to establish coordinated procedures for the prompt handling, investigation, and settlement of claims for public liability. Other provisions address issues such as judicial procedures.

Principal obstacles to a claimant's recovery for injuries or damages under the Price-Anderson Act could be the traditional legal defenses against liability such as the conduct of the claimant, fault of persons indemnified, or charitable or governmental immunity. Congress attempted to remove these obstacles in 1966 by amending Price-Anderson to introduce the concepts of extraordinary nuclear occurrence and waiver of defenses. The Act defines the term "extraordinary nuclear occurrence" (ENO) as any event causing an offsite dispersal of source, special nuclear, or byproduct material from its intended place of confinement in amounts, or causing radiation levels, off site that NRC determines to be substantial, and that NRC determines has resulted or will probably result in substantial damages to persons located off site or property off site. The 1966 Amendments authorized the Commission both to incorporate certain "waivers of defenses" into indemnity agreements and to require that insurance policies used to satisfy financial protection provisions incorporate such waivers as well. The waivers include (1) any issue or defense as to conduct of the claimant or fault of persons indemnified, (2) any issue or defense as to charitable or government immunity, and (3) any issue or defense based on any statute of limitations if suit is instituted within three years from the date in which the claimant first knew, or reasonably could have known, of the injury or damage and its cause. After an ENO,[25] claimants need only to demonstrate

- bodily injury and/or property damage
- monetary loss associated with the damage and/or injury, and
- causation of damages and losses by the release of radioactive material from the ENO

In other words, the defenses of negligence, contributory negligence, charitable or government immunity, and assumption of risk are waived in the event of an ENO; the result essentially is a system of strict or "no fault" liability. The importance of the ENO provision has diminished due to the adoption of strict liability in almost all States, which accomplishes a similar result.

Although limiting the liability of covered licensees, Congress recognized that a nuclear incident might involve damages in excess of the limit of liability. In 1975, Congress explicitly committed to take necessary action to protect the public from the consequences of a disaster of such magnitude. In the 1988 Amendments, Congress modified somewhat the language added in 1975 about incidents involving damages in excess of the aggregate liability limit; the 1988 language better defines the procedures Congress will follow and describes the goal as "full and prompt compensation" to the public for "all public liability claims" resulting from such a disaster. Furthermore, Congress added statutory language in Section 170(i) concerning the preparation of compensation plans after any nuclear incident involving damages that are likely to exceed the applicable amount of aggregate public liability.

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[25] In addition, the occurrence must arise out of, result from, or occur in the course of one or more broadly-defined activities. See 10 CFR 120.

Under existing law, original jurisdiction over a public liability action is conferred on the federal district court for the district where the nuclear incident which gave rise to the action occurred; a defendant in such action or the Commission may have any action pending in a state or another federal court removed on motion to the appropriate federal court.[26] If the incident involves damages that are likely to exceed the amount of public liability, the Commission is charged with surveying the causes and extent of damage and submitting a report to Congress, the Representatives and Senators of the affected areas, the parties involved, and the courts.[27] The court, upon the petition of an indemnitor or other interested party must determine whether public liability in the case may exceed the limit of liability or have an unusual impact on the work of the court.[28] If the court determines that public liability may exceed the aggregate public liability available in the first two layers of financial protection, the President is directed to submit to Congress an estimate of the financial extent of damages and recommendations for additional sources of funds and compensation plans providing for "full and prompt compensation for all valid claims . . ."[29]

A determination that public liability may exceed the limit of liability triggers a number of restrictions on the public liability action: total payments made by or for all indemnitors are limited to 15% of the limit of liability without prior court approval, and such approval is not authorized until the court approves a plan of distribution or finds that the payments are not likely to prejudice the subsequent adoption and implementation of the plan. The plan, which may be submitted to the court by the Commission or an interested indemnitor, must contain an allocation of "appropriate amounts" for personal injury, property, and latent injury claims and establish priorities between claimants and classes of claims to ensure the most equitable allocation of available funds. Restrictions are also imposed on the authorization of payment of legal costs to ensure that they were incurred in good faith and are reasonable and equitable.[30]

In terms of the handling, investigation, and settlement of claims, the Commission is directed to use the facilities and services of private insurance organizations and to enter into agreements with other indemnitors to establish coordinated procedures. Payments for the purpose of providing immediate assistance following the incident are explicitly authorized.[31]

The Presidential Commission on Catastrophic Nuclear Accidents considered in detail the process of compensation. The *Presidential Commission Report* reviewed the foregoing provisions for the payment of claims and concluded that, in large part, combined with existing procedural law, they might be sufficiently adaptable to effectuate its recommendations, but that constitutional issues might arise unless the statute were

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[26] Section 170(n)(2). Questions were raised as to the constitutionality of the jurisdictional provision, but the Third, Sixth, and Seventh Circuit Courts of Appeal have each upheld its constitutionality. In re TMI Litigation Cases Consolidated II, 940 F.2d 832 (3d Cir. 1991); Niemen v. NLO, Inc., 108 F.3d 1549 (6th Cir. 1997); O'Conner v. Commonwealth Edison Co., 13 F.3d 1099 (7th Cir. 1994).

[27] Section 170(i)(1).

[28] Section 170(n)(3), (o).

[29] Section 170(i)(2).

[30] Section 170(o)(2).

[31] Section 170(g), (m).

amended. It also determined that certain of its recommendations, such as the application of federal law, could not be achieved without amendment. In other cases, a sympathetic and imaginative judge would be required to implement its recommendations within the framework of existing law. The *Presidential Commission Report* also identified areas in which the possibility of implementation is unclear under existing law.[32]

Among the options for handling the complicated claims resolution process which would follow a catastrophic nuclear incident, the Presidential Commission considered the possibility of establishing an administrative mechanism such as workers' compensation or no-fault insurance as an alternative to the tort system. The Presidential Commission identified a number of benefits of this option, such as uniformity in treating like injuries, low costs, rapid decisionmaking, and evenhandedness as well as the possibility of staffing an agency with scientific and medical professionals. In addition, Congress could readily expand an agency as necessary in terms of its workload, resources, and responsibilities.

Ultimately, however, the Presidential Commission concluded that retention of the judicial model was preferable. Witnesses before the Presidential Commission cited the independence and visibility of the judiciary, the perception of the average citizen of impartiality and fair treatment, the greater flexibility which could be obtained by using a court with special masters as opposed to establishing an administrative apparatus, and the fact that the remoteness of the possibility of an accident makes it unreasonable to establish any agency before an accident actually occurred, while the courts are in place and could immediately begin the handling of claims.[33]

The Presidential Commission recommended the adoption of a system utilizing a tripartite judicial procedure coupled with administrative features for the handling of public liability claims following a catastrophic nuclear accident. The "trigger" for the application of the system would be the point at which there is a reasonable likelihood that claims will exceed the first tier of financial protection and that there will be a multiplicity of claimants. The Presidential Commission further recommended that exclusive jurisdiction and venue over a public liability claim should be vested in a single federal court applying federal statutory and common law, incorporating such features of present law as the waivers of defenses and provision for emergency payments. Congress held hearings on the *Presidential Commission Report*, but no further actions were taken.

1.2 Legal Issues Associated with Price-Anderson Litigation

1.2.1 Constitutionality

The constitutionality of the Price-Anderson Act has been confirmed in several notable cases. In Duke Power Company vs. Carolina Environmental Study Group, Inc., the Supreme Court held without dissent that the liability limitation of Price-Anderson does not violate equal protection. Chief Justice Burger stated for the Court that the liability limit was neither arbitrary nor irrational because the statutory limit was rationally related to

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[32] *Presidential Commission Report* at pp. 57-67. Since that report was prepared, there have been a number of major amendments to Title 28 of the United States Code, the Judicial and Judiciary Law, designed to improve the functioning of the federal courts.

[33] Id. at 34-6.

Congress' desire to encourage the private sector to build and operate nuclear power plants. The Court went on to state that the $560 million figure chosen as the liability limit was also constitutional.[34]

In connection with litigation related to the TMI accident, a U.S. Court of Appeals ruled that Congress did not exceed its authority under Article III of the Constitution in establishing federal jurisdiction over public liability actions relating to nuclear incidents; nor did its retroactive application violate constitutional principles of federalism, state sovereignty, due process, or equal protection.[35]

1.2.2 Coverage of Punitive Damages

In 1984, in the case of Silkwood v. Kerr-McGee Corp[36] the United States Supreme Court addressed the question of whether the federal preemption of state law in the area of regulating the safety aspects of nuclear energy[37] under the Atomic Energy Act precluded the award of punitive damages in cases involving the release of nuclear material. Kerr-McGee, supported by the United States as amicus curiae, argued that punitive damages were intended to punish and deter conduct which could create radiation hazards, and that awards of such damages were therefore regulatory in effect and inconsistent with federal preemption. The Court, relying in part on the legislative history of the Price-Anderson Act, rejected this argument.

Congress subsequently amended the Price-Anderson Act in 1988 to add a new subsection (s) which provides that:

> No court may award punitive damages in any action with respect to a nuclear incident or precautionary evacuation against a person on behalf of whom the United States is obligated to make payments under an agreement of indemnification covering such incident or evacuation.

There have been differing interpretations as to the scope of this subsection. Defendants in Price-Anderson cases have argued that it precludes any award of punitive damages against a party with whom the United States has entered into an indemnification agreement regardless of whether damages in a particular case ever reach the limit of financial protection. Plaintiffs, on the other hand, have argued that the prohibition is limited to cases in which awarded damages exceed the primary and secondary levels, if any, of financial protection and would involve the actual expenditure of government funds.

The application of the section to parties indemnified under NRC agreements was considered in a 1995 decision by the Court of Appeals for the Third Circuit. That Court, after an extensive review of the legislative

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[34] See 438 U.S. 59, 98 S.Ct. 2620, 57 L.Ed.2d 595 (1978).

[35] In re TMI Litigation Cases - Consol. II, C.A.3 (Pa.) 1991, 940 F.2d 832, certiorari denied 112 S.Ct. 1262, 1217 L.Ed.2d 491. Similarly, the Sixth and Seventh Circuit Courts of Appeal have also upheld its constitutionality in the context of claims for occupational injuries. See Niemen v. NLO, Inc., 108 F.3d 1549 (6th Cir. 1997); O'Conner v. Commonwealth Edison Co., 13 F.3d 1099 (7th Cir. 1994).

[36] 464 U.S. 238, 104 S.Ct. 615, 78 L.Ed2d 443 (this litigation did not involve a Price-Anderson claim).

[37] Pacific Gas and Electric Co. v. State Energy Resources Conservation and Development Co., 461 U.S. 190, 211-213 (1983).

history of the subsection, concluded that Congress intended to prohibit payments of punitive damages by the federal government only and that the prohibition did not apply to damages payable out of the primary and secondary levels of financial protection.[38]

The Third Circuit noted the possible inequities built into a statutory scheme where plaintiffs must resort to a finite fund to get compensatory as well as punitive damages, but declined to "usurp Congress' policymaking function."[39] Finally, the Court commented that the authority vested in the district court to prioritize claims and the adaptability of the Price-Anderson's tri-level insurance scheme to such prioritization could avoid such inequities. The Court suggested that priority should be given to compensation of the injured, rather than to payment of punitive damage awards.[40]

The Third Circuit's interpretation appears consistent with the post-1988 retention of model forms for insurance and indemnity agreements, containing clauses explicitly excluding from the application of the waivers of

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[38] In Re TMI, 67 F.3d 1119, quoting, S. Rep. No. 218, 100th Cong., 2d Sess. 12-13, reprinted in 1988 *U.S. Code Cong. & Admin. News* 1476, 1487-88 as follows:

> Punitive damage awards . . . would be prohibited in suits against licensees covered by the retrospective premium system, if, as a result of such an award, payments beyond the primary and secondary layers of financial protection would be necessary, since the United States is obligated to provide a source of funding for such claims.
>
> The bill does not otherwise affect current law regarding punitive damages.

Id. at 1126-7.

The District Court for the District of Colorado, in a case involving defendants indemnified by the DOE, interpreted the same language to prohibit the award of punitive damages in any action against any person who is party to an indemnification agreement as a DOE contractor, subcontractor or supplier regardless of the amount of actual damages. Cook v. Rockwell Intern. Corp., 755 F.Supp 1468, 1479-81 (D.Colo. 1991), relying both on the language of the statute and a statement in the Senate Report to the effect that "punitive damage awards would be prohibited in actions involving DOE contractors indemnified under" the Price Anderson Act. S.Rep. No. 100-70, 100th Cong., 1st Sess. 27, reprinted in *U.S. Code Cong. & Admin. News* 1424, 1440.

[39] 67 F.3d at 1128.

[40] "It cannot be gainsaid that '[i]f there is a limited fund, priority should be given to compensating those who have been injured rather than conferring windfalls on those who have already been compensated.' Citation omitted. We see nothing in the Act that precludes a district court from using its discretion to limit or even preclude punitive damages in accordance with the financial constraints of the fund and the Act's prohibition against punitive damage awards being paid out of the federal layer of insurance." 67 F.3d at 1128.

defenses claims for punitive damages.[41] Such clauses would be unnecessary if punitive damages were prohibited in any action governed by the Price-Anderson Act.

The *Presidential Commission Report* noted that the Act was unclear on the issue of whether punitive damages may be awarded from nongovernment funds. The Commission recommended that punitive damages not be recoverable under the Price-Anderson compensation system. If punitive damages are not excluded, the *Report* recommended that they be ascribed the lowest degree of priority in any plan of distribution adopted under 42 U.S.C. §2210(o) of the Act.[42]

It is not clear whether another circuit Court of Appeals would concur with the Third Circuit's resolution of this ambiguity, and the U.S. Supreme Court has not addressed the issue. Thus, Congress may need to consider amending the statute to address whether the prohibition on payment of punitive damages extends to every case arising under the Price-Anderson Act or only those where damages exceed the first two tiers of financial protection.

1.2.3 Costs of Investigating, Settling, and Defending Claims

The costs of investigating, settling, and defending claims (often termed "defense costs") can be substantial in amount. Treatment of these costs under the Act is complex and has varied over time. In order to ensure that Price-Anderson was used to compensate the victims of a nuclear incident and not to pay attorneys fees and other costs of processing claims, the so-called Hathaway Amendment of 1975[43] excluded the costs of investigating, settling, and defending claims from government indemnification under §170(c). Prior to the 1975 Amendments, the reasonable costs of investigation, settlement, and defense of claims had been included in the scope of the indemnification.

Because the Hathaway amendment excluded defense costs only from those sections of the Price-Anderson Act relating to government indemnity, and because no other sections of the Act were similarly amended, the insurance pools and others believed that defense costs could continue to be paid out of the required financial protection. Insurers believed that if defense expenses were not included, and they were asked to be responsible for additional undetermined sums for claims expense, insurers would reduce the amounts they commit to compensation in order to allow for the unknown expense factor, and some insurers would likely withdraw from the market because of the uncertainty that would be created. The NRC originally believed that Senator Hathaway intended that defense costs be excluded from both the financial protection and government indemnity layers so as to make available the full $560 million to compensate injured parties. To do otherwise, the Commission believed

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[41] 10 C.F.R. §140.91 App. B, ¶2(c); §140.92, App. B, Art. II, ¶5 (d); §140.93, App. C., Art. II, ¶5(d); §140.95, App. E, ¶3(d) and amendments following the enactment of the 1988 Amendments published in 54 Fed. Reg. 24158-24161 which incorporated various provisions of the 1988 Amendments, but left unchanged the provisions relating to punitive damages.

[42] *Report to the Congress from the Presidential Commission on Catastrophic Nuclear Accidents*, Volume One at pp. 4, 72, 75, 95, 100 (August 1990).

[43] Amendment of the "costs" provisions of the Price-Anderson Act was proposed by Senator Hathaway during Senate consideration of the bill. There was virtually no legislative history beyond Senator Hathaway's remarks introducing the amendment and a short colloquy that followed.

at the time, would be to negate the effect of the amendment especially as the secondary retrospective insurance layer would continue to increase and eventually eclipse the government indemnity layer. Because of these differing interpretations, the NRC requested an interpretation of the amendment by the Department of Justic The Department's response, which discussed only the scheme for power reactors, concluded that the Act should be interpreted to exclude the costs of investigation, settlement, and defense of claims from the government indemnity but include these costs in the primary layer of insurance required as financial protection.[44]

The 1988 Amendments altered the Section 170(b) provisions on amount and type of financial protection for licensees by adding that any payments made under the retrospective insurance plan shall not exceed a licensee's pro rata share of "public liability claims and costs (excluding legal defense costs subject to subsection (o)(1)(D) ..., payment of which has not been authorized under such subsection)...." Subsection (o)(1)(D) was added by the 1988 Amendments to address the distribution of funds in situations where a district court determines that the public liability from a nuclear incident "may exceed" the applicable limit of liability; among the provisions are conditions on the payment of legal costs (the costs would be payable only if they met the standards of new Section 170o(2)A and B) and specification that the court may authorize payment of legal costs only from the insurance layers. The exclusion of defense costs from the insurance layers is not otherwise required by Price-Anderson. Accordingly, NRC regulations define "financial protection" to include defense costs.[45] The 1988 Amendments left unchanged the exclusion of defense costs from any federal indemnity of NRC licensees. Also left unchanged was the aggregate public liability limit, which is defined as inclusive of legal costs authorized to be paid under subsection (o)(1)(D). The 1988 Amendments did not alter Section 170(h), which, in any settlement of a claim that arose under the Act, excludes "expenses in connection with the claim incurred by the person indemnified," from indemnification by the government.[46] However, the 1988 Amendments did alter provisions applicable to educational institutions.

1.2.4 Costs of Investigating, Settling, and Defending Claims Brought Against Nonprofit Educational Institutions

In 1996 the Regents of the University of California ("UCLA") sought indemnification from the NRC under 42 U.S.C. §2210(k), for attorneys' fees and expenses incurred in connection with the voluntary dismissal, under terms of settlement agreements, of cases arising out of alleged releases of radioactivity of an NRC-licensed reactor. Paragraph (k) grants a waivable exemption for nonprofit educational institutions from the financial

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[44] Letter from Department of Justice to Peter L. Strauss (June 23, 1977).

[45] 29 CFR 140.3(d).

[46] The section provides in pertinent part:

> The Commission . . . shall have final authority on behalf of the United States to settle or approve the settlement of any such claim on a fair and reasonable basis with due regard for the purposes of this chapter. Such settlement shall not include expenses in connection with the claim incurred by the persons indemnified.

The last sentence of this section has been interpreted by the Commission to exclude attorneys fees from government indemnity.

protection requirement and provides for indemnification by the NRC of such institutions from public liability in excess of $250,000. It also provides that

> [t]he aggregate indemnity for all persons indemnified in connection with each nuclear incident shall not exceed $500,000,000, including such legal costs of the licensee as are approved by the Commission. . . [Emphasis added].

The Regents took the position that this provision of paragraph (k), regarding legal costs, added by the 1988 Amendments, should be deemed controlling. They argued that paragraph (k) dealt specifically with licenses of the type issued to UCLA and therefore prevailed over the more general restriction of paragraph (h).[47] This argument was rejected by the Commission in a formal opinion published on June 29, 1997[48] on the grounds that: (1) the provisions of paragraph (h), left intact by the 1988 Amendments, specifically prohibited indemnifying a licensee for legal expenses incurred in connection with settling a Price-Anderson case and could not be repealed by implication; (2) "public liability" by its terms did not include legal costs, in contrast to other reactor licensees' first tier of required financial protection, and (3) the aggregate of $250,000 public liability was never reached in the UCLA cases and, in fact, no public liability was ever paid. No legal challenge was brought on the Commission's decision. Thus, there has been no further consideration of the question of whether a nonprofit educational institution that is exempt from financial protection requirements may be indemnified for legal costs incurred in connection with the settlement of a claim.

1.2.5 Removal or Transfer of Any Public Liability Lawsuit Resulting from a Nuclear Incident to a United States District Court

Pursuant to 42 U.S.C. 2210(n)(2) any public liability action arising out of or resulting from a nuclear incident can be removed or transferred from a state court to a United States District Court upon the motion of the defendant or the Nuclear Regulatory Commission or the Department of Energy. In several recent lawsuits, to which the United States has not been party, defendant mining and milling companies have sought to enjoin tribal courts from asserting jurisdiction in lawsuits claiming harm to tribal members or their property from radioactivity as a result of mining or milling operations that took place on "Indian lands." Defendants have sought under various legal theories to block consideration of the cases in tribal courts and to have them tried in U.S. District Courts. In three cases of which the Commission is currently aware, the efforts of the defendants have been unavailing. See Kerr-McGee Corp v. Kee Tom Farley, 115 F.3d 1498 (10th Cir. 1997), cert. denied, 118 S.Ct. 880 (1998) and El Paso Natural Gas v. Neztsosie, 136 F.3d 610 (9th Cir.1998) (consolidating 2 appeals from D.Ariz., *reh'g en banc* denied, petition for certiorari filed (June 26, 1998)). In El Paso Natural Gas one of the 3-judge U.S. Court of Appeals' panels which heard the consolidated cases vigorously dissented from the majority opinion, and the petition for hearing in the U.S. Supreme Court awaits decision.

In light of the substantial time remaining before the Congress will need to decide whether any aspect of these matters should be addressed in Price-Anderson legislation, the Commission believes further judicial developments could avoid or may suggest Congressional consideration in connection with this issue.

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[47] Letter dated January 31, 1987 from John A. Reding, Esq. to John F. Cordes, Esq.

[48] In re Regents of the University of California, 45 NRC 358.

PART 2: PRINCIPAL ISSUES BEARING ON THE NEED TO CONTINUE PRICE-ANDERSON

The Price-Anderson Act requires NRC to consider, in reporting on the need to continue or modify its provisions, the condition of the nuclear industry, availability of private insurance for handling claims, and the state of knowledge concerning nuclear safety. The following sections address each of these three considerations in turn.

2.1 Condition of the Nuclear Industry

At the time of the Report to Congress on the Price-Anderson Act in 1983, the nuclear power industry was undergoing substantial change. Mandatory backfits were increasing the costs of reactor unit construction and operation. No new units had been ordered, and existing orders were being canceled. Since then, the pace of backfits has slowed, operating costs have decreased, and reactor units have steadily increased capacity factors.[49] However, the current cohort of reactor units is expected to decrease over time, thereby lessening the size of the available secondary retrospective premium layer for power reactors, relative to what it would be if the number of participating reactors remained constant. Section 2.1 describes the current condition of the nuclear industry, including an industry profile and trend analysis, and assesses the implications for the Price-Anderson Act.

2.1.1 Industry Profile and Trends

2.1.1.1 Nuclear Power Reactor Industry Profile

The U.S. nuclear power industry is dominated by two models of light water reactor units: Boiling Water Reactors (BWR) and Pressurized Water Reactors (PWR). A light water reactor is a reactor unit where the cooling medium is ordinary water. How that water is used is what differentiates light water reactor unit models.

The commercial by-product of the fission process is heat. Power is generated by letting water absorb heat and transfer its potential for work to turbines. During the fission process, the level of heat within the reactor core can become excessive. If the heat is not absorbed and transferred away from the fuel rods in the reactor core, then the fission process can accelerate beyond safety limits. To prevent such an occurrence, the fission process (i.e., the heat generated by the fuel rods) is carefully managed by continually circulating water among the fuel rods to cool the reactor core.

Heat absorption can be either direct or indirect in light water reactor units. This distinguishes the BWR from the PWR in that water can either circulate directly among the fuel rods to absorb heat potential (i.e., direct system) or through piping to a steam generator where another loop of water is heated (i.e., indirect system). The former of these processes is generally known as an "open loop system" and is found in the BWR unit design. The latter process is generally known as a "closed loop system" and is found in the PWR unit design.

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[49] A reactor unit's capacity factor is a ratio of the electricity generated to the maximum electricity the unit can generate, over a given time period. Longer operating cycles, shorter refueling outages, fewer unplanned shutdowns, and improved maintenance contribute to improved capacity factors.

The BWR unit is the older technology of the two reactor types. During the 1950s, the BWR unit was adapted from military to commercial application. Ordinary water is the primary coolant and power generation medium in these units. There is one self-contained loop for both processes, hence the term "open loop." Water is heated among the core's fuel rods until steam is generated. The steam is then force-circulated by electrical power pumps into a coolant loop where it drives a turbine, thus generating electricity. After exiting the turbine, the steam cools and condenses while being pushed along the back-end of the loop. The steam then re-enters the reactor unit's core as water, where the process is repeated.

The second unit type is the PWR unit. Ordinary water is again the primary cooling medium but, in contrast to the BWR, water does not circulate through just one loop. In the PWR unit, water circulates through the reactor core (i.e., absorbing heat) in one loop to a steam generator. At the steam generator, the heat from the first loop vaporizes pressurized water in a second self-contained (closed) circulation loop. The steam from the second loop then drives a turbine and generates power. Each technology has its merits but an advantage to the PWR is its reduced volume of hazardous material relative to the BWR unit. Specifically, exposure to radioactive material is limited to one closed loop, hence the volume of water and the amount of piping contaminated is smaller. The PWR unit constitutes a majority (i.e., 66 percent) of installed units in the U.S.

In 1997 there were 110 commercially active BWR and PWR units in the continental U.S. licensed to 47 operating utilities. No commercial units exist in either Alaska or Hawaii. The 110th unit was the Watts Bar unit, which completed testing and received final licensing in 1996. This unit is expected to be the last completed of existing orders for units. Reactor units operate at 69 sites in 32 States with the majority distributed east of the Mississippi River, either in the Midwest or along the Atlantic seaboard. Exhibit 4 shows that over 70% of the reactor units are situated at multi-unit sites.

Exhibit 4 Single versus multi-reactor unit sites through 1997

Units per Site	Sites
1	32
2	33
3	4

Exhibit 5 shows reactor units' age distribution as of 1998. This exhibit highlights the industry's maturity: most reactor units are between 10 and 30 years old.

Nuclear reactor units provide a significant percentage of the total electricity used each year in the U.S. For example, in 1996 total generation by electric utilities was estimated to be 3078 billion kilowatt-hours with nuclear reactor units generating 675 billion kilowatt-hours (i.e., 22 percent of the total utility electricity generated).[50] Nuclear reactor units' contribution to the U.S. electrical grid varies significantly both within and across individual regions. For example, the Northeast (NRC Region I) is served by 29 units, which provide a generation capacity varying from 15 percent (MA) to 64 percent (CN) of total electrical needs. Alternatively,

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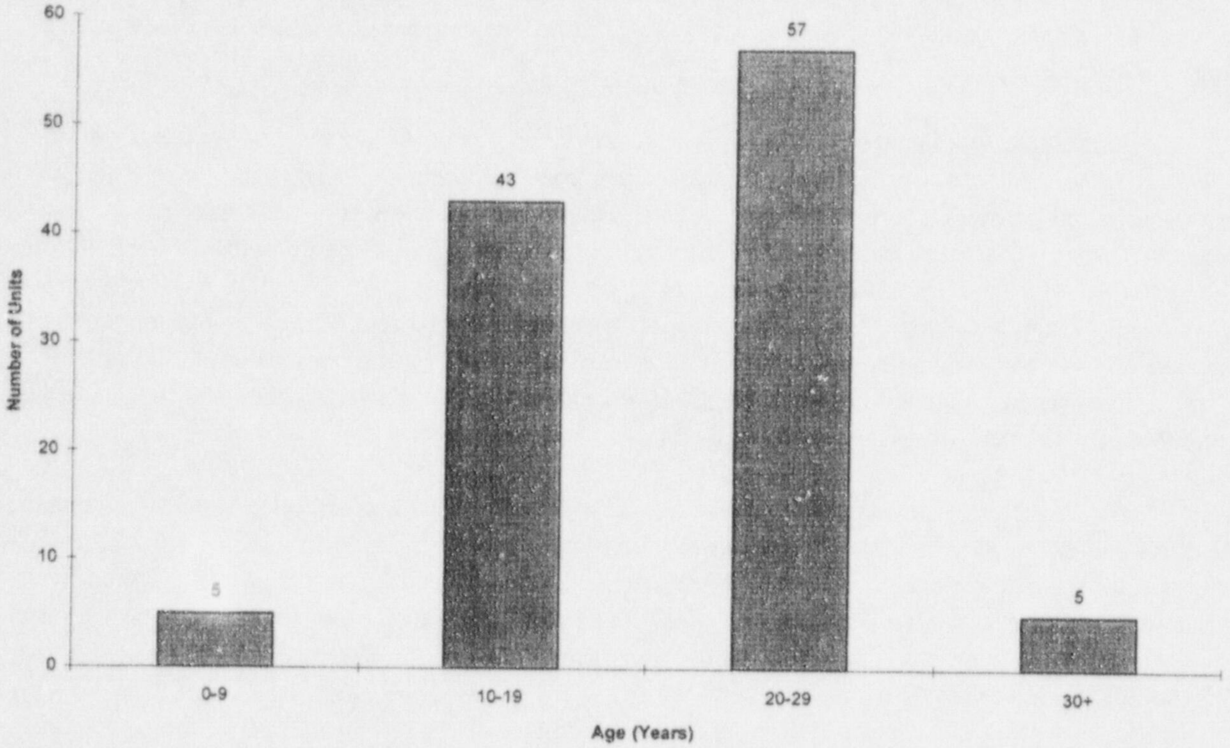
[50] U.S. Department of Energy, Energy Information Administration (EIA), *Annual Energy Review 1996*, July 1997, p. 229. See also *Nuclear Power Generation and Fuel Cycle Report 1997*, September 1997.

Exhibit 5 Reactor unit age as of 1998



11 of the 19 states in the West (NRC Region IV) do not rely on reactor units to generate any of their respective electricity even though the capability exists (i.e., the region has 19 commercially operating reactor units).[51]

As of 1997, 97 planned nuclear reactor units had been cancelled since 1974, with no units ordered since 1978. Seventy-one of these cancellations had occurred by 1983, when the last Report to Congress was completed. While no single reason can explain all of the cancellations, lower than anticipated consumer electricity demand, increased reactor unit construction costs, and additional costs resulting from NRC mandated safety requirements are likely factors in utilities' decisions to cancel orders for power reactor units.

When many of the currently operating units were being planned during the 1960s and 1970s, it was assumed that past electrical production/consumption patterns would continue. From 1949 to 1979, net electrical generation increased at an annual average of 7.1 percent.[52] This rate was almost twice the average annual rate of national economic growth in the same period. Economic analyses of the period linked this ratio to the concept

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[51] NRC 1996, p. 19, 36.

[52] EIA July 1997, p. 1.

that electricity supply was creating electricity demand and was thereby promoting economic growth.[53] With such assumptions, the key to economic growth was to build more electrical capacity. In the mid-1970s, nearly 300 reactors were forecast to be in operation by 1990. But changing circumstances during the 1980s demonstrated that electricity supply was not creating electricity demand. As the cost of electricity rose, partly in response to increased fuel prices, consumption patterns changed (e.g., firms reduced electricity consumption compared to other production inputs).

Although the positive relationship between electricity demand growth and overall economic growth continued during the 1980s, the ratio's magnitude declined from 1.5 during the 1970s to 1.0 during the 1980s. As increasing energy production costs led to increased electricity prices, it became financially more attractive to alter production patterns and/or purchase more efficient equipment and appliances. Energy intensity during this period declined at almost a 2 percent annual average rate, measured as energy use per dollar of GDP. During the mid 1980s, energy intensity continued to decline albeit at a slower rate (i.e., approximately 0.9 percent per year).[54] Consequently, net electrical generation increased an average of only 1.9 percent per year from 1980 to 1996.[55] These figures made new, large capital investments difficult to justify. The electrical generation industry instead focused on smaller, peak-load augmentation projects.

While increasing numbers of reactor units were finishing construction and being brought on-line during the 1970s and 1980s, their construction costs soared. Between 1970 and 1985, reactor unit construction costs increased more than 300 percent. Standardizing these costs into construction costs/kilowatt-hour (kWe), Exhibit 6 illustrates the change in construction costs over time. The exhibit shows that these costs were almost 4.5 times lower for the early reactor units compared to those constructed later. Of the $2400 per kWe increase, the Energy Information Administration (EIA) estimated that $1800 was due to real cost escalation and only $600 was due to time-related costs, such as increasing finance charges, higher than anticipated material costs, and/or longer construction periods.[56]

Exhibit 6 Power reactor unit construction costs in 1982 dollars

1966-1967	$700/kWe
1974-1975	$3100/kWe

Source: DOE/EIA, *An Analysis of Nuclear Power Plant Construction Costs,* DOE/EIA-0485, pp. x.

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[53] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 1997 with Projections to 2015*, December 1996, p. 48.

[54] EIA December 1996, p. 4.

[55] EIA July 1997, p. 1.

[56] U.S. Department of Energy, Energy Information Administration, "An Analysis of Nuclear Power Plant Construction Costs," March 1986, p. x-xii.

As described in Section 2.2 below, government safety regulation/oversight has been an important part of the nuclear power industry since its start. After the TMI-2 incident, the number and types of mandated safety requirements, known as "backfits," increased. In some instances these requirements occurred before construction, but more often changes to existing plants were necessary. The effects of backfits include increased unit construction and operation costs, longer construction periods, and reduced learning curve economies for construction firms and unit managers. For instance, while enhancing power reactor unit safety,[57] the backfit requirements are believed to have slowed average unit completion time to 10.5 years from approximately 8 years.

Backfits have tended to be site and reactor unit specific. In every production process, the first units are typically more expensive than the last, as the process becomes more familiar and/or streamlined. If the process is not uniform across similar products, then economies of scale and learning curves in both production and operation are minimized. For affected reactor units built and operating during the 1970s and 1980s, plant managers and construction firms in the nuclear industry were able to reduce costs from experience gained from other units and/or construction contracts, but total cost reduction was less than anticipated.

Once the pace of backfits slowed during the mid to late 1980s, nuclear units began to reduce electricity generation costs. During the 1990s, reactor units both reduced their operations and maintenance (O&M) expenditures and increased their capacity factors. For instance, between 1986 and 1996 the average net capacity factor increased from 60 percent to nearly 77 percent.

2.1.1.2 Looking Ahead

Issues both specific to the nuclear power industry and some also relevant to the entire electric utility industry may affect the Price-Anderson system by reducing the number of nuclear reactors participating in the system. These issues include the following:

- lack of new reactor units
- improving the economics of reactor units
- managing the aging of reactor unit components
- extending operating licenses by up to 20 years
- introducing competition into the electrical power industry

Lack of New Reactor Units

The EIA estimates that electricity consumption will grow by 1.5 percent per year through 2015 in its latest series of projections, which is less than projected economic (GDP) growth of 1.9 percent per year.[58] Declining energy intensity coupled with low projected growth have minimized capacity expansion in both the nuclear industry and the general electrical generation industry. The economics of nuclear energy was premised on its providing baseload power, not augmenting peakload power needs. Until demand growth outstrips current

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[57] EIA 1986, p. 12. Slower construction cannot be fully attributed to backfits because completion times for other electrical power generating technologies also slowed. Responding to lower than anticipated market demand for electricity, utilities stretched construction schedules. This increased construction costs but reduced the time a completed unit would sit idle and/or have surplus capacity.

[58] EIA December 1996, p. 4.

additions to the U.S. electrical grid, few opportunities will exist for new nuclear reactor units. No construction permit applications are under review at the NRC, and no construction permit applications are anticipated before the present Act expires on August 1, 2002. No construction permit applicants are identifiable in the foreseeable future after that date, although applications for standardized design approvals that could be used for future plants have been processed. Those utilities that might build new nuclear power plants are subject to powerful financial, load growth, political, regulatory, and other restraints on their decisions to develop more nuclear facilities.

Improving the Economics of Nuclear Power Reactors

Utilities will continue to seek further reactor unit cost reductions. Reactor units that are not economic may be subject to being closed down. Future cost reductions will result from: (1) smaller labor pools, (2) reduced total capital expenditures, and (3) more efficient reactor unit electrical generation. Shrinking the workforces at reactor units should produce lower annual costs. For example, EIA estimated that 67 percent of O&M costs are for labor; of these workers, 47 percent are directly involved with reactor unit maintenance and 16 percent are plant managers. The remaining 37 percent of the workers perform security, administrative, and managerial activities. One option for lowering labor costs is to allow for increased reliance on electronic monitoring equipment. Other alternatives likely exist that will make it possible to reduce labor costs without compromising reactor unit safety.

Another concern of utilities owning reactor units is reducing capital expenditures. According to the EIA, capital expenditures are evenly divided between regulatory compliance actions and repair/replacement of reactor unit components.[59] One example of successful capital expenditure management is Virginia Power's replacement of the steam generator at its North Anna-1 unit. The steam generator was replaced in 51 days, not the average 150, which reduced costs to $130 million versus $185 million.[60] The savings were realized after careful planning and execution, but also were due to Virginia Power's earlier experiences (i.e., "learning-by-doing") at Surry-1 and -2.

The nuclear power industry has increased its efficiency in electrical generation as a consequence of lower input costs and/or increased electrical output. Input costs include fixed (e.g., capital expenditures) and variable (e.g., labor, O&M) costs. For instance, between 1974 and 1987, real capital expenditures and real O&M costs increased at annual rates of approximately 11 percent. By comparison, between 1987 and 1993, real annual capital expenditures fell to late 1970s levels (i.e., $20-30/kW of capacity) and real O&M costs increased less than one percent per year.[61]

Moreover, increasing the number of generating days each reactor unit operates raises each reactor unit's capacity factor. Included in the capacity factor is the number of days necessary for operational and safety maintenance. With reactor unit aging, increasing numbers of components need replacement, rather than ordinary maintenance. This includes the larger and more expensive components such as steam generators and piping. In an aggressive, preventative reactor unit maintenance program, these components can be replaced and/or repaired during normal shutdown periods. This minimizes the number of days each year a reactor unit must be shutdown,

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[59] EIA 1995, p. vii.

[60] OTA 1993, p. 94.

[61] EIA 1995, p. vii.

and likely reduces the number of unplanned shutdowns. By using scheduled shutdowns to perform extensive maintenance and replacement programs, a reactor unit's capacity factor can be maximized. Ultimately, this can increase electrical generation efficiency and reduce total operation costs. Between 1980 and 1996, the industry's capacity factor increased from 58 percent to 77 percent.

Greater efficiency in electrical generation cannot prevent either components from wearing out or units from reaching the end of their operating lives. Reactor units are capital goods with expected lifetimes that can be lengthened or shortened. The key factors in estimating a unit's expected lifetime are the intensity of its use and its level of maintenance. Reactor units' expected lifetimes may not correspond with the length of their operating licenses.

Aging

Minimizing the effects of aging is important for any reactor unit's continued operation. Aging degradation may affect a broad range of plant systems, structures, and components. Aging must be addressed in areas as diverse as the degradation of electrical cable insulation, degradation of concrete structures, degradation of service water piping, and the degradation and cracking of reactor internals. When the first units were constructed, some reactor unit components' were expected to last over 60 years, but major components were expected to last at least 40 years. However, operating experience indicates that the expectation was unrealistic in some cases, such as for steam generators, due to aging degradation. Aging degradation has affected reactor units' containment shells as well as other major components, such as steam generators and piping.

Aging degradation is not unique to nuclear technologies. It occurs in all industrial settings as capital equipment is "used up." In the instance of nuclear technology, aging degradation is evident by changes in materials' physical properties (e.g., changing material dimensions, ductility, fatigue capacity, mechanical, or dielectric strength). These result from natural processes, such as fatigue, cracking, embrittlement, wear, erosion, corrosion, and oxidation.[62]

Decisions to minimize aging degradation will reflect economic factors. An aggressive maintenance program, including capital expenditures to replace major components, may significantly retard the effects of aging but the associated costs of such a maintenance program may not allow some utilities to earn an acceptable return. A recent study of optimal reactor unit lifetime found that the age of the unit affected the decision to continue operating after loss of a major component (e.g., steam generators).[63] Assuming that reactor units operate for 40 years, if a reactor unit needed a major retrofit after age 24 or before age 2, then the optimal solution was early decommissioning, according to the study. Between the ages of 2 and 24, the optimal solution was to make the retrofit and/or replace the major component, because the discounted costs of the repairs or additions would be offset by the discounted benefits of continued unit operation. However, assuming that reactor units would be able to extend their 40 year initial license to the maximum 60 years, the threshold for making a retrofit and/or replacing a major component stretched from 24 years to 38 years. This analysis suggests that with a 60 year lifetime/operating license, most reactor units would recover the increased costs associated with unit construction

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[62] U.S. Congress, Office of Technology Assessment, *Aging Nuclear Power Plants: Managing Plant Life and Decommissioning*, September 1993, p. 9.

[63] Geoffrey Rothwell and John Rust, "On the Optimal Lifetime of Nuclear Power Plants," *Journal of Business and Economic Statistics*, (Vol 15:2), p. 195-208, 1997.

during the 1970s and 1980s. This analysis further indicated that with a 60 year license period, power reactor units could become profitable. Whether a 60 or a 40 year operating lifetime will be typical is as yet uncertain.

Decisions about responding to aging equipment will also be affected by the increased competition that deregulation is expected to bring to the electric power industry.

License Renewal

The Atomic Energy Act and NRC regulations limit commercial power reactor licenses to 40 years, but also permit the renewal of such licenses. The 40-year term was originally selected on the basis of economic and antitrust considerations, not technical limitations, but once selected, individual plant designs may have been engineered based on an expected 40-year service life.[64] The extension is awarded after the licensee demonstrates the reactor unit's ability to operate safely for the additional time period, up to 20 years. Such a demonstration includes showing that the reactor unit is not affected by component aging. Investment decisions made towards this end include replacing steam generators and/or reactor unit piping. If a utility is sufficiently diversified between high and low cost electricity producers, it can continue operations at a reactor unit (i.e., invest in long-term capital additions) in order to preserve electrical generation capacity. If the utility is able to cover its variable costs of operation, it may choose to retain the nuclear option to provide additional lower cost baseload power (i.e., lower cost than available from peakload or replacement sources).

The decision on whether to seek license renewal rests with a licensee. For nuclear power plant licensees, license renewal can be a two-edged sword. The benefits of gaining 20 years on the existing investment must be weighed against the uncertainties associated with the cost of renewal, based on a consideration of economic, political, regulatory, and environmental factors. Uncertainties may exist associated with future operation and maintenance costs. The timing of major replacements, such as steam generators -- or major maintenance operations such as thermal annealing -- are major factors to be considered.

The NRC has created the regulatory structure to support license renewal. The Commission published its original license renewal rule, 10 CFR Part 54, in December 1991. However, several provisions of that rule, related to implementation issues, raised significant concerns in the nuclear power industry. After reviewing public comments, conducting stakeholder workshops, and considering carefully the various issues raised, the Commission published an amended license renewal rule in May 1995, revising the requirements that an applicant must meet to obtain a renewed operating license.

The amended rule is based on two key principles. The first principle is that the current regulatory process, continued into the extended period of operation, is considered adequate to ensure that the current licensing basis provides the foundation for, and will help to maintain, an acceptable level of safety, with the possible exception of detrimental aging effects for certain systems, structures, and components. The second key principle is that the licensing basis for each plant must be maintained during the renewal term. In other words, the foundation of license renewal hinges on the determination that currently operating plants will continue to

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[64] The NRC initial license period begins when the construction permit is finalized. However, the NRC now allows licensees to apply to recover construction time (i.e., the difference between the operating license date and the actual date the unit was operational). For example, Diablo Canyon-1's construction permit was issued in 1968 but an operating license was not issued until 1984. With full construction recapture, the operating license would expire in 2024 rather than 2008, a difference of 16 years.

maintain adequate levels of safety, and that maintenance of the licensing basis has helped and must continue to help to sustain these safety levels over the life of the plant. This assumes appropriate adjustments to address aging effects identified during license renewal review, and to address relevant operating experience.

The current U.S. nuclear power industry approach to license renewal is to submit for NRC approval plant-specific and Owners' Group technical reports on specific topics, prior to submitting complete license renewal applications. This approach is intended to establish a foundation of technical information that a licensee can use to evaluate the feasibility of a license renewal application, and to reference that information later in the application itself. The NRC is reviewing plant-specific technical reports prepared by the Baltimore Gas and Electric (BGE) Company addressing the two Calvert Cliffs units, and by the Duke Power Company addressing the three Oconee units. On March 4, 1998, BGE announced that the company intends to pursue license renewal for the Calvert Cliff facilities, and its application has been docketed. Duke Power subsequently submitted a license renewal application on July 6, 1998. Southern Nuclear Operating Company also announced plans to consider license renewal for its Hatch units as early as 1999.

The decision to either extend a unit's operating license or retire it will be driven by economic considerations. For instance, Virginia Power's decision to invest $130 million in replacing the North Anna-1's steam generator was a decision to continue operations and not pursue early decommissioning. Several units have instead chosen early decommissioning as an alternative. For example, Yankee Rowe started to extend its license but then decided that early decommissioning was a better financial alternative after the NRC questioned reactor vessel integrity. Monticello's owners deferred their application in 1992 after concern with the NRC's interpretation of the license renewal rule.[65] Trojan decided not to conduct expensive repairs and instead is decommissioning early. The relicensing process' cost is not insignificant (NRC estimates that the cost is about $30 million). Factor(s) preventing wider acceptance of the relicensing option may include uncertainty about the availability of waste disposal facilities and/or changing market conditions. On the other hand, license renewal appears to be a very attractive option financially compared to building new fossil capacity, and the Commission has committed the resources necessary to promptly review initial applications.

Economic Deregulation and Restructuring

The electric utility industry has entered a period of economic deregulation and restructuring that is intended to lead to increased competition in the industry. The EIA notes that the key factors influencing the choice of new and replacement power generation include the relative costs of fossil fuels, investment costs, discount rates (e.g., cost of capital), transportation costs, and the regulatory environment.

For existing base load generation capacity, coal-fired units represented the closest competitor to nuclear reactor units in 1997. The O&M costs of coal-fired power are two to three times lower than nuclear units' O&M costs. But the fuel for coal-fired units is two to three times more expensive than nuclear reactor unit's fuel.[66] The net result is that the two technologies have equivalent total production costs. The 1990 Clean Air Act Amendments, as well as possible global climate change agreements, may reduce reliance on coal because burning coal emits CO_2, NO_X, and SO_2, as well as other pollutants.

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[65] U.S. Congress, Office of Technology Assessment, *Aging Nuclear Power Plants: Managing Plant Life and Decommissioning*, September 1993, p. 3, 15.

[66] NRC 1997, p. 22.

Another competitor to nuclear reactor units is new natural gas turbine technology. The modern gas turbine, or Combined Cycle Combustion Turbine (CCCT), represents a formidable competitor to nuclear energy because it is modular in design, easy to assemble, and emits fewer pollutants (although greenhouse gases, such as CO_2, are still emitted). However, the turbine relies on low cost supplies of natural gas to ensure competitiveness. The EIA anticipates that the share of natural gas fired electrical generation capacity will increase from 10 to 29 percent by 2015.[67]

The competitiveness of nuclear reactor units would be enhanced by three factors: (1) if, in order to meet the new Clean Air Act Amendments, costs increased for coal-fired units (e.g., increased use of pollution control technologies); (2) the cost of natural gas supplies rose (i.e., eroding the overall cost advantage associated with natural gas); and (3) if reactor units are able to continue to contain, or reduce, O&M costs while further boosting capacity factors.

Increasing competition may motivate integrated power systems to separate (or "disaggregate") their systems into functional areas. Thus, some licensees may divest electrical generation assets (e.g., nuclear power plants) from transmission and distribution assets by forming separate subsidiaries or even separate companies for generation. Disaggregation may involve utility restructuring, mergers, and corporate spinoffs that lead to changes in owners or operators of licensed power reactors. Such changes may affect the licensing basis under which the NRC originally found a licensee to be financially qualified to construct, operate, or own its power plant.

Rate regulators have typically allowed an electric utility to recover prudently incurred costs of generating, transmitting, and distributing electric services. Consequently, in 1984, the NRC eliminated financial qualifications reviews at the operating license stage for those licensees that met the definition of "electric utility" in 10 CFR 50.2 (49 FR 35747; September 12, 1984). The NRC based this decision on the assumption that the rate process assures that funds needed for safe operation will be made available to regulated electric utilities. However, the NRC recognized that financial qualifications reviews for operating license applicants might be appropriate in particular cases in which, for example, the local public utility commission will not allow a significant part of the cost of operating the facility to be recovered through rates. To date, the NRC has found no significant instances in which State or Federal rate regulation has led to disallowance of funds for safety-related operational expenses.

The NRC issued its Final Policy Statement on Restructuring and Economic Deregulation of the Electric Utility Industry on August 19, 1997 following the receipt and analysis of responses to its publication on September 23, 1996 of a draft policy statement for public comment.[68] The NRC is concerned about the potential impact of

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[67] EIA 1996a, pp. 3, 4. See also *Nuclear Power Generation and Fuel Cycle Report 1997* (EIA, September 1997).

[68] The Commission previously expressed concern about various State proposals to implement economic performance incentive programs. *See* Possible Safety Impacts of Economic Performance Incentives: Final Policy Statement (56 FR 33945; July 24, 1991) for the NRC's concerns relating to State economic performance incentive standards and programs. As stated in footnote 2 in the NRC Final Policy Statement on the Restructuring and Economic Deregulation of the Electric Utility Industry (10 CFR Part 50, Vol. 62 *Federal Register*: August 19, 1997), the NRC has extensively reviewed State performance incentive programs and does not believe significant additional review is warranted at this time. NRC understands that States instituted many of these programs as a (continued...)

utility restructuring on public health and safety but believes that economic deregulation does not preclude adequate protection of public health and safety.[69] The NRC has not found a consistent relationship between a licensee's financial health and general indicators of safety such as the NRC's Systematic Assessment of Licensee Performance. As described in Section 2.2, below, the NRC has traditionally relied on its inspection process to indicate when safety performance has begun to show adverse trends. On the basis of inspection program results, the NRC can take appropriate action, including, ultimately, plant shutdown, to protect public health and safety.

Recognizing that the electric utility industry is likely to undergo great change as restructuring progresses, the NRC will continue to evaluate the need for regulatory or policy changes to meet the effects of deregulation. The NRC will take all appropriate actions to carry out its mission to protect the health and protect public health and safety.

In order for the NRC to make its safety views known and to encourage rate regulators to continue their practice of allowing adequate expenditures for nuclear plant safety as electric utilities face deregulation, the NRC has taken a number of actions to increase cooperation with State and Federal rate and financial regulators to promote dialogue and minimize the possibility of rate deregulation or other actions that would have an adverse effect on safety. However, the NRC is evaluating the need to develop additional requirements to ensure against potential dilution of the capability for safe operation that could arise from rate deregulation and restructuring.

Apart from potential safety concerns, deregulation may lead to more premature closures of non-economic power generating assets than would otherwise have occurred in the absence of competition. As described in Section 2.1.2 below, the [illegible] amount of Price-Anderson coverage is very sensitive to the number of nuclear reactors included in the retrospective premium pool. As the number decreases, aggregate coverage (in real dollars) also declines. Restructuring may have another effect relevant for Price-Anderson: some licensees may become less able to afford retrospective premiums (see Appendix A). Thus, apart from concerns about potential safety effects of deregulation, economic restructuring may impact the Price-Anderson system by accelerating the closure of some nuclear power reactors and by reducing the affordability of retrospective premium payments.

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[68] (...continued)
means of encouraging electric utilities to lower electric rates to consumers. As States deregulate electric utilities under their jurisdictions, these economic performance incentive programs ultimately may be replaced by full market competition.

[69] The NRC's safety and public health concerns about deregulation and restructuring lie in the areas of adequacy of decommissioning funds and the potential effect that economic deregulation may have on operational safety. Financial assurance for decommissioning reactors is the subject of other NRC activities and rulemakings that do not fall within the scope of this report. NRC safety assessments at some reactor facilities have identified deficiencies that may stem from the economic pressure on a licensee to be a low-cost energy producer, which in turn may limit the resources available for corrective actions and plant maintenance. The NRC is developing measures that could help to identify plants where economic stress may be adversely impacting safety. In addition, the NRC is conducting an integrated review of reactor-related assessment processes, to enhance the existing program for plant performance assessment.

2.1.2 Impacts of Reactor Retirement on the Price-Anderson System

More than one-third of current U.S. nuclear capacity will reach the end of the initial license period by 2015. While only 5 reactor units will reach the end of their initial licenses by 2008, in the following five years between 2008 and 2013, an additional 29 reactor units (i.e., a total of 34 reactor units by 2013) will reach the end of their 40-year initial licenses. The initial license expiration schedule for all reactors appears in Exhibit 7, assuming 40-year operating licenses. As shown, the nuclear industry had two construction completion "waves:" (1) one in the mid to late 1970s; and (2) one in the mid 1980s. These two periods of high activity correspond with two subsequent "waves" of initial license expirations. The effects these expirations may have on the industry are projected in Exhibit 8, utilizing Exhibit 7's assumed retirement schedule. After 2008, the industry is likely to shrink from its current 110 units, until 2035 when the last unit is assumed to retire. The potential for license renewal has not been factored into Exhibits 7 and 8.

Due to reactor economics, the costs of aging and license renewal, and competition, some level of *early* retirement prior to license expiration is now expected. The effects of increased unit retirements on the Price-Anderson system will depend on the magnitude and pace of the early retirements. Experts currently project between 5 and 25 additional early reactor unit retirements, depending on assumptions.[70] A number of reactors have already retired early. Exhibit 9 shows the eleven units that since the 1983 Report to Congress have been retired early and the reasons articulated for doing so. The stated reasons primarily concern issues of safety, competition, and reactor unit economics. Predictions about early retirement include the following:

- Moody's expected that at least 10 of the 110 reactor units existing in 1996 would retire early, with the possibility of another 10 retiring early also.[71]

- Public Citizen claims that at least 25 reactor units will choose to retire early because they cannot compete with lower cost generation technologies.[72]

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[70] "Is Nuclear Economic? Depends on Who You Ask," *Energy Daily*, December 18, 1996. An earlier assessment noted the difficulty in predicting which units will choose early retirement, expecting that of the 50 plants older than 15 years in 1993, approximately 1/5 or 10 reactor units are likely to retire early. See Barry M. Abramson, "The View From Wall Street. (Nuclear Power Plant Decommissioning)," *Electric Perspectives*, September/October 1993, p. 46.

[71] The Moody's Investor Service report classified the nuclear industry into reactor units with: (1) low operating costs and low capital cost (i.e., little sunk cost); (2) low operating costs and high capital cost; and (3) high operating costs and high capital cost. In a scenario where no sunk cost recovery is allowed, then the first group will likely continue to operate as it did prior to deregulation. However, the third group will cease operations and the second group will absorb either capital write-offs or write-downs. The report information is contained within a set of comments from IPALCO Enterprises, Inc., the Citizens Action Coalition of IA, Inc., and Public Citizen found on the Public Citizen web page. See also, Moody's Investor Service, "Moody's Says Nuclear Utilities' Credit-Worthiness Declining," *Nucleonics Week*, December 5, 1996.

[72] See, for example, "Is Nuclear Economic? Depends on Who You Ask," *Energy Daily*, December 18, 1996, p. 7.

Exhibit 7 Projected annual reactor license expirations, with 40-year license period

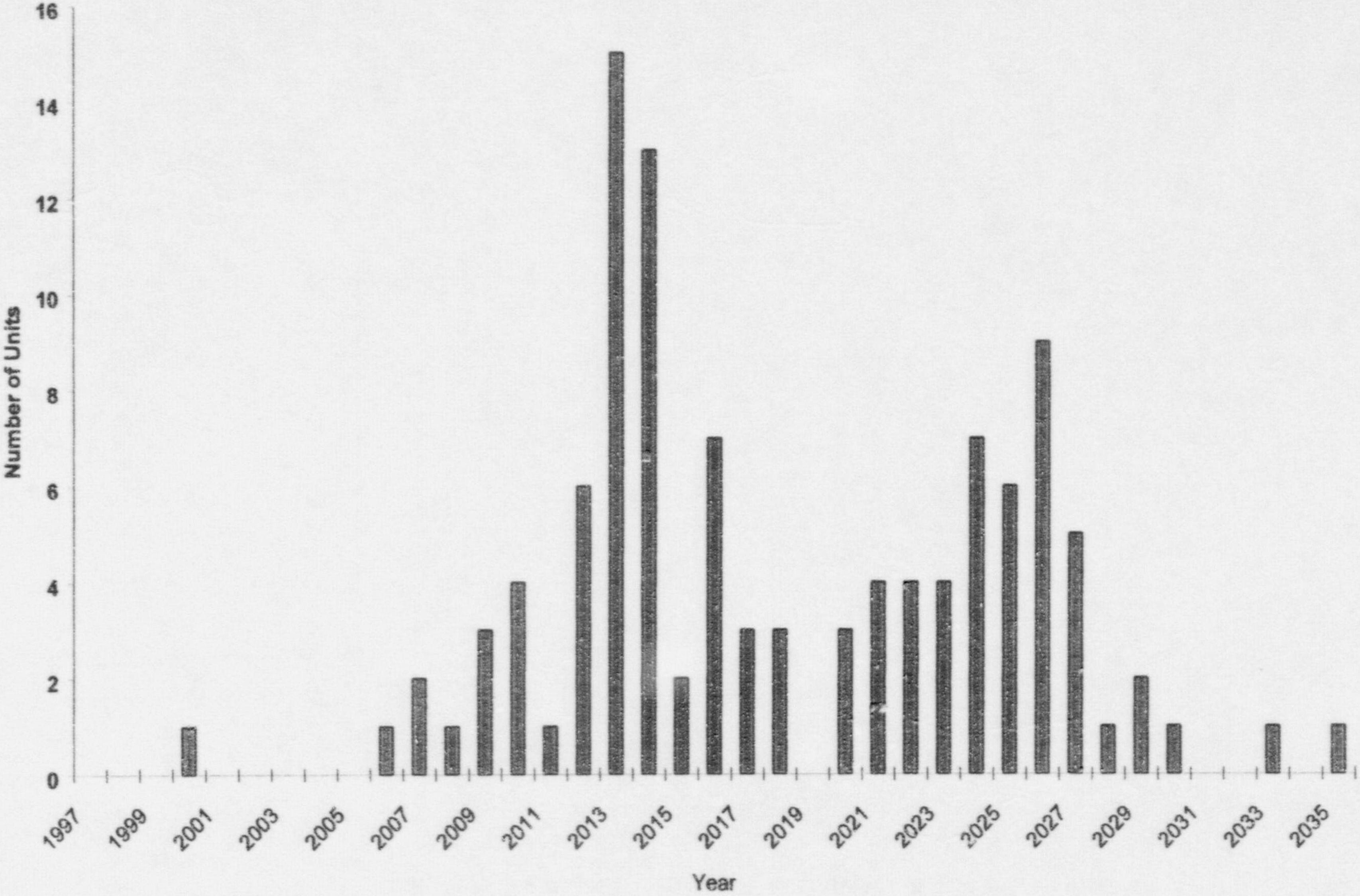

Exhibit 8 Projected industry retirement trend, based on 40-year license period

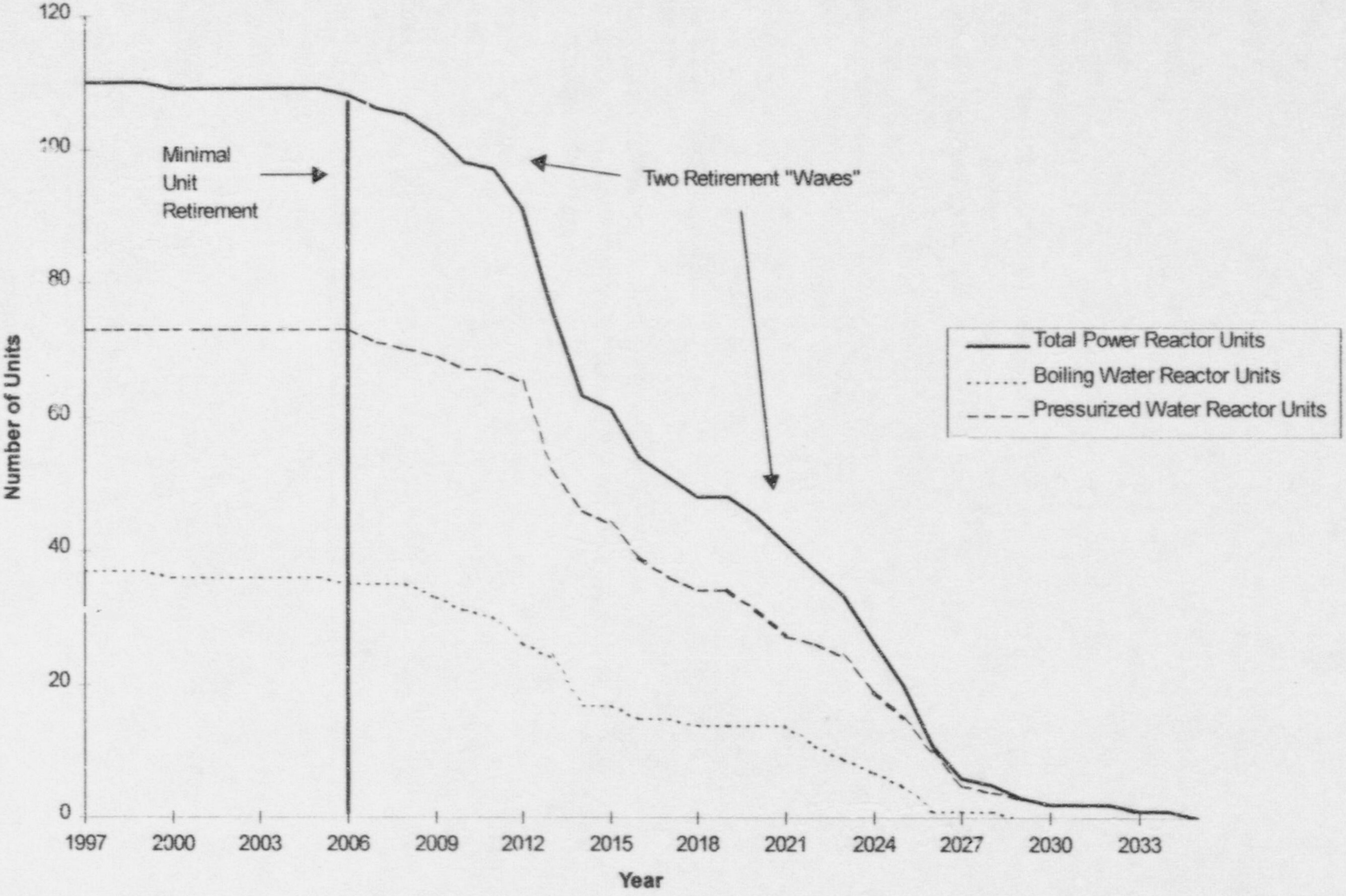

Exhibit 9 Early retirement of commercial power reactors since 1983 Report to Congress*

Reactor Unit (Year Suspended Operation)	Reasons for Decision
Fort St. Vrain (1989)	Problems with control rod assemblies and the steam generator ring headers, low plant availability (i.e., approximately 15 percent), and fuel costs.
Rancho Seco (1989)	Public concerns about plant safety and poor economic performance.
Shoreham (1989)	Safety concerns (i.e., too large a population nearby to evacuate).
San Onofre (1992)	Analysis performed for California Division of Ratepayer Advocates concluded that $135 million capital addition was uneconomic. Utility disagreed but chose to abide by decision rather than assume sole responsibility for unit.
Yankee Rowe (1991)	Age-related safety concerns closed unit. Poor regional economic performance would have meant excess capacity and alternative, lower cost sources of power made the unit uneconomic to repair.
Trojan (1992)	Steam generator replacement too expensive (i.e., $200 million to replace). Public pressure possibly also a factor.
Haddam Neck (1996)	Economic analysis indicated $100 million saved by closing the unit and purchasing replacement power outside of Connecticut.
Maine Yankee (1997)	After safety concerns shut the unit (e.g., control cables lacked mandatory fire protections) and the unit couldn't be sold, the most economic solution was decommissioning.
Zion #1 and #2 (1998)	Aging steam generators and inability to operate competitively in a deregulated electricity industry.
Millstone #1 (1998)	Insufficient value in the unit due to the changing utility structure and electricity marketplace.

* The LaCrosse (WI) unit that retired in 1987 was rated at only 167 MW; likewise, Big Rock 2, which is also retired, was rated at less than 100 MW. GPU, Inc. announced on April 10, 1997 that it is exploring the option of early retirement of Oyster Creek Generating Station to mitigate costs of continued operation of the plant. Its electricity costs about one and one-half cents more per kilowatt hour than the current market price for energy, the GPU, Inc. president stated.

Sources: U.S. Congress, Office of Technology Assessment, *Aging Nuclear Power Plants: Managing Plant Life and Decommissioning*, September 1993, p. 3, 4; *Wall Street Journal*, "Maine Yankee's Board Votes Unanimously to Close Power Plant," August 7, 1997, *New York Times*, p. A6(E); Rivkin, Andrew C., "Connecticut Reactor to Close, Victim of Economic Change," August 7, 1997, *New York Times*, v. 146, p. A18.

- A 1997 study concluded that an additional 2 reactor units would retire by 2000 and another 20 would retire by 2010.[73]

- The Department of Energy's Energy Information Administration (EIA) expects 59 nuclear units to be producing power in 2015.[74]

- In a study commissioned by the Interstate Natural Gas Association of America Foundation, Inc., prepared by the Washington International Energy Group, 37 sites containing 48 reactor units were found to be vulnerable to shutdown because their projected annual production costs were higher than projected market prices for electricity.[75]

- Another observer expects only about six plants to retire early because of competitive pressures.[76]

- A Bear Stearns analyst forecasted early shutdown of two dozen plants over the next five years.[77]

Exhibit 10 presents six retirement scenarios, three for 2008 and three for 2013, assuming that early retirements occur evenly over the period from 1998 through 2013. In the 2008 scenarios, early retirements are expected of 3, 10, and 17 reactor units. Early retirement is assumed to add 5, 15, and 25 reactor units to the expected 40-year reactor unit retirement by 2013, reflecting the experts' evaluations of the nuclear industry. The

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[73] Geoffrey Rothwell and John Rust, "On the Optimal Lifetime of Nuclear Power Plants," *Journal of Business and Economic Statistics*, 1997, (Vol 15:2), p. 195-208.

[74] The EIA has developed three scenarios for nuclear reactor retirement. The EIA's reference case assumes that most U.S. nuclear units will operate to the end of their current 40 year license terms, with 50 units retiring between 1996 and 2015. In the low case, on average, all units retire 10 years before the end of their operating license periods. In the high case, each unit operates 10 additional years beyond its current license. EIA believes that some nuclear units will be retired early due to operating costs exceeding 4.0 cents per kilowatt-hour. This prediction is supported by some recent decisions, such as closing Yankee Rowe and Big Rock Point. At Big Rock Point, electrical generation cost 6.4 cents and 4.9 cents per kWe in 1994 and 1995, respectively; it is scheduled to retire in 2000, four years early.

[75] *Nuclear Power Plants and Implications of Early Shutdown for Future Natural Gas Demand*, prepared by Washington International Energy Group for the INGAA Foundation, Inc. (February 1997). The report does not clearly tie its projection to a defined time period and the 48 vulnerable units include reactors whose initial licenses are close to expiration.

[76] "Is Nuclear Economic? Depends on Who You Ask," citing Bruce Biewald, *Energy Daily*, December 18, 1996, p. 8.

[77] Cited in "Nuclear Plants Face Huge Costs to Fix Overall Safety Problems," *Wall Street Journal* (June 18, 1997).

Exhibit 10 Early retirement scenarios

Scenario	Anticipated Reactor Unit Closures*	Additional Reactor Unit Closures	Total Reactor Unit Closures
2008			
Low	5	3	8
Middle	5	10	15
High	5	17	22
2013			
Low	34	5	39
Middle	34	15	49
High	34	25	59

* Anticipated reactor unit closures represents completion of the initial 40-year license period.

low, middle, and high scenarios for total reactor unit retirements between 1998 and 2008 are 8, 15, and 22 units. The low, middle, and high scenarios for total reactor unit retirements by 2013 are 39, 49, and 59 units.

The number of reactors participating in the Price-Anderson system is important because most of the total financial coverage derives from the secondary insurance layer. See Exhibit 3. The greater the number of participating reactors, the greater the coverage and the higher the liability limit. As the number of reactors decreases due to retirement without replacement, the amount of coverage, along with the liability limit, will decline until federal indemnification is triggered again. The return of federal indemnification is not likely to occur until sometime after 2020, unless many reactors retire early without replacement.

Legislative options include (1) maintaining in real dollars the current $9.43 billion of coverage, (2) letting the aggregate amount of coverage decline as reactor units retire, or (3) setting the aggregate coverage at another (perhaps risk-related) value.[78]

To maintain in real dollars the 1998 level of $9.43 billion per incident in insurance coverage, with reactor units retiring, each remaining reactor unit would need to increase its individual coverage level to compensate for each retirement. Maintaining the $9.43 billion in total insurance funds will necessarily place a great impact on secondary insurance funds, assuming the maximum level of primary insurance remains at the $200 million level.[79] As shown in Exhibit 11, by 2008, maximum secondary assessments would need to increase by between 10 and 28 percent in real terms to maintain current aggregate levels of coverage. By 2013, the maximum secondary assessment would need to increase by between 58 and 120 percent to maintain aggregate levels of coverage.

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[78] This report does not speculate as to what an appropriate "risk-based level" would be.

[79] Increasing the primary level of coverage will mitigate only to a small degree initially the need to increase the maximum levels of secondary assessments.

Although it is problematic to estimate with precision the affordability of different levels of retrospective payments, particularly in view of the changes that may arise from deregulation and restructuring, the update of previous affordability assessments conducted for this report (see Appendix A) indicates that most utilities should be able to handle annual payments of $20 million with little distress. A doubling of the amount of the secondary layer of coverage (and corresponding doubling of the current annual retrospective assessment) by 2013 may be required to maintain current funding levels in real dollars, as presented in Exhibit 11.

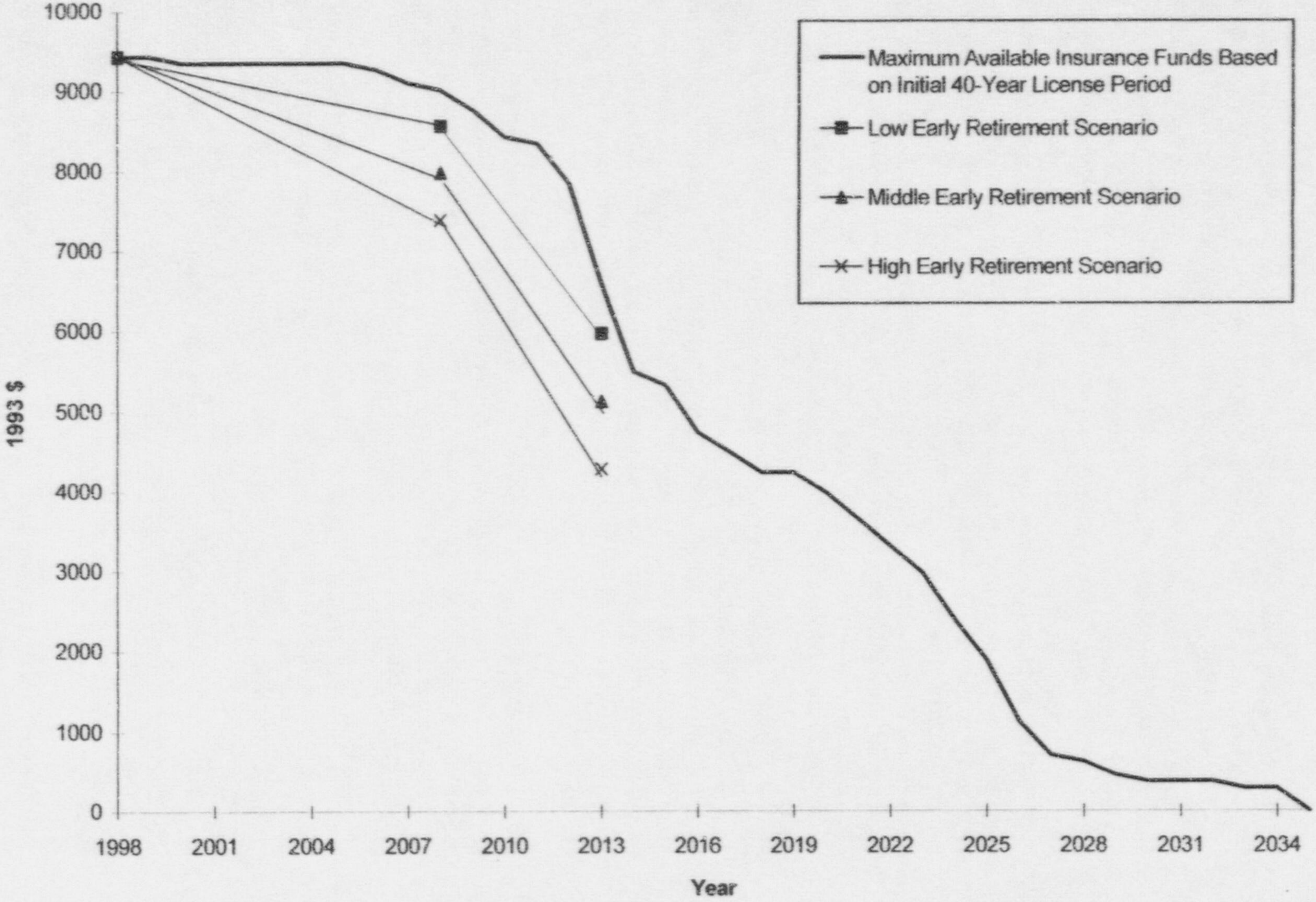
Exhibit 11 Effects of early retirement on maximum secondary insurance assessments required to maintain current coverage in real dollars

Scenario	Liability Funds ($ millions)	Total Remaining Reactor Units	Maximum Secondary Insurance Assessment ($ 1998 million)	Percent Increase from $83.9 million
2008				
Low	9,429	102	92.44	10.2
Middle	9,429	95	99.25	18.3
High	9,429	88	107.15	27.7
2013				
Low	9,429	71	132.80	58.3
Middle	9,429	61	154.57	84.2
High	9,429	51	184.88	120.4

Alternatively, holding the current $200 million primary insurance and the $83.9 million maximum assessment levels constant in real terms, by 2008 maximum available insurance funds in real terms will decline to $7.58 billion and by 2013 will shrink to $4.48 billion, assuming a high early retirement scenario occurs with only 88 and 51 reactor units operating in 2008 and 2013, respectively. Exhibit 12 portrays this graphically. Funding levels between $4.5 and $6 billion (low early retirement scenario) by 2013 should be ample, based on experience to date. However, accidents with greater off-site consequences than those associated with TMI are conceivable, with correspondingly higher amounts of potential liability claims. (See Section 2.3 below for information on nuclear claims.)

Summing up, in the near-term, the threat posed to the Price-Anderson system by reactor retirement without replacement is not critical. In the long-run, reactor retirement without replacement may seriously erode the financial protection available and/or require retrospective payment levels that may be difficult for utilities to afford.

Exhibit 12 Effects of early retirement scenarios on total amount of coverage



2.2 State of Knowledge of Nuclear S

2.2.1 Safety Management of Nuclear Power Reactors

This section of the 1998 Price-Anderson Report is divided into three sections. This introduction gives some basic safety figures and introduces key concepts that are discussed in the following sections. The following section, Nuclear Power Reactor Safety Systems, is a description of the physical characteristics of nuclear power plants that make them safe to the public and plant employees. The last section, Current NRC Safety Assurance Measures and Results, describes and analyzes current NRC safety measures and programs to determine whether the state of nuclear safety has improved over the past several years.

The fission (i.e., splitting) of atoms in the fuel of a nuclear power plant creates energy and new radioactive atoms (i.e., fission products). The process takes place in a reactor where the energy created is transformed into heat. Coolant transfers the heat to a turbine generator, which in turn produces electrical power. The risk of a nuclear power plant accident with a significant amount of radioactivity released offsite to the public is very small. This risk is minimized by diverse and redundant barriers and associated safety systems in the plant, by the training and skills of the reactor operators, by testing and maintenance activities, and by the regulatory requirements and oversight of the Nuclear Regulatory Commission (NRC). Nuclear power plants are designed to operate without any significant effect on public health and safety and the environment.

In terms of public health consequences, the safety record of the U.S. nuclear power industry has been excellent. The only incident in United States reactor history (approximately 2,000 reactor-years) that may result in injury to the public is the 1979 accident at Three Mile Island. A study reported in 1990 found no concrete evidence that the Three Mile Island accident affected cancer rates in the area immediately surrounding the plant.[80] The principal study of the effects of environmental radiation from nuclear facilities, performed by the National Cancer Institute, found "no suggestion that nuclear facilities may be linked causally with deaths from leukemia or other cancers."[81]

The Congressional Research Service has reported that the consensus among safety experts is that a severe nuclear power plant accident in the United States is likely to occur less frequently than once every 10,000 reactor-years of operation. In addition, most severe accidents would have small public health impacts. The chance of a nuclear accident resulting in death is extremely small and would likely occur much less frequently than once every 10,000 reactor-years of operation.[82]

The relatively small amounts of radioactivity released by nuclear plants during normal operation are not generally believed to pose significant hazards. Documented public exposure to radioactivity from nuclear power

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[80] Maureen C. Hatch, *Cancer Near the Three Mile Island Nuclear Plant: Radiation Emissions*. Columbia University School of Public Health, September, 1990.

[81] Jablon, Seymour, Hrubec Zdenek, John D. Boise, and B.S. Stone, *Cancer in Populations Living Near Nuclear Facilities*, National Institutes of Health Publication 90-874, July 1990.

[82] Congressional Research Service, *Issue Brief 88090: Nuclear Energy Policy*, (updated February 27, 1997).

plant waste has also been minimal. There is substantial scientific uncertainty about the level of risk posed by low levels of radiation exposure; as with many carcinogens and other hazardous substances, health effects can be clearly measured only at relatively high exposure levels. In the case of radiation, the assumed risk of low-level exposure has been extrapolated mostly from health effects documented among persons exposed to high levels of radiation.[83]

Despite a history of outstanding safety in the nuclear industry, there are risks involved in the operation of nuclear power plants. One of the most serious threats to the safety of a nuclear reactor is a loss of core coolant accident (LOCA). A LOCA occurs whenever there is a breach in the reactor coolant pressure boundary (i.e., in the valves, pumps, pipes, heat exchangers, and vessels that contain the coolant, under pressure, which removes heat from the reactor). LOCA risk is minimized by the NRC's "defense in depth" safety philosophy,[84] which (1) requires high quality in the design, construction, and operation of nuclear plants to reduce the likelihood of malfunctions in the first instance; (2) recognizes that equipment can fail and operators do make errors, therefore requiring safety systems to reduce the chances that malfunctions will lead to accidents that release fission products from the fuel; and (3) recognizes that, in spite of these precautions, serious fuel damage accidents can happen, therefore requiring containment structures and other safety features to prevent the release of fission products offsite.

2.2.1.1 Nuclear Power Reactor Safety Systems

This section describes the physical safety systems of the nuclear reactor that protect the surrounding population and plant workers. These systems are in place because the possibility of an accident at a nuclear plant does exist and the licensee has a duty to protect human life and other natural habitation if such an unlikely event should occur. The section describes shutdown systems, cooling and pressure control systems, safety system power, and barriers designed to contain radioactivity.

A nuclear power plant is equipped with four major types of safety systems to prevent an accident and reduce its effects if it should occur: A system to quickly shut down the reactor system and stop the fission chain reaction; numerous systems to continue cooling the reactor fuel and to control reactor pressure--that is, to carry away the heat that continues to be generated even after the reactor is shut down; electrical, control, and instrument systems for safety systems and for monitoring reactor conditions; and a system of barriers to contain radioactivity if it should escape from the reactor fuel in an accident.

Shutdown Systems

Each reactor has a system to insert control rods into the reactor core within seconds to stop the fission reaction. This immediate shutdown, called a reactor scram or reactor trip, can be triggered by a reactor operator or by automatic controls that protect the reactor from any damage threatening conditions in the plant.

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[83] Ibid.

[84] As part of its "defense in depth" philosophy, the NRC has begun promoting the use of probabilistic risk assessment (PRA). PRA is an analytical process that estimates quantitatively the potential risk to public health and safety considering the design, the operational, and the maintenance practices of a plant. Section 2.2.2 discusses PRA.

Cooling And Pressure Control Systems

When a reactor is operating, the heat energy from the fission reaction is carried off in the cooling water. That energy is used as steam to spin the turbine generator, making electricity. A reactor shutdown stops the fission reaction, but heat is still generated by the radioactive fission byproducts, which have built up in the reactor fuel. Much less heat is created than when the reactor is operating, but the heat, if it is not removed, is still sufficient to damage the fuel. As time passes after the reactor shutdown, the amount of heat produced in the fuel in the reactor core decreases. Continued cooling of the fuel remains necessary, however, for some time after shutdown. Both normal and emergency cooling systems have at least two parallel parts so that if one fails, the other part remains available to continue to cool the reactor.

The emergency core cooling system (ECCS) consists of pumps and valves and pipes that are independent of the normal cooling system. The ECCS includes equipment that can pump at high pressure to inject water into the reactor when the pressure inside is at the high levels maintained during operation. In addition, low pressure systems pump water into the reactor when coolant pressures are low, such as might result from a LOCA that causes pressure inside the reactor to drop or from a controlled depressurization of the reactor.

Controlled depressurization can be initiated to reduce reactor coolant pressure by releasing steam. Reactor systems also include valves that can be opened to reduce pressure by releasing steam. These relief valves open automatically if pressure gets too high in the reactor system. Some of the valves can be opened using controls in the reactor control room. These pressure-reduction systems can also be used to reduce reactor pressure so that low pressure cooling systems can function.

Safety System Power

Most of the safety systems are powered by electricity, although some alternate pumps use steam as a source of power. Because of this reliance on electrical power, nuclear plants are required to have multiple sources of electricity. In addition to using a portion of the power it generates to run plant equipment, a nuclear power plant also must have at least two connections to a utility's electrical distribution system so that it can immediately shift to offsite power sources if a shutdown occurs. Should there be a failure in the offsite power connections, each plant has emergency diesel generators with sufficient capacity to supply electricity to critical safety systems. For control and instrument systems that normally use direct current (DC) electricity, large banks of batteries provide DC power if there is an interruption in the normal sources of electricity.

Containment Systems

Nuclear power plants have four principal barriers to prevent the release of radioactive fission products to the environment: the first barrier is the nuclear fuel itself (fuel is in the form of ceramic pellets, and most of the radioactive by-products created during the fission process remain locked inside the pellets); the second barrier is the fuel cladding (i.e., zirconium alloy tubes which hold the pellets) that are strong and resistant to damage from radiation and corrosion; the third barrier is the reactor coolant pressure boundary; and the fourth barrier is the steel lined reactor containment building that houses the reactor and isolates the reactor environment from the rest of the plant and its surroundings. With these four barriers in place, the likelihood of an accident that would affect the outside environment is very small. The NRC requires that the reactor containment be periodically tested to show it meets requirements to prevent leakage from inside the structure.

Although reactor containments were designed to cope with many types of serious reactor accidents, they may not withstand the conditions that result from an extremely unlikely accident in which all cooling capability is lost in the reactor. Under these circumstances, the energy produced by the radioactivity remaining in the fuel could cause the fuel to melt. Melting of the fuel could eventually lead to a pressure buildup in the containment that could cause leakage of radioactive gases through seals and gaskets or in other ways cause containment failure. The molten fuel could also damage the concrete base of the containment, leading to a possible release of radioactive material. Even in these cases, however, most of the long-term hazardous radioactive material would remain inside the containment structure.

In the only major commercial power reactor accident in the United States, the Three Mile Island accident in 1979, there was extensive fuel damage. Radioactive gases and contaminated cooling water filled the containment. Although some radioactive material was released to the atmosphere by an indirect route, the containment itself performed as designed and kept the radioactivity safely bottled up inside. The effectiveness of the containment was the major factor in preventing the release of large amounts of radioactive materials to the environment.

In 1986 a much more serious accident occurred at Chernobyl in the former Soviet Union. The reactor was very different from those used in the United States. The plant had no containment system like that of U.S. plants. The Chernobyl accident severely damaged the reactor core, releasing large quantities of radioactive material to the environment. Radioactive material from the Chernobyl accident was deposited in nearby countries, and radioactivity was detectable at very low levels in the United States.

2.2.1.2 Current NRC Safety Assurance Measures and Results

This section describes and analyzes the results of current NRC-mandated safety regulations. The section begins with a discussion of personnel training and emergency preparedness and moves into the numerical analyses used to compare plants within the industry and to characterize the level of safety within the industry as a whole. These areas include the Performance Indicator program, the Systematic Assessment of Licensee Performance program, and Senior Management Meetings/NRC Watch List.

The NRC evaluates the performance of nuclear power plant licensees through several coordinated processes: Plants must assure NRC that workers are properly trained to handle situations that might occur; plants must assure the NRC that adequate emergency planning and preparedness guidelines are in place; plants must undergo a lengthy and rigorous renewal process to extend their 40-year licenses; NRC inspectors perform ongoing evaluations during plant inspections and analyze operational data; regional and headquarters managers perform short-term integrated assessments of performance, at least twice a year, through the plant performance review process; regional and headquarters managers assess licensees' long-term performance through the Systematic Assessment of Licensee Performance (SALP) process; and Senior Management Meetings (SMMs) bring to the attention of the highest levels of NRC management those plants whose operational safety performance is of most concern.

Human Factors

Human performance is a crucial element in nuclear power plant safety. More than half of the incidents reported by commercial nuclear power plant licensees have human performance as a root cause. Humans perform multiple functions, and while accomplishing these functions can cause, prevent, mitigate, recover from, or be affected by events that might threaten the overall safety of the plant. During FY 97, the NRC's Human Factors Assessment Branch staff participated in 21 inspections to help determine the root causes and continuing factors of events involving human performance, and to identify and analyze those conditions that contribute to human errors. The Human Performance Investigation Process (HPIP) is often used in such inspections. The NRC developed HPIP specifically to consider issues related to human performance--the design of human-systems interfaces, plant procedures, training, and communications, as well as the effects of supervision, management, and organization. The NRC staff also developed the Human Factors Information System (HFIS) to track, trend, and manage various types of information on human performance at nuclear power plants. HFIS information is an input the NRC staff uses to determine the need for, and focus of, plant-specific and generic inspections and other reviews, such as event investigations, relating to human performance. In addition, the staff also uses HFIS to monitor plant-specific and national trends of issues related to human performance.

The NRC also conducts research into issues of human performance. For example, in October 1995, the NRC released the results of a shift staffing study that informed licensees of the adequacy of minimum shift staffing levels at nuclear power plants. The study gave licensees several insights into problems that could result from inadequate controls to ensure that shift staffing is sufficient to accomplish all functions required by an event.

Another way the NRC staff assures the effectiveness of licensee training efforts is by monitoring the Institute of Nuclear Power Operations (INPO)[85] training program accreditation process. During FY 97, NRC personnel observed 13 meetings of the National Nuclear Accrediting Board during which utility training programs are evaluated for initial accreditation or accreditation renewal. NRC staff members also observed two INPO accreditation team site visits. The staff concluded that the industry continues to conduct effective training in accordance with NRC requirements. The Commission continues to endorse the INPO accreditation program as an effective means of ensuring proper nuclear plant personnel training.

Emergency Planning and Preparedness

As discussed in NUREG-0396,[86] NRC regulatory practice requires that events which may be anticipated to occur one or more times during the lifetime of a facility lead to no significant releases of radioactive material to the environment. Despite the efforts made to prevent accidental releases of significant quantities of radioactive

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[85] INPO was established in December 1979 as a result of the March 1979 accident at Unit 2 of the General Public Utilities nuclear plant at Three Mile Island. INPO, which is neither government funded nor operated, was created with the expressed purpose of developing nuclear standards, conducting inspections, and investigating accidents. Its stated goal is to promote excellence in all plant operations. INPO inspectors make a visit to each plant about every 18 months. The findings of every INPO assessment, which rates the reactors using performance indicators similar to those in the NRC's performance indicator program, are shared with both plant and corporate management, and are based on the best practices found in the nuclear energy industry worldwide. INPO's evaluations are conducted in large part by industry peer reviewers, and a finding that a plant is performing poorly results in peer pressure from other members of the industry.

[86] NRC, *Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants: A Report Prepared by a U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency Task Force on Emergency Planning*, NUREG-0396, EPA 520/1-78-016, December 1978.

material, the possibility does exist that such accidents may occur. Therefore, nuclear power plant licensees are required by NRC regulation to develop emergency response plans, and to coordinate portions of these plans with State and local officials, to protect public health and safety in the unlikely event of a significant release of radioactive material from the nuclear power plant to the environment.

Following the accident at Three Mile Island in 1979, the NRC reexamined the role of emergency planning for protection of the public in the vicinity of nuclear power plants. The Commission issued regulations requiring that before a plant could be licensed to operate, the NRC must have "reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency." The regulations set forth 16 emergency planning standards and define the responsibilities of licensees and State and local organizations involved in emergency response. The Commission's 16 emergency planning standards, contained in 10 CFR Part 50.47, cover the following topics:

(1) Assignment of Responsibility
(2) Onsite Emergency Organization
(3) Emergency Response Support and Resourc
(4) Emergency Classification System
(5) Notification Methods and Procedures
(6) Emergency Communications
(7) Public Education and Information
(8) Emergency Facility and Equipment
(9) Accident Assessment
(10) Protective Response
(11) Radiological Exposure Control
(12) Medical and Public Health Support
(13) Recovery and Reentry Planning and Post-Accident Operations
(14) Exercises and Drills
(15) Radiological Emergency Response Training
(16) Responsibility for the Planning Effort: Development, Periodic Review and Distribution of Emergency Plans

Emergency planning adds to the defense-in-depth philosophy by providing that, even in the unlikely event of a release of radioactive materials to the environment, there is reasonable assurance that actions will be taken to protect the population around nuclear power plants.

For planning purposes, the Commission has defined a plume exposure pathway emergency planning zone (EPZ) consisting of an area about 10 miles in radius and an ingestion pathway EPZ about 50 miles in radius around each nuclear power plant. EPZ size and configuration may vary due to such conditions as demography, topography, land characteristics, access routes, and jurisdictional boundaries. The Commission requires full participation exercises involving plant personnel as well as state and local emergency preparedness officials and agencies every two years.

Detailed requirements and guidance about emergency planning and preparedness is contained in 10 CFR 50.47, Appendix E of 10 CFR Part 50, and in NUREG-0654 (FEMA-REP-1), a joint publication of the NRC and the Federal Emergency Management Agency (FEMA) entitled "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants."

For each power reactor in the U.S. there are onsite and offsite emergency plans to assure that adequate measures are taken to protect the public in the event of a radiological emergency. Federal oversight of emergency planning for licensed nuclear power plants is shared by the NRC and FEMA through a memorandum of understanding. These emergency plans have benefited several communities where nuclear plants are located: these plans have been successfully activated to protect and evacuate people following tornadoes, floods and other natural disasters, as well as following accidents involving chemical spills and leaks.

Nuclear Power Plant Inspections

The primary safety consideration in the operation of any nuclear reactor is the control and containment of radioactive material, under both normal and accident conditions. Numerous controls and barriers are installed in reactor plants to protect workers and the public from the effects of radiation. Both the industry and NRC have roles in providing these protections and ensuring that they are maintained. The NRC establishes regulations and guides for the construction and operation of nuclear reactors. Licensees must abide by these regulations and are directly responsible for designing, constructing, testing, and operating their facilities in a safe manner.

Through selective examinations, the NRC inspection program ensures that licensees meet their responsibilities. The NRC inspection program is audit-oriented to verify that relevant activities are properly conducted and equipment properly maintained to ensure safe operations. The staff determines which items to sample, as well as the sample sizes and inspection frequencies, based on the importance of the activity or system to overall safety and on available resources. The inspection process monitors the licensee's activities and gives feedback to the licensee's management for appropriate corrective action. However, the NRC inspection program does not supplant the licensee's programs or attenuate its responsibilities. Through the inspection program, the NRC seeks to independently verify the effectiveness of the licensee's implementation of its programs to ensure that operations are being carried out safely and in accordance with applicable NRC requirements. Inspections are performed on power reactors under construction, in test conditions, and in operation.

Inspections are a vital part of the NRC's review of applications for licenses, as well as the process leading to issuance of construction permits and operating licenses. Inspections continue throughout the operating life of a nuclear facility and are conducted in the following stages:

- Before construction, the inspection program concentrates on the applicant's establishment and implementation of a quality assurance (QA) program. Inspections cover QA activities related to design, procurement, and planning for fabrication and construction of the facility.

- During construction, samples taken across the spectrum of licensee activities are examined to confirm that the licensee is following the requirements of the construction permit issued by the NRC, and that the plant is being built according to the approved design and applicable codes and standards. Construction inspectors look for qualified personnel, quality material, conformance to approved design, and a well-formulated and well-implemented quality assurance program.

- As construction nears completion, pre-operational testing begins in order to demonstrate the operational readiness of the plant and its staff. Inspections during the pre-operational phase involve reviewing overall test procedures, examining selected test procedures for technical adequacy, and witnessing and assessing selected tests to verify that test objectives have been met. Inspectors also review the qualifications of operating personnel and verify that operating procedures and QA plans are properly developed and implemented.

- The NRC also verifies that the licensee is operating safely through selective inspections. An onsite resident inspector provides a continual inspection and regulatory presence, as well as a direct contact between NRC management and the licensee. The activity of the resident inspector is supplemented by the work of engineers and specialists from the NRC Regional Office and Headquarters who perform inspections in a wide variety of engineering and scientific disciplines, ranging from civil and structural engineering to health physics and reactor core physics.

The NRC Inspection Manual defines the frequency, scope, and depth of the inspection program for operating reactors, and detailed inspection procedures provide instructions and guidance for NRC inspectors. The program consists of three major elements:

(1) core inspections--the minimum required at all plants

(2) plant-specific regional initiative inspections--focus on plant performance

(3) generic safety issues inspections--focus on a significant safety problem of a generic nature

The program is structured to ensure that the resources available for inspection are used efficiently and effectively, with particular attention accorded to those plants where past performance indicates the need to improve the levels of protection and safety-consciousness.

The inspection program is designed to ensure that nuclear power plants are constructed and operated safely and in compliance with regulatory requirements. The NRC considers the results of the inspection program when making its overall evaluation of licensee performance for the SALP program. When a safety problem or failure to comply with requirements is discovered, the NRC requires prompt corrective action by the licensee, confirmed, if necessary, by appropriate enforcement action. The NRC periodically assesses the inspection program to evaluate its effectiveness in achieving its regulatory objectives.

Results of Performance Indicators Program

The NRC monitors the performance of licensees who operate the 110 commercial nuclear power plants currently licensed for operation in the United States. The NRC uses the findings of this monitoring effort to adjust its plant-specific regulatory programs. The NRC staff has developed several tools for use in monitoring licensee performance. One of these tools is a set of performance indicators.[87]

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[87] The other tools, the Systematic Assessment of Licensee Performance (SALP) and the Senior Management Meeting (SMM) are discussed in sections that follow.

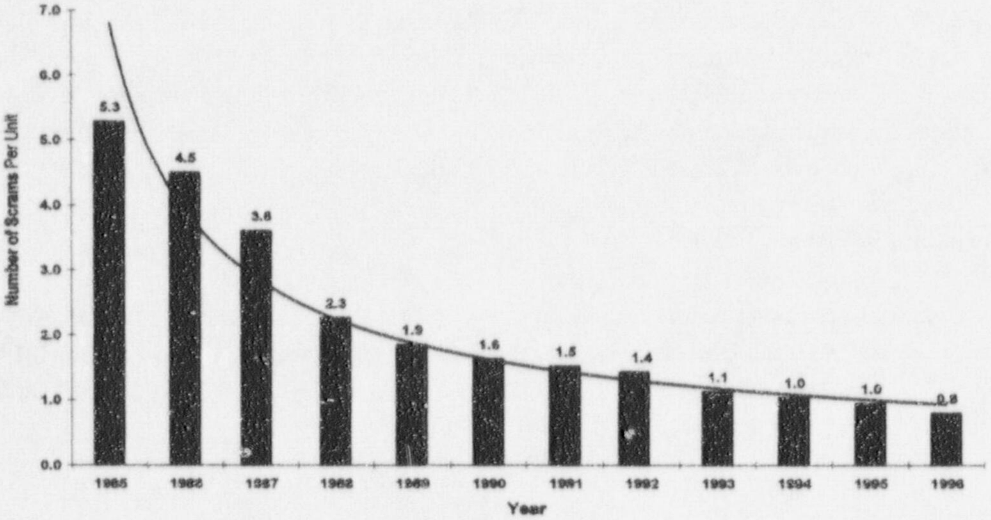
The Performance Indicator (PI) program started in May 1986. The first PI Report was published in February 1987 and contained quarterly data on six indicators for 1985 and 1986. Additional indicators were added in 1987 and 1989. Reports were provided quarterly to NRC management until June 1993, when the frequency was changed to twice a year. In 1996 the PI Report was changed to a fiscal year report, which is published each January with quarterly data on eight indicators for the twelve quarters ending the previous September.

The eight performance indicators for operating commercial nuclear power plants are: (1) automatic scrams while critical; (2) safety system actuations; (3) significant events; (4) safety system failures; (5) forced outage rate; (6) equipment forced outages per 1000 commercial critical hours; (7) collective radiation exposure; and (8) cause codes.

The following exhibits use performance indicator data that are extracted from LERs submitted in accordance with 10 CFR 50.73, immediate notifications to the NRC Operations Center in accordance with 10 CFR 50.72, monthly operating reports in accordance with plant technical specifications, and screening of operating experience by NRC staff. Radiation exposure data are obtained from INPO.

Automatic Scrams While Critical is the number of unplanned automatic scrams that occurred while the affected reactor was critical. Examples of the types of scrams included in this indicator are those that resulted from unplanned transients, equipment failures, spurious signals, or human error. Also included are those that occurred during the execution of procedures in which there was a high chance of a scram occurring, but the occurrence of a scram was not planned. Scram data are primarily derived from 10 CFR 50.73 Licensee Event Report (LER) information and supplemented as necessary from 10 CFR 50.72 Immediate Notification reports. The reactor was "critical" if the report so states. Otherwise, criticality is determined from a detailed review of the other operational information. Exhibit 13 depicts a declining (i.e., favorable) trend in automatic scrams while critical over a twelve-year period.[88]

Exhibit 13 Automatic scrams while critical



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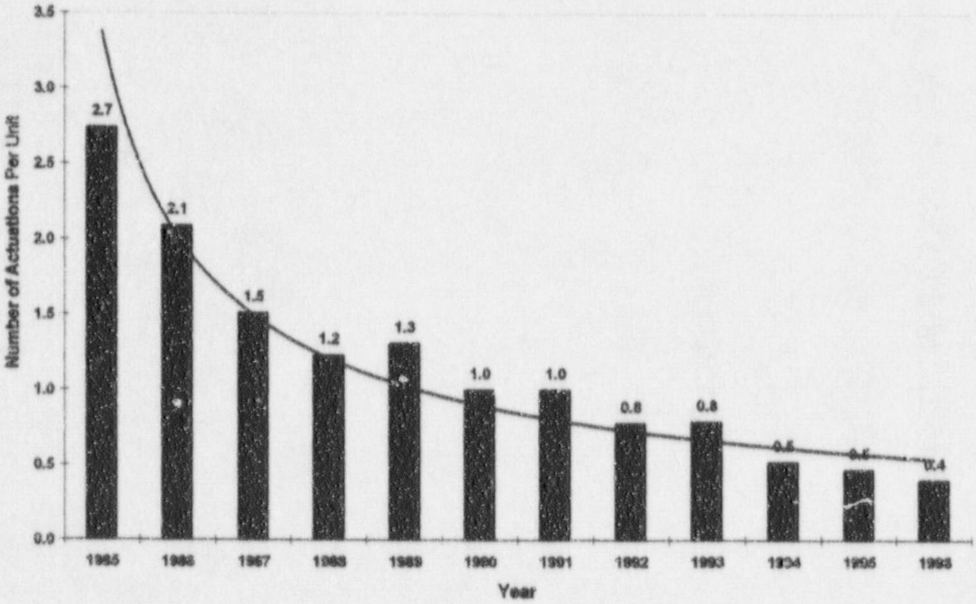
[88] Data used to construct Exhibits 13-20 were extracted from the Nuclear Regulatory Commission's *Performance Indicators for Operating Commercial Nuclear Power Reactors*.

Safety System Actuations are manual or automatic actuations of the equipment related to Emergency Core Cooling Systems (ECCS) or in response to an actual low voltage on a vital bus. Exhibit 14 depicts a declining (i.e., favorable) trend in safety system actuations over a twelve-year period.

Exhibit 14 Safety system actuations

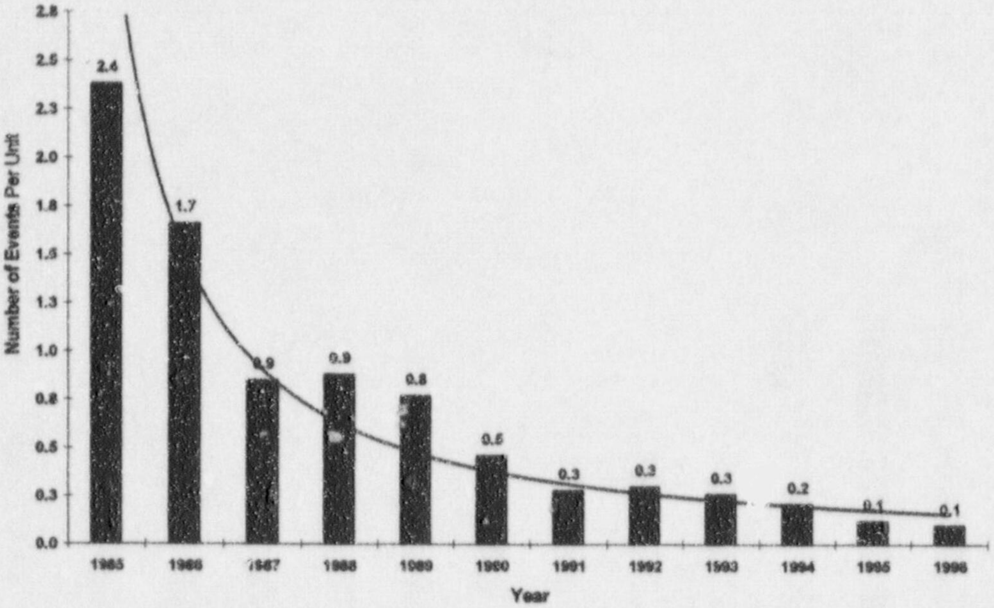


Significant Events are those events identified by NRC staff through detailed screening and evaluation of operating experience. The screening process includes daily review and discussion of all reported operating reactor events, as well as other operational data such as special tests or construction activities. An event identified from the screening process as a significant event candidate is further evaluated to determine if any actual or potential threat to the health and safety of the public was involved. Examples of some criteria considered during the significant event screening and evaluations include the following:

- degradation of important safety equipment
- unexpected plant response to a transient
- degradation of fuel integrity, primary coolant pressure boundary, important associated structures
- scram with complication
- unplanned release of radioactivity
- operation outside the limits of the technical specifications

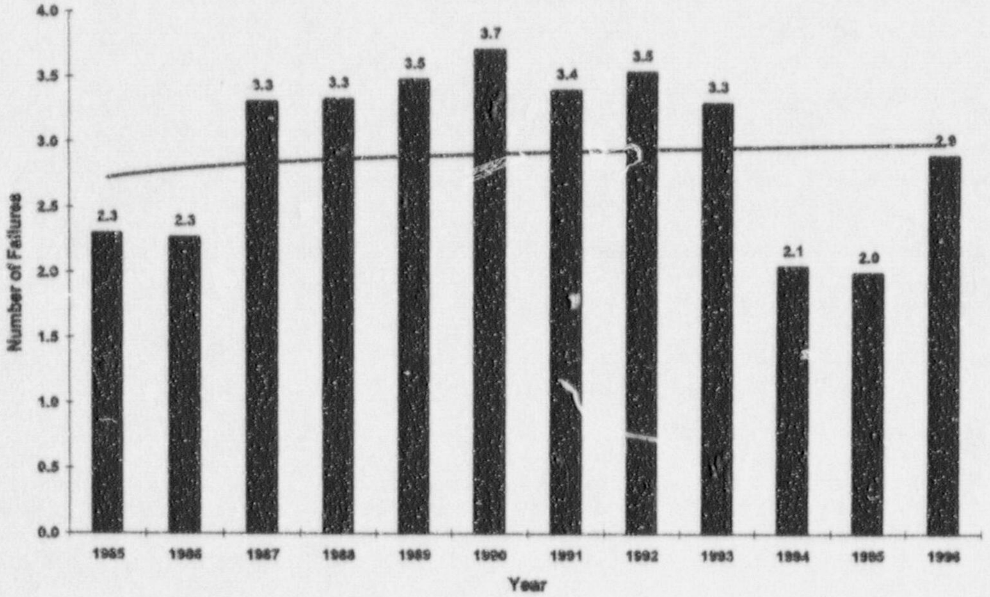
Exhibit 15 depicts a declining (i.e., favorable) trend in significant events over a twelve-year period.

Exhibit 15 Significant events



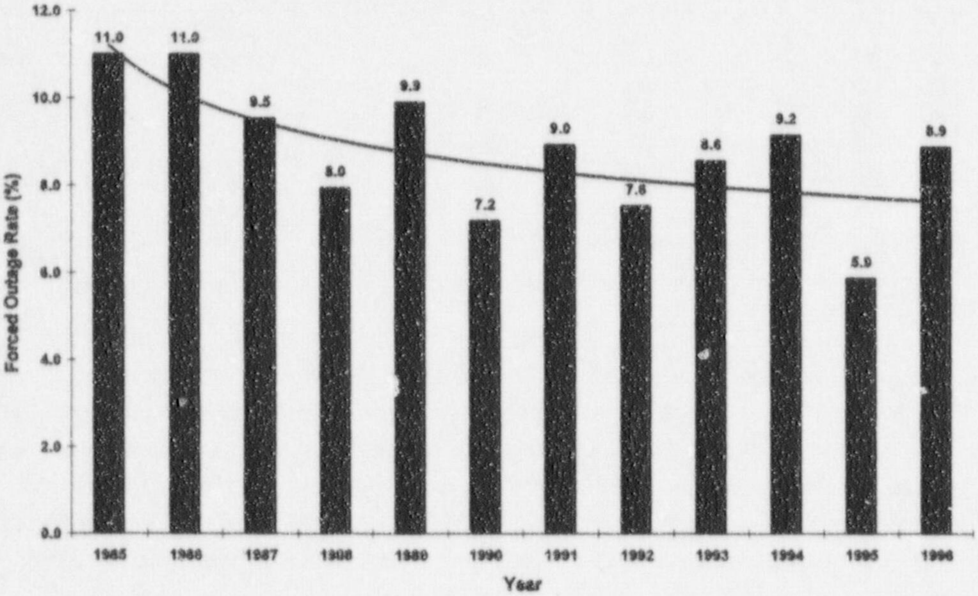
Safety System Failures are any events or conditions that could prevent the fulfillment of the safety function of structures or systems. If a system consists of multiple redundant subsystems or trains, failure of all trains constitutes a safety system failure. Failure of one of two or more trains is not counted as a safety system failure. Exhibit 16 depicts an initially rising, but eventually falling (i.e., favorable), trend in safety system failures over a twelve-year period.

Exhibit 16 Safety system failures



Forced Outage Rate (%), is the percentage of outages[89] required to be initiated no later than the end of the weekend following the discovery of an off-normal condition. Based on the data provided in the monthly operating reports, the forced outage rate is the number of forced outage hours divided by the sum of unit service hours (i.e., generator on-line hours) and forced outage hours. Exhibit 17 depicts a declining (i.e., favorable) trend in the forced outage rate over a twelve-year period.

Exhibit 17 Forced outage rate (%)



Equipment Forced Outages/1000 Commercial Critical Hours is the number of forced outages caused by equipment failures per 1000 critical hours of commercial reactor operation. It is the universe of the mean time between forced outages caused by equipment failures. The source of these data is the same as that for the forced outage rate. Exhibit 18 depicts a declining (i.e., favorable) trend in equipment failures per 1000 critical hours of commercial operation over an eleven-year period.

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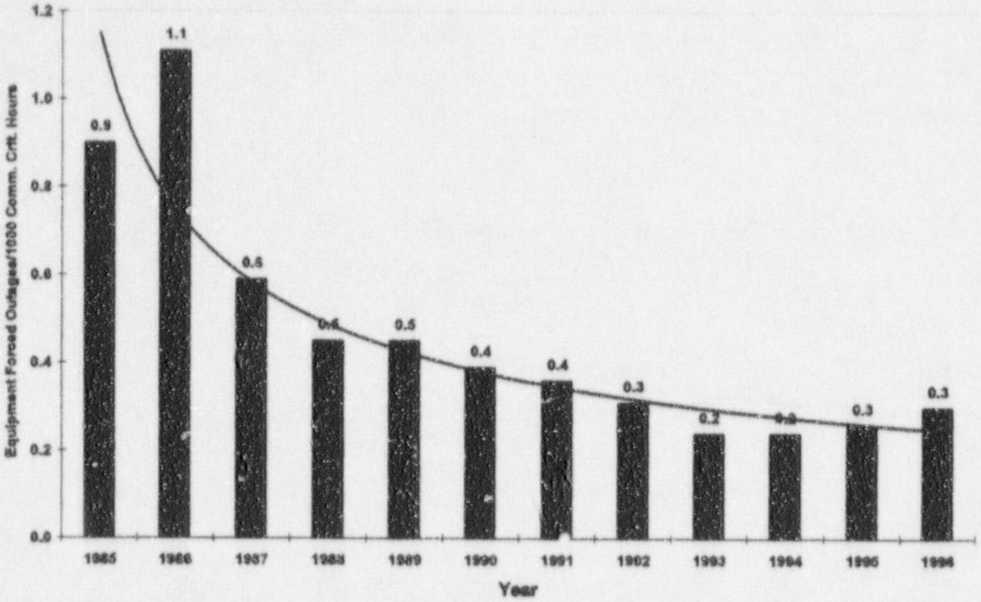
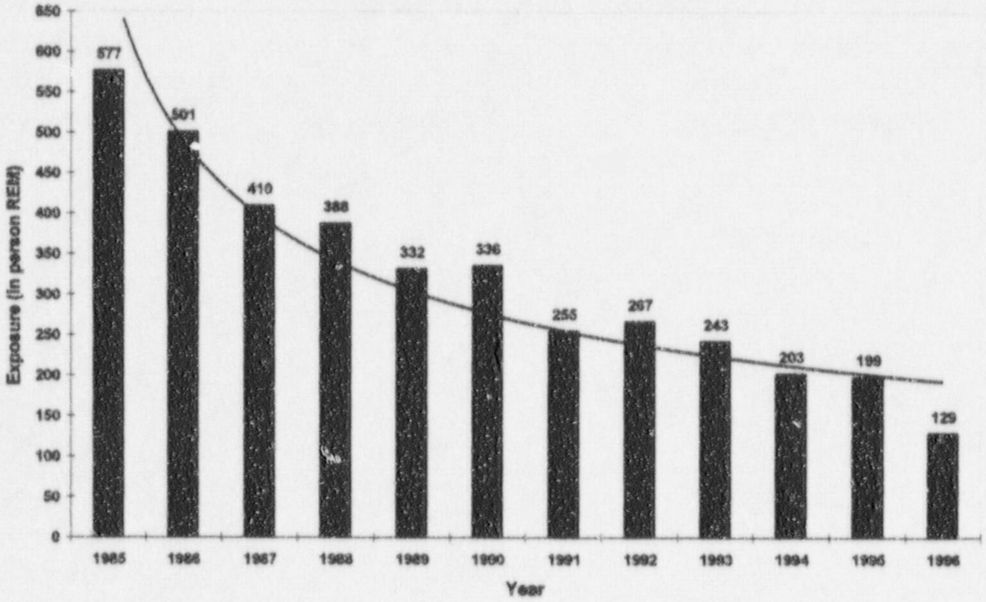
[89] An outage occurs when a plant is shut down so that work items (emergency and routine maintenance) can be safely completed.

Exhibit 18 Equipment forced outages/1,000 commercial critical hours



Collective Radiation Exposure is the total radiation dose accumulated by unit personnel. Prior to the third quarter of 1992, values at multi-unit sites were reported as site averages, with the exception of the Indian Point and Millstone sites which reported individual unit values. Beginning with the third quarter of 1992, some multi-unit sites reported site average values, while other multi-unit sites reported individual unit values. The radiation exposure data are obtained from INPO and because of the techniques employed in gathering the data, these data lag the other performance indicator data by one quarter. Exhibit 19 depicts a declining (i.e., favorable) trend in collective radiation exposure over a twelve-year period.

Exhibit 19 Collective radiation exposure



Cause Codes are intended to identify possible deficiencies in six programmatic categories. The cause code data are developed using the NRC's Sequence Coding and Search System (SCSS) database. Any event can have any or all of the cause codes assigned to it, but only one of each type of cause can be assigned to any one event. The programmatic categories include

- Administrative Control Problems
- Licensed Operator Errors
- Other Personnel Errors
- Maintenance Problems
- Design/Construction/Installation/Fabrication Problems
- Miscellaneous (one-time electronic malfunctions due to extreme acts of God)

Exhibit 20 depicts a slightly downward (i.e., favorable) trend in the number of overall cause code events from the last quarter of 1993 to the third quarter of 1996. Unlike the other 7 performance indicators, data is not available for cause codes before the last quarter of 1993, so the twelve year trend cannot be observed.

Exhibit 20 Cause codes

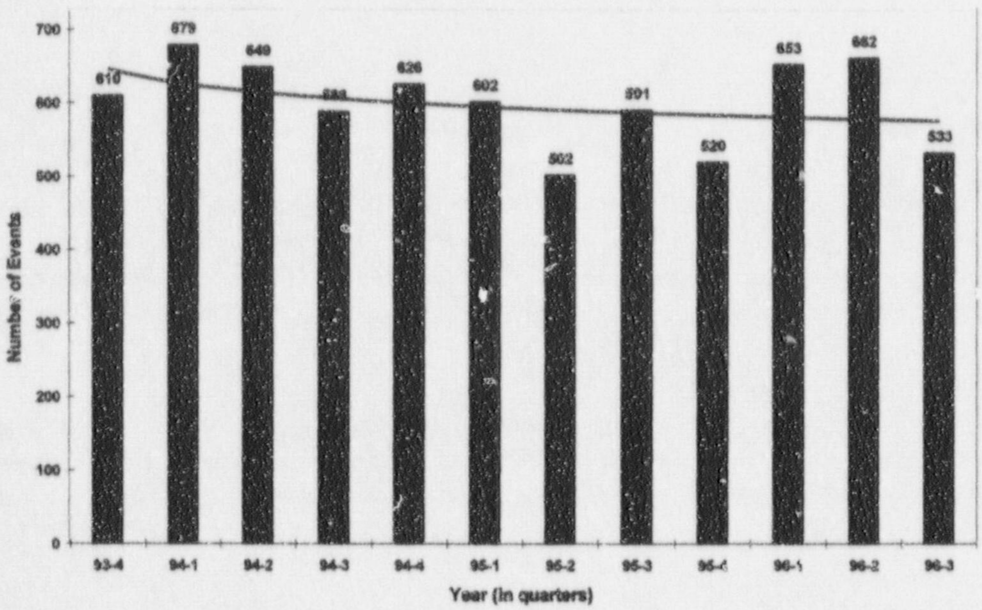
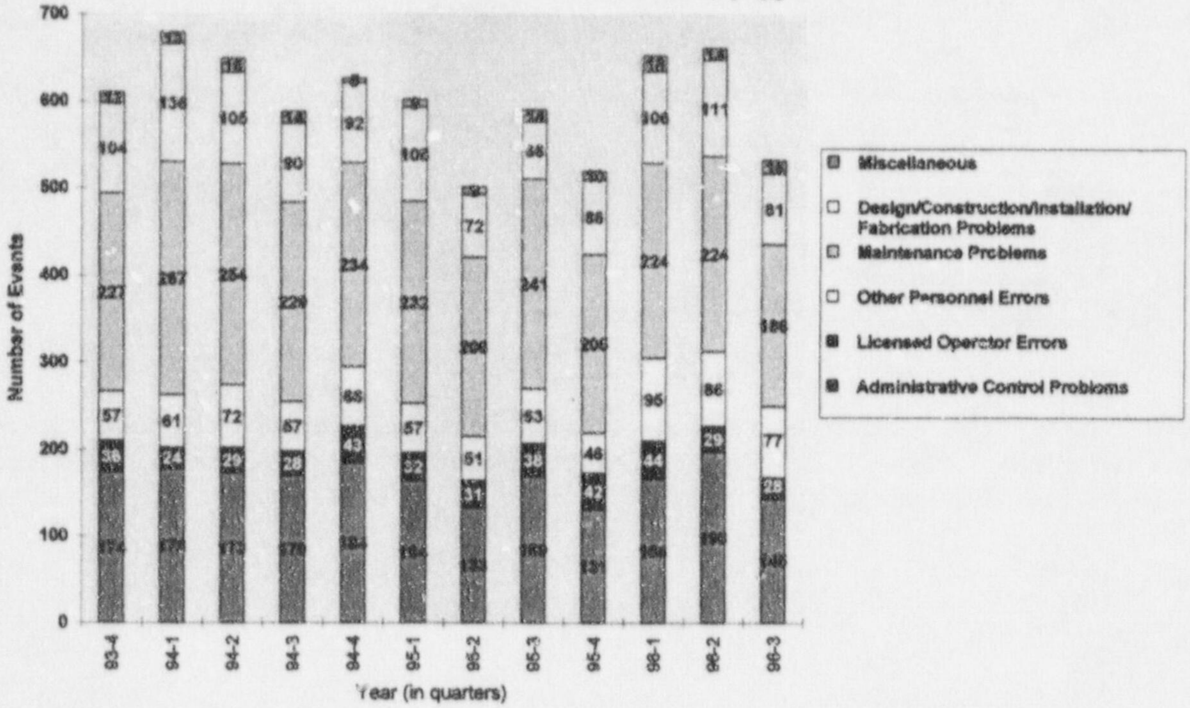


Exhibit 21 is similar to Exhibit 20 except that it separates each quarterly bar into segments that reflect the individual categories of cause codes. Moving from bottom to top, they are administrative control problems, licensed operator errors, other personnel errors, maintenance problems, design/construction/installation/fabrication problems, and miscellaneous. The variation from the average for these categories is the highest for design/construction/installation/fabrication problems and the lowest for maintenance problems. The trend for total cause codes in Exhibit 21 is the same as Exhibit 20.

Exhibit 21 Cause codes (by type)



Results of Systematic Assessment of Licensee Performance (SALP) Program

The Systematic Assessment of Licensee Performance (SALP) program is a principal and regular method for assessing licensee safety performance. Under the SALP program, the performance of each licensee with a nuclear power facility in operation in the United States is evaluated through the periodic, comprehensive evaluation of available data, including inspection findings, event review results, and similar licensing and inspection-related information.

The SALP program is designed to arrive at an overall assessment of how well licensee management at a given plant is directing and guiding operations for the requisite assurance of plant safety. The purpose of the SALP review is to focus both NRC and licensee attention on, and to direct NRC resources to, those areas that could most likely affect nuclear safety and that need improvement.

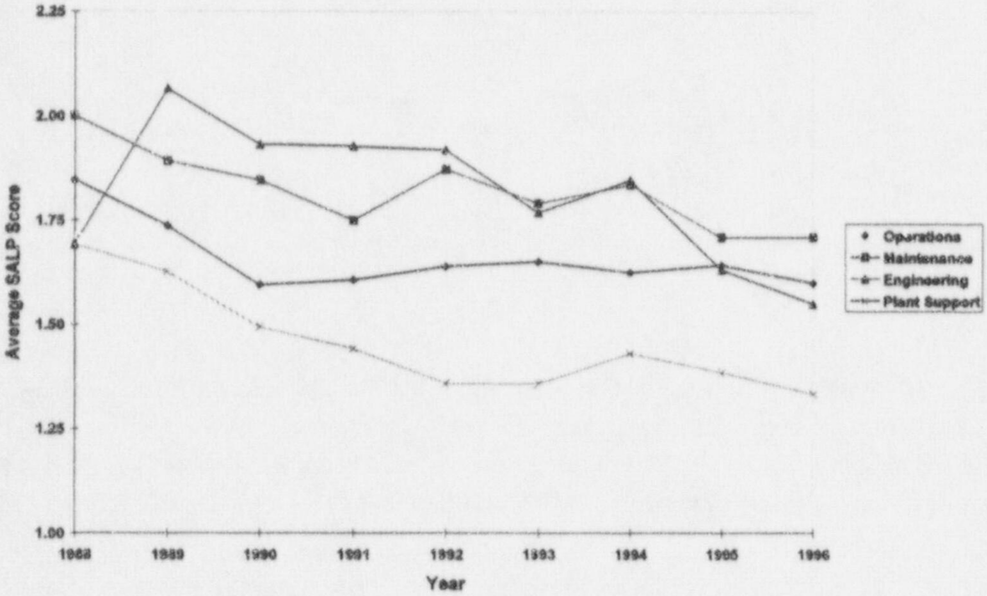
The SALP includes a review of reported events, inspection findings, enforcement history, and licensing issues for the previous 1 to 2 years. Also important are evaluations by resident and regional-based inspectors, licensing project managers, and senior managers, all of whom are familiar with the facility's performance. New data are not necessarily generated in conducting a SALP assessment, which consists of performance evaluations in specific functional areas.

For facilities in operation that have been evaluated since July 1993, the functional areas include operations (OPS), maintenance (MAINT), engineering (ENG), and plant support (PS). The plant support functional area includes radiological controls, emergency preparedness, and security issues. From June 1988 until July 1993, the functional areas included plant operations, maintenance/surveillance, engineering/technical support, radiological controls, emergency preparedness, security, and safety assessment/quality verification.

Based on a review of the consolidated information, each functional area is placed into one of three performance categories. A Category 1 rating designates a superior level of safety performance. A Category 2 rating designates a good level of performance. A Category 3 rating designates an unacceptable level of performance where NRC will consider increased levels of inspection effort.

Exhibit 22 shows the average of industry-wide SALP scores for the years 1988 through 1996. Data elements include all SALP scores for each of the aforementioned categories (Operations, Maintenance, Engineering, and Plant Services).[90] As each reactor is not evaluated every year, annual data points represent the average score for every reactor analyzed in that particular calendar year. For example, in 1992, 86 SALPs were performed by NRC. Therefore, the data points in the graph that correspond to 1992 are averages of the 86 SALP scores conducted in that year.

Exhibit 22 SALP scores by year



Trends in SALP scores from 1988 to 1996 are as follows: Operations decreased from 1.85 to 1.60; Maintenance decreased from 2.00 to 1.71; Engineering decreased from 1.69 to 1.55; and, Plant Services decreased from 1.69 to 1.33. These figures show improvement in licensee performance over this period. Historically, SALP scores for Plant Support and Operations have been lower (better) than those for Engineering and Maintenance. Although Plant Support SALP scores continue to outperform the other areas, Operations scores have not improved since 1990 and have since been outperformed by Engineering scores.

Exhibit 23 combines the four SALP categories from Exhibit 22 into one industry-wide average score for the period 1988 through 1996. Again, data points are averages of all SALP reports completed in a given calendar

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[90] Between June 1988 and July 1993, NRC provided separate scores for radiological controls, emergency preparedness, and security issues. Since 1993, NRC has grouped these criteria under the heading Plant Services. To provide a better means for comparison with post-1993 data, 1988-1993 radiological controls, emergency preparedness, and security issues data have been averaged and considered Plant Services data.

year. As shown, the average SALP score decreased from 1.81 in 1988 to 1.55 in 1996, indicating an improvement in licensee performance over this period.

Exhibit 23 Average SALP score (1988-1996)

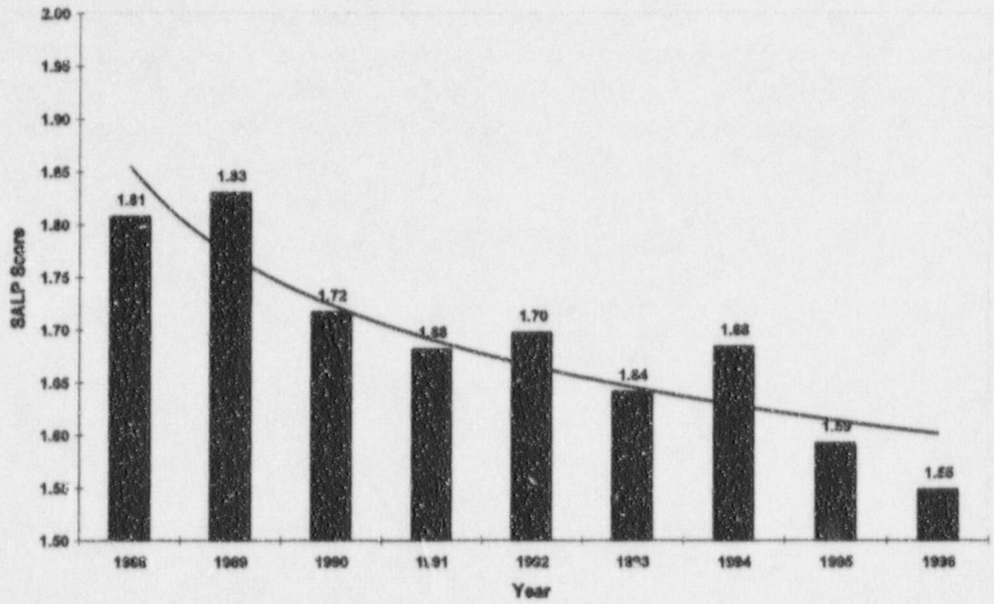

Exhibit 24 shows the most recent SALP scores for 107 of the 110 reactors currently licensed to operate in the U.S.[91] Each bar represents a "functional area" that the SALP reports describe. The bars are divided according to the number of reactors that achieve category 1, 2, or 3 ratings within each functional area. Overall, 48 percent of SALP scores fall into Category 1,[92] 46 percent into Category 2, and 6 percent into Category 3.[93]

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[91] Most recent SALP scores are not available for Watts Bar (recently operational) and Browns Ferry 1/3.

[92] 15 reactors achieved a Category 1 ranking in all four areas, 28 reactors achieved a Category 1 ranking in three areas, 20 reactors achieved a Category 1 ranking in two areas, 23 reactors achieved a Category 1 ranking in one area, and 21 reactors achieved no Category 1 rankings.

[93] All twenty-five Category 3 rankings were achieved by 16 of the 107 reactors.

Exhibit 24 Most recent SALP scores by category

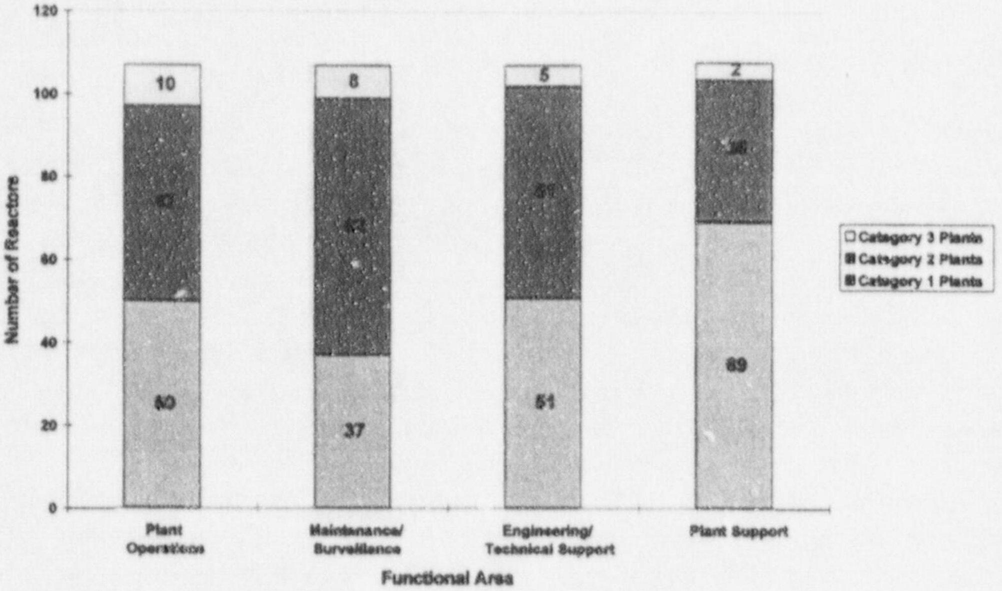
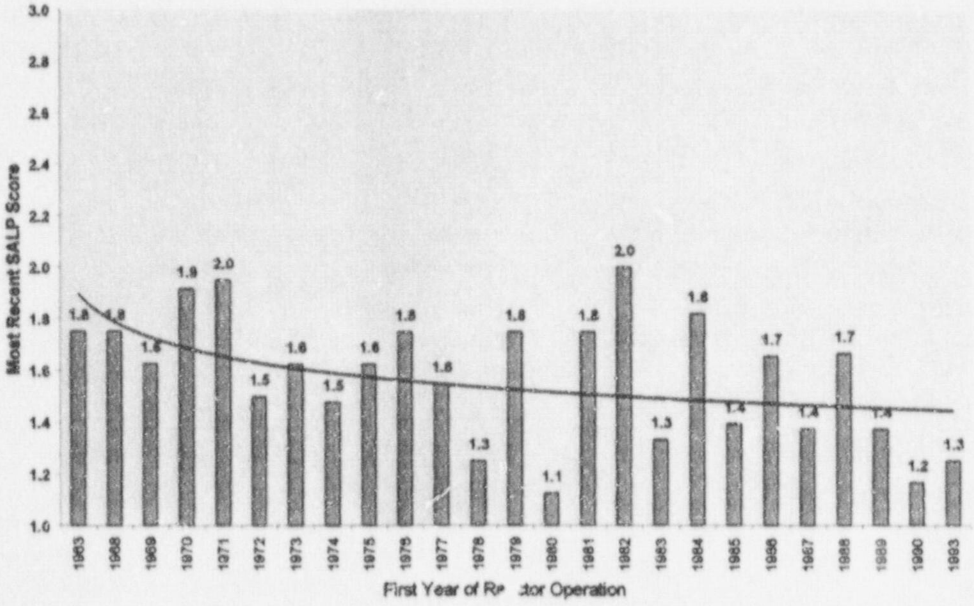


Exhibit 25 shows the most recent SALP scores for all nuclear power reactors according to the year the plant commenced operations. The graph shows the relationship between the age of the plant and its performance. As indicated by the trendline, plants that began operations more recently tend to have better SALP scores. The NRC recognizes that as plants grow older, additional testing and precautions must be carried out to minimize the effects of plant aging. These effects include degradation of key systems, structures, and components. The NRC will continue to work with the nuclear power industry to improve the effectiveness of inspection and test

Exhibit 25 Current SALP scores for plants built since 1963



programs.[94] The NRC is actively engaged in monitoring and inspection programs to ensure the continued safety of all, and specifically, aging, nuclear power reactors.

Results of Senior Management Meetings (SMM)

The NRC established the senior management meeting (SMM) process following a loss-of-feedwater event at the Davis-Besse nuclear plant in 1985. That event revealed weaknesses in the NRC's integration of information and led a special review group to recommend that senior NRC managers should meet periodically to review the agency's observations and integrate findings regarding operating nuclear reactors.

The NRC Executive Director for Operations (EDO), the regional administrators, and the headquarters program office directors conducted the first SMM in April 1986. Since then, SMMs have been held every 6 months. Over the years, management has expanded the scope of the meetings to include major fuel facilities and material licensees, superior performers (since discontinued), and plants whose performance is declining.

The process for power reactors begins with screening meetings. Each reactor's performance is reviewed for plant events, inspection findings, operating experience, performance indicators, licensee event reports, and enforcement history. The review emphasizes the effectiveness of licensee self-assessment and corrective actions. Those plants that are of most concern are identified for discussion at the SMM.

During the SMM discussions, managers determine which plants, if any, to place in the following categories: Category 1, plants removed from close NRC scrutiny; Category 2, plants authorized to operate that the NRC will closely monitor; and Category 3, shutdown plants requiring NRC authorization to restart and that the NRC will closely monitor. The managers also review resource questions and coordinate the actions that the NRC plans to take. For plants removed from Category 2, NRC reviews plant performance over the next year to ensure that improved performance continues.

In addition to placing some plants in the three categories, senior managers identify plants that exhibit declining performance trends that, if not corrected, may result in the plants being placed in Category 2 in the future. Strong evidence exists that most licensees take robust actions to remediate such adverse performance trends. In order to gain a balanced view of industry performance, the senior managers also identify superior performing plants that deserve formal recognition by NRC's Executive Director for Operations.

NRC senior managers may also determine that additional information is needed on a plant to assess performance or determine the cause of poor or declining performance. In such cases, they may recommend that a special inspection or evaluation be conducted at the plant before the next SMM. This evaluation gives a fresh perspective on safety performance and facilitates the identification of weaknesses in NRC programs that may have contributed to or failed to detect declining or marginal performance.

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[94] "Regulation of Aging Power Plants: Ensuring Safety in a Changing Environment," by Dr. Shirley Ann Jackson, Chairman, U.S. Nuclear Regulatory Commission, keynote address to the Plant Life Management and Plant Life Extension International Conference and Exhibit (December 8, 1997).

As a result of SMM discussions, the EDO issues letters to the licensees of the plants placed in Categories 1, 2, and 3. The list of plants in these categories is commonly referred to as the "Watch List." Letters are also sent to plants exhibiting adverse performance trends and to plants that are recognized for superior performance. The results of the SMM are discussed with the Commission at a public meeting twice a year and announced in a news release.

Once placed on the "Watch List" a plant must demonstrate consistent improved performance before it is removed from the list. The review is performed by senior NRC managers who then present their assessments to the Commission in a public meeting. Since June 1993, the managers have also identified plants where performance is declining, but which do not warrant being placed on the Watch List (these plants are placed on the "Declining Trend List"). The senior managers' evaluations are drawn from inspections of the plants by NRC inspectors, NRC managers' visits to the plants, performance data, events and information reported by the utilities, and other information.

The NRC's Watch List categories are described as follows:

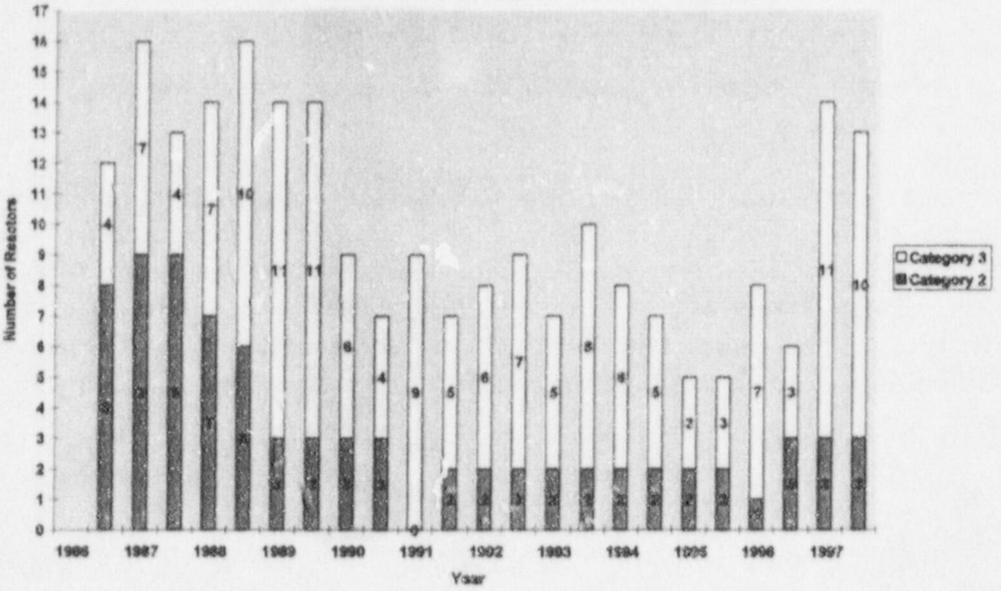
- *Category 1*: Plants removed from the list of problem facilities. Plants in this category have taken effective action to correct identified problems and to implement programs for improved performance. No further NRC special attention is necessary beyond the regional office's current level of monitoring to ensure improvement continues.

- *Category 2*: Plants authorized to operate that the NRC will monitor closely. Plants in this category are having or have had weaknesses that warrant increased NRC attention from both headquarters and the regional office. A plant will remain in this category until the licensee demonstrates a period of improved performance.

- *Category 3*: Plants in this category are having or have had significant weaknesses that warrant maintaining the plant in a shutdown condition until the licensee can demonstrate to the NRC that adequate programs have both been established and implemented to ensure substantial improvement.

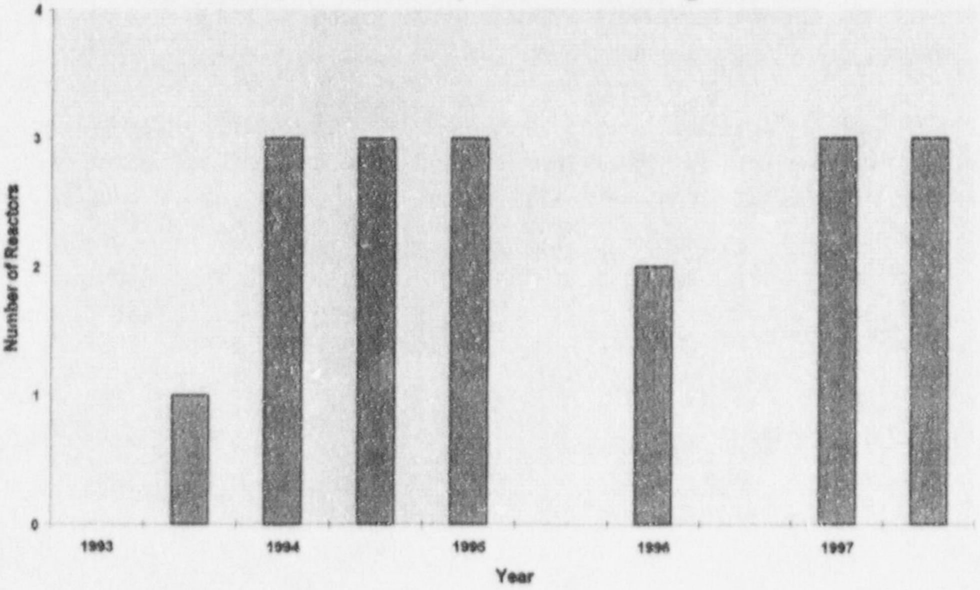
Exhibit 26 shows the number of reactors on the NRC Watch List (Categories 2 and 3) since it began in 1986. At most, the Watch List contained sixteen reactors. At its least, the Watch List contained only five reactors. As of June 1997, the Watch List contained thirteen reactors.

Exhibit 26 The history of NRC's watch list



In addition to the three Watch List categories, the NRC has developed a category for reactors with declining performance trends. A *Declining Trend Plant* is defined as a plant with safety performance trending downward but not yet warranting designation as a Category 2 plant. Exhibit 27 shows the number of reactors on the NRC Declining Trend List since it began in 1993. At most, there have been three reactors on the Declining Trends list. At times, the Declining Trend List contained zero reactors. As of June 1997, the Declining Trend List contained three reactors.

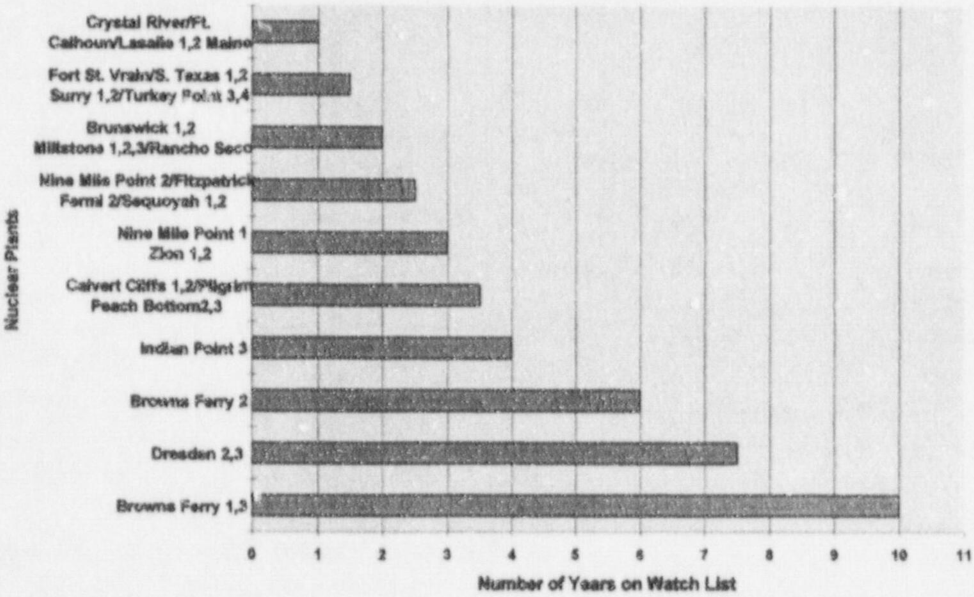
Exhibit 27 The history of NRC's declining trend list



Despite a generally downward sloping trend in Watch List membership over the past eleven years, the number of reactors on the Watch List has increased since mid-1995, reaching fourteen in early 1997. This trend can also be seen in the Declining Trend List, which contained zero reactors as recently as mid-1996, but contained three reactors as of June 1997.

Since 1986, 40 reactors, representing 36 percent of the reactor population, have appeared on the NRC's Watch List. As of June 1997, Browns Ferry Unit 1 has been on the Watch List for 10 of its 24 years and Browns Ferry Unit 3 for 10 of its 20 years. Twelve other reactors have been on the list for three or more years. Exhibit 28 shows which reactors most frequently have been on the Watch List and for how many years. When plants are shut down, the NRC requires them to address their backlogs of safety concerns before allowing a restart.

Exhibit 28 The reactors most often on NRC's watch list



The NRC is increasing efforts to become a more proactive participant in removing troubled plants from the Watch List and the Declining Trend List. The NRC is working with plant owners and managers to identify plant deficiencies and suggest remediation procedures to ensure safe operation in the future.

2.2.2 Potential for Occurrence of Accidents

The state of knowledge of nuclear safety requires consideration of various types of possible accidents that may pose a public risk. Probabilistic risk assessment (PRA) is an analytical process that estimates quantitatively the potential public risk, considering the design and the operational and maintenance practices of a plant. It generally encompasses the following activities:

- identification and delineation of the event combinations that, if they occur, would lead to a severe accident (or any other undesired event)

- estimation of the frequency of occurrence for each combination, and

- estimation of the consequences associated with each combination

As practiced by the nuclear industry, PRAs generally focus on accidents that can severely damage the reactor core and can challenge the containment, because such accidents pose the greatest potential public risk. The PRA integrates into a uniform methodology the relevant information about plant design, operational practices, operating history, component reliability, human actions, the physical progression of core-damage accidents, and the potential environmental and health effects to assess public risk as realistically as possible. In some cases, limited scope PRAs can be completed that calculate the frequencies of various accident sequences, but do not assess health impacts.

The assessment of plant-specific risk provides both a measure of potential accident risks to the public and insights into the adequacy of plant design and operation, including dominant accident sequences and plant features contributing significantly to risk. Knowledge of the most probable severe accidents assists both the NRC and the nuclear industry in developing strategies for coping with accidents beyond current design basis accidents. This information provides a focus for training operators to deal with such accidents. PRA results help place emphasis on diagnosing the most-probable severe accident sequences and are used in accident management programs to assist in providing information and guidance to operators on how to cope with such accidents. In addition, PRAs estimate the timing and location of containment failure and the magnitude of the potential release and radioactive material for each accident sequence. This information is used as an input to develop emergency response plans.

Risk Concepts

For PRAs, the term "risk" usually expresses not only the potential for an undesired consequence, but also how probable it is that such a consequence will occur. Thus two nuclear power plants with the same radioactive inventory can pose vastly different risks, depending upon the effectiveness of their safety systems.

A common mathematical definition of risk is:

Risk (consequence/unit time) =
Frequency (event/unit time) x
Magnitude (consequence/event)

As an example, the annual risk of death from automobile accidents in the United States using this equation is:

(15,000,000 accidents/year) x
(1 fatality/300 accidents) =
50,000 fatalities/year

(Adapted from: *Readings in Risk*, Resources for the Future, 1990).

The use of PRA in the assessment of plant safety is achieved by identifying those sequences of potential events that dominate risk and establishing which features of the plant contribute most to the frequency of such sequences. These plant features may be potential hardware failures, common-mode failures, human errors during testing and maintenance, or procedural inadequacies leading to human errors. Further, a PRA reveals the features of a plant that may merit close attention and provides a focus for improving safety. Thus, PRAs provide not only a technique for assessing the safety of a particular facility but also an information base that is applicable to a wide variety of issues and decisions.

PRA accounts for certain processes and phenomena that occur infrequently and may involve severe conditions that are difficult to replicate and instrument, particularly in the proper scale. Thus, because certain aspects of these processes may not be well known and data on component behavior may not be fully processed or readily available without significant effort, uncertainties in estimating risk arise. PRA illuminates these uncertainties and provides a way of considering them in the analysis.

2.2.2.1 Safety Goals and Objectives

In 1986, the Commission issued its "Policy Statement on Safety Goals for the Operations of Nuclear Power Plants."[95] This policy statement focused on the level of risks to public health and safety that the industry should strive for in its nuclear power plants. In the policy statement, the Commission established two qualitative safety goals:

(1) Individual members of the public should be provided a level of protection from the consequences of nuclear power plant operation such that individuals bear no significant additional risk to life and health.

(2) Societal risks to life and health from nuclear power plant operation should be comparable to or less than the risks of generating electricity by viable competing technologies and should not be a significant addition to other societal risks.

To quantify these goals, the Commission also established the following two quantitative health objectives (QHOs):

(1) The risk to an average individual in the vicinity of a nuclear power plant of prompt fatalities that might result from reactor accidents should not exceed one-tenth of one percent (0.1 percent) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed.

(2) The risk to the population in the area near a nuclear power plant of cancer fatalities that might result from nuclear power plant operation should not exceed one-tenth of one percent (0.1 percent) of the sum of cancer fatality risks resulting from all other causes.

In developing this policy statement, the Commission considered that severe core damage accidents can lead to more serious accidents with the potential for life-threatening offsite release of radiation, for evacuation of members of the public, and for contamination of public property. The safety goals are substitutes for neither the NRC's regulations nor the defense-in-depth concept, rather they are intended to define "how safe is safe enough."

As a result of the policy statement, NRC staff established a subsidiary safety goal objective for core damage frequency (CDF) of 1:10,000 ($1x10^{-4}$) per reactor year. The staff uses this objective for prioritizing regulatory activities and for comparing predicted plant performance under severe accident conditions against the Commission's safety goals.

2.2.2.2 Development and Use of PRA in the NRC's Regulatory Program

The Commission has been considering severe accidents (accidents more severe than design basis accidents in which substantial damage is done to the reactor core whether or not there are serious offsite consequences) in its regulatory decisions and actions since its early days. These include decisions in which severe accidents have been considered directly in making regulatory decisions (i.e., specific regulatory requirements to

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[95] NRC, "Safety Goals for the Operation of Nuclear Power Plants: Policy Statement," 51 FR 30028, August 21, 1986.

address accidents more severe than design basis accidents) and decisions in which severe accidents have been considered more indirectly in making decisions (e.g., by considering the results of cost/benefit analyses in the decision-making process). The probability of a severe accident occurring, as well as the potential consequences of the accident, were considered qualitatively by agency decision makers during the early regulatory decisions. These qualitative considerations involved the use of engineering judgement and were made in the context of a deterministic consideration of accidents beyond the design basis. Typically, reliance was placed upon the concept of defense-in-depth to minimize the likelihood and consequences of such accidents. The "risk" of severe accidents, as that term is generally used in current NRC lexicon as the quantitative product of a probability times a consequence, was not utilized by the agency until relatively recently.

In an early study, in 1957, the AEC published WASH-740, "Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants." This study evaluated the potential consequences for several accident scenarios and discussed in broad terms a range of likelihoods for the occurrence of such accidents. In 1975, the NRC completed the first quantitative study of design basis accidents postulated for commercial nuclear power plants -- WASH-1400, the Reactor Safety Study.[96] WASH-1400 evaluated the probability of postulated accident sequences for two nuclear power plants[97] that could lead to core damage. WASH-1400 found that the probabilities of accidents such as core damage caused by accidents such as small LOCAs were higher than previously believed but that the offsite consequences (to the public and the environment) were significantly lower. However, the Commission did not regard the WASH-1400 study's numerical estimate of the overall risk of reactor accidents as reliable.

Following completion of these first PRAs, the NRC initiated research programs to improve the NRC's ability to assess the risks of severe accidents in commercial nuclear power plants. Development began on advanced methods for assessing the frequencies of accidents. For example, the NRC initiated improved means for the collection and use of plant operational data and developed new techniques for assessing the impacts of human errors and other common-cause failures. It also researched the key severe accident physical processes identified in WASH-1400 such as the interactions of molten core material with concrete.

In parallel, the NRC gradually introduced the use of PRA into its regulatory process. It investigated a spectrum of generic safety issues important to public risk and developed a list of higher priority issues.[98] The NRC began studying other PWR and BWR plant designs as well.[99] However, criticism from the peer review of

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[96] U.S. Nuclear Regulatory Commission, *Reactor Safety Study -- An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants*, WASH-1400 (NUREG-75/014), October 1975.

[97] The two nuclear power plants were Surry-1 (a Westinghouse-designed three-loop PWR in a subatmospheric containment building, located near Williamsburg, Virginia) and Peach Bottom-2 (a General Electric-designed BWR-4 in a Mark I containment building, located near Lancaster, Pennsylvania).

[98] U.S. Nuclear Regulatory Commission, "Reporting the Progress of Resolution of Unresolved Safety Issues in the NRC Annual Report," SECY-78-616, November 27, 1978.

[99] Carlson, D.D., et al., *Reactor Safety Study Methodology Applications Program*, Sandia National Laboratories, NUREG/CR-1659, Volume 1, SAND80-1897, April 1981.

WASH-1400, commonly known as the Lewis Committee report,[100] and subsequent Commission policy guidance to the staff[101] tempered such uses of PRA.

Prior to the accident at Three Mile Island Unit 2 (TMI) in 1979, the focus of the Commission was on design basis accidents. Following the accident at TMI, there was a shift in the Commission's focus to provide greater consideration of the risks from severe accidents in its decision making. The core damage accident at Three Mile Island substantially changed the character of NRC's analysis of severe accidents and its use of PRA. Based on the comments and recommendations of two major investigations of this accident, the NRC planned and initiated a substantial research program on severe accident phenomenology.[102] The program included both experimental and analytical studies of accident physical processes and also the development of computer models to simulate these processes. Both major investigations recommended that the NRC increase its use of PRA to complement its traditional, non-probabilistic methods of analyzing nuclear plant safety. Thus, the NRC refocused its severe accident policy in two respects: (1) the need to specifically consider additional severe accidents (e.g., those involving multiple system failures) in the licensing process and (2) the need for probabilistic safety goals to help define the level of plant safety that was "safe enough."

As the Commission continued to evaluate potential new requirements for plants to deal with accidents that were considered to be beyond the normal design basis, it issued two rules in the 1980s that dealt with Anticipated Transients Without Scram (ATWS, July 1984) and Station Blackout (June 1988) each of which had been identified in previous safety studies as potentially being an important contributor to risk.

- Anticipated transients without scram (ATWS) are accident sequences that signal the reactor protection systems (RPS) to trip or "scram" but fail to shut down the reactor. Because anticipatory trips are a part of the RPS, a failure or maintenance action in the anticipatory scram could cause other trips relied on in the accident analysis to be degraded below an acceptable level. These accidents had been a concern because under certain postulated conditions they could lead to severe core damage and release of radioactivity to the environment.[103] The Commission issued requirements to reduce the risk from ATWS events (10 CFR 50.62) to shut down the reactor following anticipated transients and to mitigate the consequences of an ATWS. In promulgating the ATWS rule, the Commission stated that this regulation would "significantly reduce the risk of nuclear power plant operation." The regulatory analysis for the ATWS rule used PRA information to evaluate the costs and values of various alternatives for implementing ATWS requirements. The estimated benefit from implementing the rule was a reduction

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[100] Lewis, H.W., et al., *Risk Assessment Review Group Report to the U.S. Nuclear Regulatory Commission*, NUREG/CR-0400, September 1978.

[101] U.S. Nuclear Regulatory Commission, "NRC Statement on Risk Assessment and the Reactor Safety Study Report (WASH-1400) in Light of the Risk Assessment Review Group Report," January 18, 1979.

[102] Larkins, J.T. and M.A. Cunningham, *Nuclear Power Plant Severe Accident Research Plan*, NUREG-0900, January 1983.

[103] See U.S. Nuclear Regulatory Commission, *Anticipated Transients Without Scram for Light Water Reactors*, NUREG-0460, April 1978.

in the frequency of core damage per reactor-year due to ATWS and the associated reduction in risk to the public from accidental release of radioactive material.

- Station blackout (SBO) involves the concurrent failure of both offsite and onsite emergency AC power supplies. This condition represents an accident beyond the normal design basis. In 1975, the results of the Reactor Safety Study (WASH-1400) showed that station blackout could be an important contributor to the total risk from nuclear power plant accidents. Subsequent technical evaluations and risk studies showed that no undue risk existed with or without promulgation of the station blackout rule. However, station blackout could still be an important contributor to residual risk. Therefore, the Commission issued the Station Blackout Rule (10 CFR 50.63) to enhance safety by accident prevention and thereby reduce the likelihood of a core damage accident caused by a station blackout event. IPE results from draft NUREG-1560, "Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance," dated November 1996, indicate that significant reduction in CDF is achievable through the implementation of the SBO rule. For 15 plants, including both PWRs and BWRs, for which risk reduction values were provided, the average value of CDF reduction was reported to be $2x10^{-5}$ per reactor year.

In promulgating these rules, the Commission considered the reduction in risk to the public associated with the implementation of the rule and the costs to implement the new requirements. In both cases, the Commission established deterministic requirements that, when met, served to reduce the risk from severe accidents.

By the mid-1980s, the technology for analyzing the physical processes of severe accidents evolved to the point that researchers developed a new computational model of severe accident physical processes, the Source Term Code Package. Meanwhile, the NRC developed general procedures for performing PRAs and published a summary of PRA perspectives available at that time. In August 1985, the Commission published its "Policy Statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants."[104] In the policy statement, the Commission said that it had concluded that existing plants posed no undue risk to public health and safety and saw no basis for immediate action on generic rulemaking or other regulatory actions to deal with severe accidents. However, the Commission indicated its intention to initiate a systematic examination of each nuclear power plant for possible significant risk contributors. In the policy statement, the Commission also said that it fully expected that designers of new plants would achieve a higher standard of severe accident performance than prior designs.

In its design certification process for advanced reactors, the Commission established a requirement in Part 52 that all future reactor design applications include a PRA so that the NRC can evaluate the design for severe accidents. The Commission has successfully applied these requirements as a significant part of the design certification reviews for the latest advanced reactors. The Commission expects that if licensees reference a certified design, they will maintain the design features that were included to prevent and mitigate severe accident risk.

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[104] U.S. Nuclear Regulatory Commission, "Policy Statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants" (50 FR 32138; August 8, 1985).

Subsequently, in 1988, the NRC requested licensees to perform a plant-specific search for vulnerabilities to design basis accidents. This effort, known as the Individual Plant Examination (IPE) program, was designed to identify possible safety weaknesses that could result in severe accidents. Every licensee used PRA to assess the likelihood and consequences of severe accidents. The first phase of this program investigated internal events such as equipment failures. In total, the licensees have reported that approximately 500 improvements in plant design or operation have been implemented as a result of the IPE effort. The second phase of the IPE program addresses accidents that could be initiated by external events such as earthquakes.[105]

In 1990, the NRC issued NUREG-1150[106] as an update of the Reactor Safety Study. In NUREG-1150, the NRC used improved PRA techniques to assess the risk associated with five nuclear power plants, including the two plants originally evaluated in WASH-1400.[107] The study was a significant turning point in the use of risk-based concepts in the regulatory process and enabled the Commission to greatly improve its methods for assessing containment performance after core damage and accident progression. The methods developed for and the results produced by NUREG-1150 provided a valuable foundation in quantitative risk techniques.

The principal results obtained from the five PRAs that formed the basis of NUREG-1150 were probability distributions. For simplicity, these distributions may be described by a number of statistical characteristics: the mean, the median, and the 5th and 95th percentile of the distributions. In addition to calculations of risk, the study described the results of analyses which attempted to predict the uncertainties in the predictions of a number of relevant quantities, including core melt frequency and the probabilities of early and delayed fatalities.

NUREG-1150 used a specialized Monte Carlo method, called Latin Hypercube Sampling, to sample the probability distributions. The sample observations were propagated throughout the individual analyses to produce probability distributions for core damage frequency and risk.

Monte Carlo and Latin Hypercube Sampling

Monte Carlo methods produce results that can be analyzed with a variety of statistical techniques such as regression analysis. Such techniques easily treat distributions with wide ranges. Latin Hypercube Sampling provides for a more efficient sampling technique than straightforward Monte Carlo sampling while retaining the benefits of Monte Carlo techniques. Since many of the probability distributions used in the five PRAs for NUREG-1150 are subjective distributions, the composite probability distributions for core damage frequency and risk must also be considered subjective.

Exhibit 29 displays the probability distributions for core damage from NUREG-1150 for each of the five reactors.

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[105] The NRC expects to complete the second phase in 1999.

[106] U.S. Nuclear Regulatory Commission, *Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants*, NUREG-1150, December 1990.

[107] The five nuclear power plants were Surry-1, Peach Bottom-2 (evaluated in WASH-1400), Zion-1 (a Westinghouse-designed four-loop PWR in a large, dry containment building, located near Chicago, Illinois), Sequoyah-1 (a Westinghouse-designed four-loop PWR in an ice condenser containment building, located near Chattanooga, Tennessee), and Grand Gulf-1 (a General Electric-designed BWR-6 reactor in a Mark II containment building, located near Vicksburg, Mississippi).

Exhibit 29 Core damage frequency results from NUREG-1150

Frequency Results	*Surry-1*	*Peach Bottom-2*	*Zion-1*	*Sequoyah-1*	*Grand Gulf-1*
Internal Events					
5%	68/10,000,000	35/100,000,000	11/100,000	12/1,000,000	17/100,000,000
Median	23/10,000,000	19/10,000,000	24/100,000	37/1,000,000	12/10,000,000
Mean	4/100,000	45/1,000,000	34/100,000	57/1,000,000	4/1,000,000
95%	13/100,000	13/100,000	84/100,000	18/100,000	12/100,000,000
External Events [a]					
5%	37/100,000,000	53/1,000,000,000	---	---	---
Median	15/1,000,000	44/10,000,000	---	---	---
Mean	12/100,000	77/1,000,000	---	---	---
5%	44/100,000	27/100,000	---	---	---

[a] The analysis of accident frequencies for Surry-1 and Peach Bottom-2 included the consideration of accidents initiated by external events (e.g., earthquakes, fires, floods). The values shown here are only for earthquakes, using the analytical protocol developed by Lawrence Livermore National Laboratory.

NUREG-1150 was considered a "risk re-baselining" study because, in comparison to earlier studies (especially WASH-1400), it incorporated then-current analytical methods, both generic and plant-specific data, and the latest computer codes. In addition, the risk calculations made use of NRC's Source Term Code Package (STCP) which included much of the available research information on severe accidents.

NUREG-1150 found that station blackout (SBO) accidents dominated the CDFs for both Surry-1 and Peach Bottom-2. Previously, in WASH-1400, loss-of-coolant accidents (LOCAs) dominated the CDFs for Surry-1, while anticipated transient without scram (ATWS) accident sequences dominated the CDFs for Peach Bottom-2. NUREG-1150 reasoned that plant modifications since WASH-1400 had changed the dominant accident initiators for these two plants. NUREG-1150 also found reductions in the CDFs for internal events both plants since WASH-1400. The study reasoned that both advances in PRA methodology and plant modifications had contributed to this reduction in the estimated CDFs from internal events. Despite the wealth of plant data and the many advances in PRA methods and codes, the results of NUREG-1150 did not lead to a general conclusion about the risk of commercial nuclear reactor operations.

In November 1990, the Advisory Committee on Reactor Safety (ACRS) commented on the conclusions presented in NUREG-1150 and the interpretation of those conclusions by the staff. The Committee stated that although a general conclusion about the risk of nuclear power operations could not be reached, NUREG-1150 did demonstrate that the risks calculated for each of the five plants analyzed (although calculated only for internal initiators) fell within the QHOs established by the Commission's 1986 Safety Goal Policy Statement. Further, the ACRS pointed that the fact that these five plants, which were supplied by different vendors and constructed at different locations by different organizations over a period of more than a decade, with different containment designs and balance of plant configurations, had CDFs that fell within the QHOs, validated NRC's regulations for implementing the reactor safety goals.[108]

In 1995, the Commission issued a final policy statement on the use of PRA methods in NRC activities so that the many potential applications of PRA methodology can be implemented in a consistent and predictable manner that promotes regulatory stability and efficiency and enhances safety.[109] The policy consists of four basic elements:

(1) The use of PRA technology should be increased in all regulatory matters in a manner that complements the NRC's traditional defense-in-depth philosophy.

(2) PRA and associated analyses should be used to reduce unnecessary conservatism associated with current regulatory requirements and guides, license commitments, and staff practices. Where appropriate, PRA should be used to support a proposal for additional regulatory requirements in accordance with the NRC's Backfit Rule. The existing rules and regulations shall be complied with unless subsequently revised.

(3) PRA evaluations in support of regulatory decisions should be as realistic as practicable and appropriate supporting data should be publicly available for review.

(4) The Commission's safety goals and subsidiary numerical objectives are to be used with consideration of uncertainties in making regulatory judgments on the need for proposing and backfitting new generic requirements on nuclear power plant licensees.

In parallel with the publication of the final policy statement, the NRC developed an implementation plan to define and organize PRA-related activities. Quarterly reports provide updates on the progress of activities in the PRA Implementation Plan. General guidance for risk-informed activities has already been developed and issued for public comment. These general documents are the draft Regulatory Guide DG-1061, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Current Licensing Basis"; its companion Standard Review Plan, "Use of Probabilistic Risk Assessment in Plant-Specific, Risk-Informed Decision-Making: General Guidance, Draft SRP Chapter 19, Revision L"; and draft NUREG-1602, "The Use of PRA in Risk-Informed Applications." Also, a series of draft application-specific regulatory guides (Regulatory Guide 1.174 through 1.178) and standard review plans addressing the topics of in-service testing, plant technical specifications and graded quality assurance have been developed and issued for public comment. Similar documents for in-service inspection are currently being prepared for comment. When approved, these documents will provide a framework for future consideration of risk-informed regulatory activities.

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[108] See ACRS letter, dated November 15, 1990, Subject: "Review of NUREG-1150, Severe Accident Risks: An Assessment For Five U.S. Nuclear Power Plants."

[109] 60 FR 42622, August 16, 1995.

2.2.2.3 Scopes of Probabilistic Risk Assessments and Tasks

Probabilistic risk assessments can be performed at many levels of scope, depending on the objectives of the study, the perspective sought in the study (i.e., whether just the core damage frequency is important or whether a measure of risk is desired), and the availability of time and staff. PRA practitioners generally describe three discrete levels of scope:

(1) Level 1 PRA: systems analysis
(2) Level 2 PRA: systems and containment analysis
(3) Level 3 PRA: systems, containment, and consequence analysis

A description of each discrete level of scope follows:

- A Level 1 PRA consists of an analysis of plant design and operation focuses on the accident sequences that could lead to a core damage, their basic causes, and their frequencies. It is comprised of three essential elements as follows: (1) the delineation of those events that, if not prevented, could result in a core damage state and the potential release of radionuclides; (2) the development of models representing the core damage events; and (3) the quantification of the models in the estimation of the core damage frequency. Although a Level 1 PRA does not investigate the frequency or the mode of containment failure or the consequences of radionuclide releases, its does produce a list of the most probable core damage sequences and insight into their causes. An analysis of such scope provides an assessment of plant safety, an assessment of design and procedural adequacy, and plant models from the perspective of preventing core damage, but it does not permit a numerical assessment of the health risk associated with the plant. Nor can the core damage sequences be differentiated into those with potentially high consequences and those with lower consequences.

- A Level 2 PRA consists of an analysis of the physical processes of the accident and the response of the containment in addition to the analysis performed in a Level 1 PRA. As well as estimating the frequencies of core damage sequences, a Level 2 PRA analyzes the time and the mode of potential containment failure as well as the inventories of radionuclides that might be released to the environment. As a result, core damage accidents can be categorized by the severity of the release. Such an analysis adds information and perspective to a Level 1 PRA, but because it does not evaluate consequences to public health and safety, a Level 2 PRA still does not provide sufficient information for a full assessment of plant risk. Nevertheless, a level 2 PRA does provide considerable insight into risk by estimating the relative frequencies of various release categories.

- A Level 3 PRA analyzes the transport of radionuclides through the environment and assesses the public-health and economic consequences of an accident in addition to performing the tasks of a Level 2 PRA. An analysis of this scope does permit an assessment of plant risk because it estimates both the consequences and the frequencies of various accident sequences. The results are generally presented in the form of a "risk curve" depicting the frequency of various consequences. Both WASH-1400 and NUREG-1150 included Level 3 PRAs.

An analysis of external events may be added to any of the three levels of PRA described above. The external events that are selected for analysis depend on the site, but they usually include events such as fires, floods, and earthquakes.

Tasks

As stated above, PRA involves developing a set of possible accident sequences and determining their outcomes. To this end, two sets of models are developed and analyzed: (1) those relating to plant systems and (2) those relating to the containment. Plant-system models generally consist of event trees, which depict initiating events and combinations of system successes and failures, and fault trees, which depict ways in which the system failures represented in the event tree can occur. These models are analyzed to assess the frequency of each accident sequence.

(1) Accident Sequence Development

The accident sequences are generally depicted at the functional or systemic level of detail. The selected functions or systems are dependent on the scope of the success criteria analysis. The success criteria determines those functions or systems, or combination of functions or systems, which if performing to defined conditions, will maintain the core in a safe condition (i.e., prevent the occurrence of a core damage state). Conversely, the success crite ria identify those combinations of functions or systems, which if not performing to specified conditions, will result in an unsafe condition (i.e., core damage). Generally, in most PRAs, the core is assumed to be in a safe condition when the consequences of the radionuclide releases from the damaged fuel would be negligible.

(2) Modeling

The containment models represent the events occurring after the accident but before the release of radioactive material from the containment. They cover the physical processes induced in the containment by each accident sequence as well as the transport and deposition of radionuclides released within the containment. The analysis examines the response of the containment to these processes, including possible failure modes, and evaluates the releases of radionuclides to the environment.

The outcome of an accident in terms of public health effects and economic losses is assessed by means of environmental transport and consequence models. These models use site-specific meteorological data (and sometime topographic data as well) to assess the transport of radionuclides from the site. Local demographic data and health effects models are then used to calculate the consequences to the surrounding population.

(3) Uncertainty Analysis

The results of the risk assessment are analyzed and interpreted to identify the plant features that are the most significant contributors to risk. An integral part of the risk assessment process is an uncertainty analysis, which involves not only uncertainties in the data but also uncertainties arising from the modeling assumptions. Analyses which depend only on the ability to separate the important from the obviously unimportant (prioritizing inspection effort, for example) may require only a general understanding of the magnitude of the uncertainty; other applications, such as decisions regarding plant backfits, may require detailed uncertainty or sensitivity analyses.

(4) Development and Interpretation of Results

The final step in performing PRAs is to integrate the data obtained in the various tasks of the analysis and to interpret the results. This integration includes, among other things, the tabulation of frequencies for accident sequences important to risk, the development of complementary cumulative distribution functions for the plant, and the development of distributions reflecting the uncertainties associated with accident sequence frequencies.

(5) Documentation of Results

The results of the PRA must be substantiated and fully documented. All major assumptions made in the analysis should be discussed. Where possible, supporting analyses in the literature should be referenced. The report should describe all tasks of the analysis in sufficient detail to permit the reader to understand how the plant systems work, to independently calculate the frequencies of the dominant accident sequences, and to calculate or at least understand the derivation of quantities that are important in the assessment of public risk, such as the magnitude of the radionuclide source terms and the interval between the awareness of an impending core damage and the start of radionuclide release to the environment.

Definition Of Some Key Risk Analysis Terms

- Core damage frequency: The frequency of combinations of initiating events, hardware failures, and human errors leading to core uncovery with reflooding of the core not imminently expected.
- Internal Initiating Events: Initiating events (e.g., transient events requiring reactor shutdown, pipe breaks) occurring during the normal power generation of a nuclear power plant.
- External initiating events: Events occurring away from the reactor site that result in accidents in the plant.
- Source term: The portion of the radionuclide inventory in the reactor at the start of an accident that is released to the environment.
- Offsite consequences: The effects of a release of radioactive material from the power plant site, measured as, for example, the number of early fatalities in the area surrounding the site and within 1 mile of the site boundary, latent cancer fatalities in the area surrounding the site and within 10 miles of the power plant, and population dose in the area surrounding the site and within 50 miles of the power plant.
- Cumulative distribution function: The cumulative distribution function gives the probability of a parameter being less than or equal to a specified value.

2.2.2.4 Assessments of the Use of PRA in Regulating Nuclear Reactor Risks

Relationship Between PRA and Defense-In-Depth

Defense-in-depth is a philosophy embodied in NRC regulations and requirements for design, manufacturing, construction, operation and maintenance, testing, training, and quality assurance. It includes prevention of initiating events, avoidance of core damage accidents, and mitigation of radioactive releases and associated health effects. Use of a defense-in-depth philosophy establishes multiple independent "barriers" preventing a radiological impact to public health and safety. These barriers are physical, procedural, and programmatic in nature. The number and type of defense-in-depth barriers were historically chosen to establish margins against the loss of plant safety functions given an initiating event and a single system failure. These margins were considered adequate on the basis of engineering judgment about the estimated consequences of a selected set of design basis event sequences. These calculations often assumed conservative values for initial plant conditions and equipment performance, to compensate for knowledge limitations of physical processes (e.g., uncertainties in engineering models and equipment response during accident conditions). For design basis event sequences, defense-in-depth margins often depend heavily upon maintaining system redundancy, independence, and diversity.

Using PRA to identify and assess plant safety issues requires understanding the defense-in-depth modeling assumptions that affect the importance of the accident sequences. A PRA accounts for system redundancy, independence, and diversity by modeling the multiple component failures that must occur to lose a safety function. Other defense-in-depth features, such as preventive maintenance, testing, training, and quality assurance, may be factors in the estimation of probabilities for equipment availability and reliability and human error. The relative importance of the various defense-in-depth features will vary for each modeled sequence, depending on whether the particular sequence involves multiple failures (making redundancy, independence, and diversity more important) or a fewer number of less probable failures (making quality assurance measures, maintenance, testing, and inspection more important).

The defense-in-depth philosophy establishes a variety of design and operational margins against the loss of safety functions. PRA attempts to identify where these margins are relatively weak (and relatively strong) and to better understand their dependency on plant design (e.g., redundancy, common-cause failure potential) and operation (e.g., maintenance/testing, operator actions). Dominant accident sequences may point to relatively weak defense-in-depth, and can provide useful risk insights only if they are understood in terms of their underlying assumptions.

Strengths and Limitations of PRA

The strengthens of PRA are its ability to improve understanding of system interactions, to link potential equipment and operator failures through the more probable accident sequences, to identify subtle but risk-important system/operator dependencies, to provide a broad information base and systematic approach for NRC and licensee decision-making (e.g., benefits or detriments of potential plant design or operational changes), and to encourage an interdisciplinary approach to managing plant risk. In addition, PRA is a particularly useful tool for comparing the risk differences resulting from alternative decisions or possible actions.

Like traditional engineering analyses, the limitations of a PRA must be considered before applying its results. These include limitations in scope (e.g., the degree to which plant structures, systems, components, operating modes, and initiating events were considered or omitted in the analysis), level of detail (e.g., number of components, component interactions, and physical processes modeled), and quality of analysis (e.g., accuracy of initiating event frequencies, basic event failure rates, and success criteria). Data often are not available on important initiating event frequencies and component reliability, and their specific applicability and usefulness may vary somewhat from plant to plant. Thus, while a comprehensive plant-specific data analysis is within the current capabilities, it sometimes is not performed because of the lack of basic failure data for a plant, as well as the costs and resource allocations required.

Uncertainty in Traditional Engineering Analysis and PRA

Uncertainty exists in the results of both traditional engineering analyses and PRA. It is addressed differently within each of these approaches. In traditional engineering practice, bounding analyses and a defense-in-depth approach are often used. PRA allows greater flexibility to assess the sources of uncertainty and their impact on the PRA results, primarily because uncertainty is treated as a probability distribution, rather than a single point estimate. This flexibility also requires greater understanding of these impacts in order to use PRA effectively. Sources of uncertainty can be categorized into three major knowledge limitation areas.

The first area of knowledge limitation is uncertainty about the values of input data. In PRA this is known as parameter uncertainty and is associated with the uncertainty surrounding initiating event frequencies (e.g., LOCA frequencies) and equipment/human failure probabilities. These can be addressed by defining each probability value as an individual probability distribution, then combining them statistically within the PRA model to provide an output probability distribution for core damage frequency. In traditional engineering the input parameters are often chosen to have the most conservative possible values, resulting in a "bounding" analysis. The probabilistic and statistical analysis methods of PRA can estimate the likelihood of any given range of outcomes, whereas traditional engineering analysis generally gives only a single result.

The second knowledge limitation is related to the degree that plant response can be predicted and accurately modeled. In PRA this is known as model uncertainty and is associated with modeling such issues as the expected amount of leakage from reactor coolant pump seals under station blackout conditions, or the required combination of equipment to successfully perform primary safety functions(i.e., success criteria). A PRA can include sensitivity studies to show the effect of using alternate plausible models. Traditional engineering analysis is often restricted to models based on physical experimentation or clearly understood physical principles (e.g., Ohm's law). The greater flexibility of PRA requires that its results be used only with a clear understanding of its more sensitive modeling assumptions. PRA practitioners generally strive for "best estimate" modeling assumptions. Use of overly conservative assumptions can potentially skew PRA results. However, conservative modeling assumptions may be used to demonstrate that certain accident sequences contribute insignificantly to risk, and to provide the basis for dropping them from further consideration.

The third knowledge limitation is related to that which is not accounted for because it is not known to exist, or is known to exist but cannot be modeled. In PRA this is known as completeness uncertainty and is the unanalyzed risk contribution from what is not modeled. This might include organizational and management influences, human errors-of-commission, or unrevealed system interaction effects. It was this type of uncertainty that primarily drove the development of defense-in-depth philosophy for traditional engineering analysis of nuclear plants.

Comprehensive uncertainty analyses of PRA models are only now being performed. The ability to perform comprehensive uncertainty analyses, including consideration of both modeling uncertainties as well as those associated with input parameters, has improved greatly. The most detailed study of this type is found in NUREG-1150. However, that method relies heavily on expert elicitation and is extremely resource intensive and time consuming. Improved, more efficient methods are needed if such analyses are to be routinely used.

All PRAs (like most traditional engineering analyses) are necessarily simplifications that must be understood for what they are, as well as for what they are not. Using PRA insights requires understanding the sources of their uncertainty and integrating this understanding with related technical and engineering knowledge of the plant, no differently than is required for using insights from other licensing documents.

2.2.2.5 Summary

The Commission has historically considered severe accident risk in making regulatory decisions. The degree to which severe accident considerations have affected the Commission's regulatory activities has increased regularly and substantially over time both in scope and in level of sophistication as improved information about severe accident risk has been developed. This includes information on the estimated frequency of severe accidents as well as their consequences. As more information has become available, additional insights have enhanced the ability of the Commission to make risk-informed decisions. The Commission's safety goal policy and regulatory analysis guidelines have played a strong role in developing requirements to address and reduce severe accident risk. Based on continuing research at the NRC and in other countries, the knowledge base on the probability and consequences of severe accidents will continue to increase. This will lead to improved understanding of severe accident phenomenology that will improve the quality of future regulatory decision making.

2.3 Availability of Private Nuclear Liability Insurance in the U.S.

2.3.1 Establishment of the Nuclear Insurance Pools

The Price-Anderson Act motivated the private insurance industry to develop a means by which nuclear power plant operators could meet their financial protection responsibilities. The insurance industry chose the "pooling" technique. Pooling provides a way to secure large amounts of insurance capacity by spreading the risk of a small number of exposure units (i.e., reactors and other nuclear-related risks) over a large number of insurance companies. The pooling concept has and continues to be successfully used to provide liability and property insurance for commercial airlines, offshore drilling rigs, and a number of other commercial enterprises with a need for large amounts of liability and/or property insurance.

The nuclear risk was and is still viewed by insurers as unique. It is a classic example of a risk which presents low frequency, high severity loss potential. There has been, in fact, only one significant nuclear accident in the U.S. since the advent of nuclear power operations - the Three Mile Island accident in 1979.

For most lines of insurance, insurers can spread their risk over a large, fairly stable premium base. This process is often referred to as "*interpersonal loss spreading*." It is particularly well suited where accidents are fairly common and the severity of loss is moderate as, for example, with automobile insurance. Knowledge of loss frequency and severity allows insurers to develop risk premiums based on statistical probabilities. This is not the case for the nuclear risk.

In the special area of nuclear insurance, the probability of a catastrophic accident is perceived as much lower than for natural disasters. Nevertheless, the theoretical "worst case" consequences are as high and perhaps higher. This, coupled with the small number of insured risks and no significant loss experience, presents unique challenges for insurers. Since actuarial assessments are not possible, insurers must rely on underwriting judgment to make decisions involving such issues as coverage and rates.

Under these circumstances, the only practical way of insuring the nuclear liability risk is to insure the nuclear industry as a whole and to spread the risk of loss over extended periods of time. This technique is sometimes called "*intertemporal loss spreading.*" It assumes that past losses will be paid, in part, out of future premiums and future losses will be paid, in part, out of premiums collected in the past and reserved for loss. The concept requires a stable supply of insurance and a stable premium base.

Historically, a distinction has prevailed within the insurance industry between two groups of insurers: those organized as stock corporations and those organized as mutual corporations. Although this distinction has lost much of its earlier relevance, the distinction was maintained in establishing the nuclear insurance pools. Stock insurers created the Nuclear Energy Liability Insurance Association (NELIA) and the Nuclear Energy Property Insurance Association (NEPIA). In 1974, NELIA and NEPIA were merged and became the Nuclear Energy Liability - Property Insurance Association (NEL-PIA). In 1978, NEL-PIA changed its name and became American Nuclear Insurers (ANI).

Mutual insurance companies created the Mutual Atomic Energy Liability Underwriters (MAELU) and the Mutual Atomic Energy Reinsurance Pool (MAERP). These organizations maintained their respective names and basic functions over the years. Together, the stock and mutual pools worked cooperatively in order to bring to bear their combined resources on the nuclear risk. However, in 1996, the Board of Directors of MAELU/ MAERP voted to end their participation in the nuclear liability program over a two year period. Effective December 31, 1997, MAELU's "fronting" role under nuclear liability policies ended, although they retain a small reinsurance role in the program which ends on December 31, 1998. (The decision on the part of the mutual insurance companies to exit the liability program is further described in Section 2.3.6 below.) ANI now writes 100% of the nuclear liability policy limit.

2.3.2 Organizational Structure and Amount of Insurance Available

ANI is an unincorporated joint underwriting association that acts as managing agent for its member companies. Its Board of Directors is comprised of representatives from 18 of its member companies. Several standing committees provide technical input in areas including underwriting, engineering, claims, and finance. The association writes nuclear liability and property insurance for nuclear facilities in the U.S. Through reinsurance arrangements with similar pools outside the U.S., it also provides insurance for foreign-based nuclear facilities. ANI operates several different underwriting syndicates: Domestic Liability, Domestic Property (primary), Supplemental Property (excess), and Foreign. In 1998, ANI's members totaled 58 of which 47 participate in the nuclear liability program.

ANI issues policies, collects premiums, remits the premiums annually to participating insurers, handles claims, and otherwise administers the program. Technically, however, ANI is not an insurance company. The insurance is provided by participating member insurance companies. Each member company participating in a particular ANI syndicate signs a declaration of participation, in which it agrees to pay a specified portion of insured losses up to a specified maximum per policy. Each insurer then receives the commensurate portion of the premiums, after allowance for expenses. The obligation of each member company is several and not joint - i.e., no member insurer is liable for the default of any other member insurer with respect to payment of insured losses.

Although there are 47 participating insurers in the liability syndicate, only 23 are listed on the policy as subscribers - i.e., as insurers. ANI has chosen to use as subscribers only those participants that are admitted as insurers in all states.[110] These 23 insurers subscribe to respective portions of the insurance under each policy issued by ANI. In case of insured loss, each subscriber is liable for its proportion of the loss up to the maximum amount of insurance per policy committed by the subscriber.

Insured losses, however, are spread among all 47 participating members in the liability syndicate. The declaration of participation, as referred to previously, provides that premiums and the responsibility for payment of insured losses are allocated among all of the participating members of the syndicate - not just the subscribing members named in the policy. This arrangement allows a member company that has not been admitted into all the states to be a participant in all of the business of the syndicate.

In 1998, ANI's members retained 31.1% of the liability exposure under each policy and ceded 68.9% to reinsurers around the world. ANI's reinsurers include similar pooling operations in more than 20 foreign countries - each comprised of their own native group of member insurance companies. This approach allows ANI to marshal the resources of the worldwide insurance community and spread the uncertainties of the risk over a very large financial base. A portion of the reinsurance ceded by ANI is currently being ceded to a utility captive insurer in the U.S. This is a recent development which is further described below.

As of January 1, 1998, ANI issued nuclear energy liability policies covering the following risk categories:

Type of Risk	Number of Policies
Operating Power Reactors	69*
Non-power Reactors, including University Reactors	27
Fuel Fabrication Facilities	6
Waste Disposal/Storage Facilities	12
Miscellaneous Nuclear Facilities, including Nuclear Laundries and Research Laboratories	55
Discontinued Facility Operations	20
Suppliers and Transporters	225

* Policies are written on a site basis, not on the basis of individual reactors.

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[110] Under the laws of the several states, unless an insurer has been licensed by a given state as an admitted insurer, the insurer may not conduct business (except by mail) in that state. A licensed insurer whose charter was issued by that state (that is, a domiciled company) is an admitted insurer in that state. For an insurer whose charter was issued by another state to be licensed (and thereby to be admitted to conduct business) in a given state, the insurer must satisfy the state as to adequacy of capitalization, degree of financial solidity, integrity of business practices, and related matters. Once an insurer has been admitted into a state, the insurer can issue policies in that state but, in so doing, becomes subject to the insurance regulatory laws of that state.

The first nuclear energy liability policy was issued on June 1, 1957 to a transporter of nuclear material. On September 1, 1958, ANI issued its first policy to a nuclear reactor operator. At that time, the maximum nuclear liability limits written by insurers was $60 million. This limit has been increased over the years and currently stands at $200 million - the level it reached in 1988 coincident with the last renewal of the Price-Anderson Act. Exhibit 30 shows the limits of liability written by insurers over time.

Exhibit 30 History of maximum nuclear liability insurance available from 1957-1998

Year	Liability limits ($ in millions)	% Increase over prior limit
1957	60	----
1966	74	23.3%
1969	82	10.8%
1972	95	15.8%
1974	110	15.8%
1975	125	13.6%
1977	140	12.0%
1979	160	14.3%
1988-Present	200	25.0%

2.3.3 Special Features of Nuclear Energy Liability Insurance

There are four basic policies written by ANI covering nuclear liability exposures in the U.S. Three of these (the Facility Form, the Secondary Financial Protection Master Policy, and the Master Worker Policy) are used by power reactor licensees to satisfy their financial protection obligations under the Price-Anderson Act. The remaining policy form (the Suppliers and Transporters Form) is issued to entities that provide products or services to nuclear facilities.

In the brief descriptions that follow, no effort is made to summarize all of the policy provisions or to state precisely any of the provisions. Such details may be found in the policies themselves. Certain provisions are highlighted and paraphrased for general information purposes only. All policy terms, conditions, and exclusions should be carefully read to determine the scope of policy coverage.

2.3.3.1 The Facility Form Policy

The Facility Form is issued to licensees of nuclear production or utilization facilities, including the operators of nuclear power reactors. This policy has been used by reactor licensees as evidence of the primary financial protection required under the Price-Anderson Act. ANI is currently able to write limits up to $200 million under this policy.

Definition of Insured

A key feature of the Facility Form policy is its broad omnibus definition of insured which, in addition to the named insured, includes any other person or organization. (The only exception to the definition of insured is the U.S. Government or any of its agencies.) This provision is very unusual. The definition of insured in conventional liability insurance is much more restrictive.

In effect, the broad definition of insured in the nuclear liability policy results in economic channeling of liability to the facility operator even though others might be primarily liable under ordinary tort law principles. The definition of insured in conventional liability insurance is much more restrictive. Channeling of liability enables insurers to maximize the resources they can place at risk for a clearly identifiable nuclear incident by eliminating the potential "stacking" of policy limits that might otherwise occur without channeling. It also offers injured parties the benefits of not having to identify the defendant with the "deepest pockets."

Policy Period and Limit

Once issued, the policy remains in effect continuously until cancelled or terminated by exhaustion of its limit of liability. The policy contains a single aggregate limit of liability for the entire policy period. The limit is automatically reduced by payments for claims or claims expense. If reduced by payments for claims or claims expense, the limit can be reinstated by insurers at their option. Reinstatements have generally been approved by ANI as a matter of course.

Defense Costs Within Limits

The expenses of investigating and defending claims or suits have been included within the limit of liability of policies issued since 1957. Their inclusion within the limit is considered by insurers to be absolutely essential to the underwriting of the nuclear risk, although this provision is not generally found in most conventional insurance policies. In the absence of this provision, insurers believe they would have no way of knowing the actual dollars committed to the nuclear risk. ANI and others believe that the inclusion of these costs within the policy limit allows insurers to obtain the largest capacity commitments its members and reinsurers are willing to provide under nuclear liability policies.

Waiver of Defenses

The policy is amended by endorsement to provide that, in the event of an Extraordinary Nuclear Occurrence (ENO), insurers and insureds waive most standard legal defenses normally available to them under state law. The effect of this provision is to create strict liability for a severe nuclear accident. To be compensated under such circumstances, claimants have to show only that the injury or damage suffered was caused by the release of nuclear material from the insured facility. Fault on the part of a particular defendant need not be established. The provision helps to assure more timely compensation of accident victims.

Scope of Coverage

The policy obligates insurers to pay on behalf of the insured all sums (up to the policy limit) which the insured becomes legally obligated to pay as "covered damages" because of "bodily injury" or "property damage," or as "covered environmental cleanup costs" because of "environmental damage." The coverage afforded by the policy applies only to claims for bodily injury, property damage, or environmental damage caused during the policy period by the "nuclear energy hazard," if such claims are brought within ten years of policy cancellation or termination. For an ENO, the ten year discovery period is extended to twenty years from the date of the occurrence. The term "nuclear energy hazard" means "the radioactive, toxic, explosive, or other hazardous properties of nuclear material...." The definition further specifies that the insurance applies only to nuclear material which (i) is at the facility described in the policy declarations, (ii) has been discharged or dispersed therefrom without intent to relinquish possession thereof to any person or organization, or (iii) is in transit to or from the insured facility. Because coverage under the policy is limited to the "nuclear energy hazard," it does not eliminate the need for separate conventional liability insurance. (See the policy for the definitions of the other terms quoted in this paragraph.)

Insured Shipments

In addition to providing coverage for liability arising out of operations at the insured facility, the policy also affords coverage for liability that arises out of an "insured shipment" as defined in the policy. In effect, this coverage provides the insured with protection against public liability claims that are brought as a result of an incident involving specified categories of nuclear material while in transit.

Additional Costs Incurred by a State or Municipality

A new coverage was added to the policy in 1994 - specifically under Facility Form policies issued to power reactor licensees. Coverage was added for the additional costs incurred by a state or municipality in responding to a severe nuclear incident. The coverage provides for a direct reimbursement for the added costs incurred in providing emergency food, shelter, transportation, or police services stemming from an evacuation of the public. The coverage applies only to those additional costs incurred by a state or municipality during the time the official evacuation order is in effect plus an additional 30 day period immediately thereafter. For coverage to apply, the evacuation would have to be (i) the result of an event that causes imminent danger of bodily injury or property damage from the nuclear energy hazard, and (ii) initiated by a state official who is authorized to do so. This coverage was added at no additional cost to policyholders.

Exclusion of Coverage for Workers Compensation and Employers Liability

The Facility Form policy excludes coverage for workers compensation and employers liability. These exclusions are consistent with the exclusion of such claims under the Price-Anderson Act. The exclusions are also intended to dovetail with the coverage available in the conventional insurance market for radiation-related workers compensation or employers liability claims. There are no standard nuclear exclusions in conventional workers compensation and employers liability policies.

2.3.3.2 The Master Worker Policy

Although claims under State or Federal workers compensation statutes are excepted by the Price-Anderson Act, radiation <u>tort</u> claims of workers - i.e., a claim alleging radiation-related bodily injury by a worker against someone other than his or her employer - are not excluded. Examples of such claims include (i) a claim by a power plant employee against a contractor or (ii) a claim by an employee of a contractor against the power plant operator. These claims are covered by ANI under the Master Worker Policy.

The Master Worker Policy provides liability coverage for the tort claims of those persons engaged in work-related activities at nuclear facilities insured by ANI. The policy is subject to a single industry-wide aggregate limit of $200 million which can be reinstated by insurers. In this sense, the policy can be thought of as a kind of group insurance contract. Coverage under the Master Worker Policy applies to individual insureds through Certificates of Insurance. The Master Worker Policy was issued effective January 1, 1998 and replaced an earlier version which expired by its terms on December 31, 1997.

Coverage under the policy applies only to bodily injury to a worker which (i) is caused by the nuclear energy hazard on or after the inception date of the Facility Form policy identified in the Certificate, (ii) is first reported to ANI on or after January 1, 1998, and (iii) is discovered and for which a written claim is made against the insured not later than one year after the end of the continuous policy period. The net effect of all this is to provide coverage retroactively to the date coverage started under a particular Facility Form policy if claims are brought within one year of cancellation or termination of the Master Worker Policy.

The separate Master Policy approach to providing coverage for worker tort claims was first introduced in 1988. It was the result of a joint effort by insureds and insurers to provide coverage for occupational exposures without diluting the protection available to the public under the Facility Form for onsite accidents that result in severe offsite consequences.

2.3.3.3 The Secondary Financial Protection Master Policy

ANI administers the secondary level of required financial protection. Section 170(b) of the Price-Anderson Act requires commercial power reactor licensees to participate in a retrospective premium program for loss in excess of primary financial protection. The program is written and administered by ANI. Should circumstances warrant, ANI would collect the retrospective premiums due and administer the disposition of the funds pursuant to the terms of its Secondary Financial Protection (SFP) Master Policy.

The SFP Master Policy provides "following form" coverage (i.e., it tracks the coverage provided under underlying policies) for "excess losses" - the latter term defined, in part, to mean all damages and claim expenses which are in excess of all sums paid or payable under all applicable primary financial protection. Coverage applies to individual insureds through Certificates of Insurance. Among other things, each Certificate identifies the named insured, the particular reactor to which the Certificate applies, and the underlying primary financial protection (i.e., the individual Facility Form policy and the Master Worker Policy) applicable to the reactor.

In the event of loss that exceeds primary limits, each participant in the SFP program is jointly and severally liable under the terms of the SFP Master Policy to pay retrospective premiums of up to $83.9 million (plus 5% should those premiums be insufficient),[111] per reactor insured, per incident subject to a maximum annual retrospective premium of $10 million per reactor, per incident.

The limit of the insurers' liability under this program is equal to the amount of retrospective premium that is actually collected from participating insureds plus a contingent liability of up to $30 million for one incident or up to $60 million for more than one incident to cover retrospective premiums that are in default. However, under the terms of a bonding agreement, ANI would expect to be reimbursed with interest for any monies it advances under the program.

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[111] Sec. 170(o)(1)(E). The Commission uses the baseline retrospective premium figure without the potential 5 percent surcharge in its statements and this report.

2.3.3.4 The Suppliers & Transporters (S&T) Policy

The S&T policy is purchased primarily by companies that provide products or services to operators of nuclear facilities in the U.S. The policy is designed to apply excess of the limit available under someone else's Facility Form policy up to a maximum combined limit of $200 million under all policies that may apply to the same occurrence. In certain very limited circumstances, the S&T can provide the insured with primary insurance protection. This might occur, for example, where liability arises out of a nuclear facility that is not covered by a Facility Form policy.

As under the Facility Form policy, coverage under the S&T policy is limited only to liability arising out of the "nuclear energy hazard." Unlike the Facility Form, coverage applies on a "single interest" basis only to the named insured. The S&T policy is not used by NRC licensees as evidence of required financial protection.

2.3.4 Premium Development Under Nuclear Energy Liability Policies

This section describes the method by which premiums are determined under nuclear liability policies.[112] The section also outlines the Industry Credit Rating Plan - a program which allows insurers to make premium refunds on the basis of industry-wide loss experience.

After more than forty years of operation, the basic risk circumstances that confronted the original underwriters continue to exist today. The loss experience of the nuclear industry remains very limited and the country-wide spread of risk is very small. In the absence of credible loss experience, underwriting judgment represents the predominant factor in the rating process. In the exercise of that judgment, underwriters strive to develop premiums that equitably reflect exposure on a comparative risk basis.

2.3.4.1 Calculation of Premiums for the Facility Form Policy

To assure consistency in the treatment of similar risks, the premiums that apply under Facility Form policies issued to reactor operators are developed based on a careful review of the following risk characteristics:

- Reactor Type (Boiling Water, Pressurized Water, Gas Cooled)
- Reactor Use (Power, Test, Training, Research, etc.)
- Reactor Size (Mwt Power Level)
- Reactor Location (Population Densities, Property Values, etc.)
- Reactor Containment (Fully[113] or Less than Fully Contained)
- Reactor Operating History (Environmental Releases, Regulatory Performance, Abnormal Occurrences, etc.)

Reactor "size" and "location" are usually the most variable factors and have the greatest impact on premium. The relative risk presented by the size of a reactor represents an evaluation of the relative exposure

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[112] This section describes the calculation of premiums for power reactors only. Other rating approaches are used to develop premiums for other facilities or for policies issued to suppliers or transporters.

[113] All power reactors are fully contained.

presented at various power levels. Assuming all other risk characteristics are equal, a larger reactor will pay a higher premium than a smaller unit.

The evaluation of the location and its environs centers around population densities and property values within a given radius of the insured facility. Factors such as seismology and meteorology are also considered. Again, assuming all other risk characteristics are equal, a reactor located in an area of high population densities and high property values will pay a higher premium than one not so situated.

In reviewing a reactor's operating history, the performance of each reactor is measured against the performance of all insured reactors. Premium credits or charges can be applied to reflect individual reactor performance.

After an evaluation of all six risk characteristics, judgment values are assigned to each characteristic. The values are then multiplied to determine a base premium for the first $1 million of policy limit. The Increased Limits Table used to develop premiums for policy limits in excess of $1 million is shown below:

Percent of base premium amount of insurance	Per $1 million*
First $ 1 Million	100%
Next $ 4 Million	50%
Next $ 5 Million	25%
Next $10 Million	12%
Next $20 Million	6%
Next $20 Million	2.5%
Over $60 Million	2%

* Subject to applicable Minimum Premiums.

In those cases in which a Facility Form policy is covering more than one reactor at the same location, a substantial discount is applied to the premium for the second or third unit. The discount is intended to reflect the fact that the policy limit is shared. The discount schedule generally used is shown below:

Amount of insurance	Discount
First $ 1 Million	20%
Next $ 4 Million	40%
Next $ 5 Million	60%
Next $10 Million	70%
Next $20 Million	75%

Liability premiums will vary from one location to another based on individual risk characteristics. In 1998, premiums for power reactors at full policy limits of $200 million ranged from $190,500 for a single unit site in a rural area to $722,500 for the largest rated reactor at a multi-unit site in an urban area. The average premium generated under policies issued to power reactor licensees was $410,000 at limits of $200 million. This resulted in an average rate per million of limit of $2,050. Up to 75% of premiums paid are refundable to insureds under the terms of the Industry Credit Rating Plan as described later in this section.

2.3.4.2 Calculation of Premiums for the Master Worker Policy

In the absence of any clearly identifiable distinguishing factors associated with tort claims of workers at different locations, the premiums applicable to individual power reactor licensees under the Master Worker Policy are "flat" premiums. In 1998, flat premiums of $23,100 per insured reactor were applied. Lesser premiums were applied for non-reactor facilities which are also insured under this policy. The total industry-wide premium produced under the Master Worker Policy in 1998 was approximately $2.7 million.

2.3.4.3 Calculation of Premiums for the Secondary Financial Protection Policy

ANI's liability under this program is limited to the retrospective premiums actually collected from participating insureds plus a contingent liability to cover possible defaults in retrospective premium obligations. A flat charge of $7,500 per insured reactor was applied in 1998 to reflect this contingent liability and to cover administrative costs associated with the program. With 110 reactors participating in the program in 1998, a total industry-wide premium of $825,000 is produced.

2.3.4.4 The Industry Credit Rating Plan (ICRP)[114]

In recognition of the lack of any actuarially significant loss data, the ICRP provides a mechanism to adjust premiums over time based on the experience of all domestic liability policyholders. All Facility Form policies, S&T policies, and the Master Worker Policy are subject to the plan. The Secondary Financial Protection Policy is not subject to the Plan.

Under the Plan, approximately 75% of each insured's basic liability premium is set aside in a reserve fund,[115] the sole purpose of which is to pay claims or claims expense. (Investment income on the fund balance is retained by member companies and reinsurers, and represents the predominant portion of their income for the risks they insure.) Reserve premiums are held for ten years, after which the unused portion is returned to policyholders. Thus, any refund due on reserve premium paid in 1998 will be made in 2008. The last refund, made in July 1997, amounted to just over $29 million - or approximately 65% of the reserve premium paid in 1987. On a total cumulative basis, insurers have returned to policyholders more than $209 million - or about 62% of total reserve premiums paid from 1957-1987. Exhibit 31 shows annual industry-wide premiums collected and refunds made by insurers since inception in 1957.

2.3.5 Nuclear Liability Claims History

Claims in many areas of liability insurance may be slow to emerge. Asbestos-related claims illustrate the delay that can occur between the time of exposure to time of manifestation of injury or disease. This latency period or "long tail" can be even more pronounced for radiation exposure and consequently for nuclear liability claims.

The nuclear liability policies issued by ANI include policy periods that are continuous unless the policy is canceled or terminated. Some of ANI's policies date back as early as 1957. The effect of having a continuous policy period is to make the discovery period for claims irrelevant unless triggered by policy cancellation or

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[114] For a more detailed description, see Gerald R. Hartman, "A Review of the Operation of the Nuclear Liability Insurance Pools, 1957-73," in *Possible Modification or Extension of the Price-Anderson Insurance and Indemnity Act*, Hearings, Joint Committee on Atomic Energy, 93rd Cong., 2d sess., Part 2 (May 9-10, 14-16, 1974).

[115] The remaining 25% of the premium is available to insurers for administrative expenses, engineering expenses, state premium taxes, brokers' commissions, and profit.

Exhibit 31 Premiums and refunds under the industry credit rating plan through January 1, 1998

	Dollars in thousands				
Year	Industry standard premium	Industry reserve premium	Industry reserve premium refund *	Industry standard premium refunded	Industry reserve premium refunded
1957	$70	$48	$46	65.7%	95.8%
1958	357	243	241	67.5%	99.2%
1959	715	492	478	66.9%	97.2%
1960	1,167	814	785	67.3%	96.4%
1961	1,496	1,048	1,018	68.0%	97.1%
1962	1,735	1,217	1,167	67.3%	95.9%
1963	2,048	1,450	1,393	68.0%	96.1%
1964	2,085	1,472	1,434	68.8%	97.4%
1965	2,130	1,501	1,468	68.9%	97.8%
1966	2,408	1,703	1,682	69.9%	98.8%
1967	2,775	1,972	1,951	70.3%	98.9%
1968	3,054	2,179	2,157	70.6%	99.0%
1969	3,382	2,420	2,055	60.8%	84.9%
1970	4,228	3,047	850	20.1%	27.9%
1971	5,726	4,169	1,653	28.9%	39.6%
1972	6,553	4,784	2,302	35.1%	48.1%
1973	8,389	6,163	3,250	38.7%	52.7%
1974	11,494	8,484	5,014	43.6%	59.1%
1975	14,194	10,516	4,946	34.8%	47.0%
1976	15,351	11,373	4,239	27.6%	37.3%
1977	17,533	13,008	6,752	38.5%	51.9%
1978	19,186	14,233	7,669	40.0%	53.9%
1979	20,316	15,070	9,077	44.7%	60.2%
1980	23,002	17,080	10,702	46.5%	62.7%
1981	27,521	20,454	13,637	49.6%	66.7%
1982	30,256	22,501	15,313	50.6%	68.1%
1983	32,389	24,101	16,969	52.4%	70.4%
1984	35,543	26,463	16,638	46.8%	62.9%
1985	42,054	31,376	19,293	45.9%	61.5%
1986	55,402	41,465	26,074	47.1%	62.9%
1987	60,029	44,969	29,044	48.4%	64.6%
1988	73,513	55,183	-	-	-
1989	71,147	53,405	-	-	-
1990	75,489	56,677	-	-	-
1991	61,152	45,649	-	-	-
1992	52,836	39,362	-	-	-
1993	52,845	39,407	-	-	-
1994	52,767	39,465	-	-	-
1995	53,663	40.043	-	-	-
1996	53,407	39,931	-	-	-
1997	45,084	33,714	-	-	-
1998	41,092	30,464	-	-	-
Total	$1,085,583	$809,115	$209,297	19.3%	25.9%

* Refund made ten years after the premium for a given calendar year is paid, thus, the refund on reserve premiums paid in 1987 was made in 1997.

termination. Given the coverage afforded by the policy and the long latency period associated with radiation exposure, it is possible for claims to be filed against insurers many years after the alleged exposure. For this reason, claims experience to date may not necessarily be indicative of what lies ahead. The importance of the ICRP reserve fund is reinforced by the "long tail" nature of nuclear liability claims.

2.3.5.1 Summary of Claims Data

Exhibit 32 summarizes claims experience in nuclear liability insurance for 195 alleged nuclear incidents reported from inception in 1957 through December 31, 1997. Since ANI provides nuclear liability insurance for indemnified and non-indemnified facilities and suppliers to such facilities, the claims experience in Exhibit 32 includes loss and expense payments made on behalf of all insureds. The bulk of the loss and expense payments shown are related to indemnified nuclear facilities. Total insurance payments of $131 million for indemnity and defense costs have made during this period. Of this amount, $70 million has been paid in connection with the TMI accident that occurred in 1979. The following observations and commentary trace the evolution of these incidents over four decades:

- Discrete events clearly identifiable in terms of time and location were the focus of claims during the early decades. However, in more recent years, claim activity often flows from incidents with little identity except for the appearance of latent injuries. The kind of incident is usually described as the alleged effect (e.g., somatic, psychosomatic, genetic) from exposure to radiation at low levels over years of employment at nuclear facilities or residency in surrounding communities.

- In some instances, information was so limited that it was impossible to identify a "date of incident" apart from the latent injury demonstrated at a subsequent point in time. Therefore, the date of receipt of notice of claim was substituted as the only relevant piece of information.

- The nature and scope of property damage liability incidents have shifted dramatically. Early events in nuclear fuel cycle operations were largely triggered by damages of one sort or another to shipping containers used to transport nuclear material. Recent liability claims for property damage have focused not so much on discrete events as on alleged "stigmatization" of property because of its proximity to nuclear facilities. In these cases, the measure of damage is alleged to be the diminution in value of property unrelated to any invasion or presence of contaminants.

- Because of the very limited incidence of alleged radiation-induced physical harm preceding the TMI accident, insurers not only monitored incidents of interest (primarily, workers compensation proceedings arising out of occupational exposure), but recorded them as potentially giving rise to public liability claims. The reasoning was that workers compensation activity might lead to personal injury lawsuits for compensatory damages. However, for the period of 1957-1979, such lawsuits did not materialize. Therefore, the practice of reporting incidents in the absence of notice of intent to pursue a claim has been discontinued.

Exhibit 32 Summary of claims activities nuclear energy liability policies 1957 through 1997

Inc. no.	Date of incident or receipt of claim	Closed	Active	Prop. damage	Bodily injury	Loss of life	Policy type	In suit	No coverage	Paid indemnity	Paid expense	Paid total
1	06/15/62	X		X			S&T			1,183.00	101.52	1,284.52
2	01/04/63	X		X			FACILITY			3,519.57	0.00	3,519.57
3	01/17/63	X		X	X	X	FACILITY	X		300,000.00	28,763.48	328,763.48
4	06/27/62	X		X			FACILITY			0.00	0.00	0.00
5	05/01/64	X		X			S&T	X		1,250.00	0.00	1,250.00
6	07/14/64	X			X	X	FACILITY	X		70,000.00	6,403.25	76,403.25
7	06/01/65	X			X		FACILITY			0.00	0.00	0.00
8	02/28/66	X		X			FACILITY			183.00	80.13	263.13
9	05/01/66	X		X			FACILITY			895.85	63.93	959.78
10	01/26/65	X		X	X		FACILITY	X		1,500.00	11,012.36	12,512.36
11	08/08/67	X			X		FACILITY		X	0.00	0.00	0.00
12	09/09/68	X		X	X		FACILITY			0.00	1,460.41	1,460.41
13	11/13/68	X		X	X		FACILITY			0.00	2,631.21	2,631.21
14	06/13/63	X		X			FACILITY		X	0.00	105.58	105.58
15	05/01/66	X			X		FACILITY	X		0.00	1,962.07	1,962.07
16	09/20/69	X			X		S&T	X		0.00	54,838.68	54,838.68
17	09/20/69	X			X		S&T	X		1,275.00	5,215.09	6,490.09
18	05/16/72	X		X	X		FACILITY			25,099.26	10,199.67	35,298.93
19	05/15/72	X		X			S&T			5,077.25	33.86	5,111.11
20	08/17/72	X			X	X	S&T	X		10,000.00	18,850.90	28,850.90
21	05/30/72	X			X	X	S&T	X		6,500.00	11,520.42	18,020.42
22	05/05/72	X			X		FACILITY			0.00	0.00	0.00
23	05/25/73	X		X	X		FACILITY			0.00	0.00	0.00
24	12/21/72	X		X	X		FACILITY			0.00	0.00	0.00
25	03/12/74	X		X			FACILITY			0.00	0.00	0.00
26	11/05/74	X		X	X	X	FACILITY	X	X	595,632.12	1,099,189.78	1,694,821.90
27	03/03/75	X			X		FACILITY			0.00	450.00	450.00
28	10/01/56	X			X	X	S&T	X	X	0.00	0.00	0.00
29	05/01/59	X			X	X	S&T	X	X	0.00	0.00	0.00
30	01/01/69	X			X		FACILITY	X		0.00	7,002.98	7,002.98
31	04/23/76	X			X		FACILITY	X		0.00	4,683.11	4,683.11

Exhibit 32 Summary of claims activities nuclear energy liability policies 1957 through 1997 (continued)

Inc. no.	Date of incident or receipt of claim	Closed	Active	Prop. damage	Bodily injury	Loss of life	Policy type	In suit	No coverage	Paid indemnity	Paid expense	Paid total
32	10/01/75	X			X		FACILITY	X		0.00	11,972.91	11,972.91
33	11/23/77	X			X		FACILITY	X		385,000.00	205,104.56	590,104.56
34	01/24/78	X		X			FACILITY	X		0.00	6,839.17	6,839.17
35	06/01/77	X			X		FACILITY	X		0.00	1,886.88	1,886.88
36	06/01/77	X			X		FACILITY			0.00	0.00	0.00
37	02/01/78	X			X		FACILITY			0.00	0.00	0.00
38	09/01/75	X			X	X	FACILITY	X		1,000.00	27,217.31	28,217.31
39	06/21/77	X			X		FACILITY			0.00	217.02	217.02
40	03/28/79		X	X*	X**	X	FACILITY	X	X	41,657,828.24	28,011,684.62	69,669,512.86
41	10/10/71	X			X		FACILITY	X		0.00	3,636.21	3,636.21
42	01/01/72	X		X	X		FACILITY	X	X	0.00	83,878.30	83,878.30
43	08/12/76	X			X		FACILITY	X		26,500.00	21,671.23	48,171.23
44	02/11/76	X			X	X	FACILITY	X		0.00	5,249.68	5,249.68
45	01/01/73	X			X		FACILITY	X		0.00	95,263.86	95,263.86
46	07/01/78	X			X		FACILITY	X		15,000.00	38,579.36	53,579.36
47	01/01/79		X	X			FACILITY, S&T		X	0.00	0.00	0.00
48	01/01/60	X			X	X	S&T			0.00	0.00	0.00
49	05/01/68	X			X	X	FACILITY			0.00	0.00	0.00
50	04/04/79	X			X		FACILITY			0.00	0.00	0.00
51	01/01/57	X			X	X	S&T	X		0.00	0.00	0.00
52	01/01/71	X			X		FACILITY			0.00	0.00	0.00
53	01/01/79	X			X		FACILITY		X	0.00	0.00	0.00
54	01/01/79	X			X	X	FACILITY	X	X	0.00	0.00	0.00
55	04/05/79	X			X		FACILITY			0.00	0.00	0.00
56	06/01/77	X			X		FACILITY			0.00	0.00	0.00
57	02/01/78	X			X		FACILITY	X		0.00	0.00	0.00
58	10/03/77	X			X		FACILITY			0.00	0.00	0.00
59	01/19/78	X			X		FACILITY			0.00	629.24	629.24
60	08/19/79	X			X	X	FACILITY			0.00	0.00	0.00
61	01/01/76	X			X	X	FACILITY			0.00	0.00	0.00
62	01/01/76	X		X	X		FACILITY	X		0.00	22,812.54	22,812.54

Exhibit 32 Summary of claims activities nuclear energy liability policies 1957 through 1997 (continued)

Inc. no.	Date of incident or receipt of claim	Closed	Active	Prop. damage	Bodily injury	Loss of life	Policy type	In suit	No coverage	Paid indemnity	Paid expense	Paid total
63	10/13/77	X			X		FACILITY	X		14,400.00	75,931.10	90,331.10
64	10/23/78	X			X		FACILITY	X		7,500.00	6,729.69	14,229.69
65	01/01/79	X			X		FACILITY			0.00	200.00	200.00
66	05/01/75	X			X	X	S&T	X	X	0.00	0.00	0.00
67	01/26/76	X			X*		FACILITY	X	X	0.00	95,429.77	95,429.77
68	04/06/79	X			X		FACILITY	X		0.00	5,881.88	5,881.88
69	01/01/77	X					FACILITY	X		0.00	48,853.32	48,853.32
70	03/23/79	X			X		FACILITY	X		0.00	150,800.47	150,800.47
71	05/21/77	X			X		FACILITY	X		1,500.00	4,414.98	5,914.98
72	10/06/76	X			X		FACILITY			0.00	0.00	0.00
73	01/01/71	X			X		FACILITY			0.00	0.00	0.00
74	12/03/80	X						X	X	0.00	0.00	0.00
75	05/27/79	X			X		FACILITY			0.00	0.00	0.00
76	12/05/80	X						X	X	0.00	0.00	0.00
77	01/01/74	X			X		FACILITY			0.00	0.00	0.00
78	01/01/80	X						X	X	0.00	0.00	0.00
79	01/01/63	X			X	X	S&T	X	X	0.00	0.00	0.00
80	11/30/66	X			X		FACILITY	X	X	0.00	0.00	0.00
81	03/17/81	X			X		FACILITY			0.00	0.00	0.00
82	11/26/79	X			X			X		0.00	725.70	725.70
83	03/05/81	X			X		FACILITY	X		37,500.00	142,087.69	179,587.69
84	11/20/78	X			X		FACILITY	X		0.00	1,484.50	1,484.50
85	01/01/66	X			X	X	FACILITY	X	X	0.00	0.00	0.00
86	07/24/79	X			X		S&T		X	0.00	0.00	0.00
87	09/19/76	X		X	X		S&T	X	X	0.00	0.00	0.00
88	03/19/81	X			X		FACILITY			0.00	0.00	0.00
89	01/25/82	X		X*			FACILITY	X	X	0.00	291,618.88	291,618.88
90	05/01/80	X		X			FACILITY	X		237,500.00	376,486.70	613,986.70
91	09/07/81	X			X		S&T			0.00	91.00	91.00
92	06/09/82	X			X	X	FACILITY	X		0.00	15,328.34	15,328.34
93	03/01/77	X			X	X	FACILITY	X		0.00	46,112.17	46,112.17

Exhibit 32 Summary of claims activities nuclear energy liability policies 1957 through 1997 (continued)

Inc. no.	Date of incident or receipt of claim	Closed	Active	Prop. damage	Bodily injury	Loss of life	Policy type	In suit	No coverage	Paid indemnity	Paid expense	Paid total
94	01/01/76	X			X	X	FACILITY	X		0.00	77,195.72	77,195.72
95	01/01/58	X			X	X	FACILITY	X		0.00	3,558.19	3,558.19
96	09/01/82	X		X			FACILITY			136,409.71	0.00	136,409.71
97	01/01/66	X			X	X	S&T	X	X	0.00	21,092.43	21,092.43
98	12/04/80	X			X		FACILITY	X		0.00	36,732.97	36,732.97
99	02/25/80	X			X		FACILITY	X		0.00	478,623.44	478,623.44
100	02/15/81	X			X	X	FACILITY	X		0.00	243,153.43	243.153.43
101	04/04/81	X			X		FACILITY	X		0.00	462,402.82	462,402.82
102	03/04/82	X			X		FACILITY	X		25,000.00	188,475.00	213,475.00
103	10/09/80	X			X		S&T	X	X	0.00	571.12	571.12
104	01/19/82	X			X		FACILITY	X	X	8,500.00	3,238.99	11,738.99
105	07/30/83	X		X			FACILITY		X	120,000.00	0.00	120,000.00
106	04/08/77	X		X			S&T	X	X	720,661.25	279,338.75	1,000,000.00
107	01/01/57	X		X			S&T	X	X	0.00	0.00	0.00
108	10/01/83	X			X		FACILITY	X		0.00	1,413,215.00	1,413,215.00
109	09/01/74	X			X		FACILITY	X		0.00	27,711.77	27,711.77
110	06/01/76	X			X		FACILITY	X		0.00	3,286.04	3,286.04
111	03/21/81	X			X		FACILITY	X		0.00	23,390.62	23,390.62
112	01/01/77	X			X	X	FACILITY	X		0.00	2,695,522.86	2,695,522.86
113	01/01/81	X		X**	X**		FACILITY	X		500,000.00	9,786,544.01	10,286,544.01
114	12/01/80	X			X		FACILITY	X		0.00	365,515.23	365,515.23
115	04/16/83	X			X		FACILITY	X		0.00	3,109.04	3,109.04
116	05/04/85	X			X		FACILITY	X		0.00	658,498.89	658,498.89
117	01/01/83	X			X	X	FACILITY	X		0.00	362,064.48	362,064.48
118	06/15/84	X			X		FACILITY	X		0.00	215,252.96	215,252.96
119	01/01/83	X		X	X		FACILITY	X		0.00	42,917.63	42,917.63
120	01/01/78	X		X			FACILITY, S&T	X	X	0.00	118,355.76	118,355.76
121	01/01/86		X	X			FACILITY, S&T	X	X	0.00	5,195.46	5,195.46
122	01/01/83	X			X		FACILITY	X		0.00	244,501.06	244,501.06
123	02/23/84	X			X		FACILITY	X		0.00	132,816.88	132,816.88
124	01/08/86	X			X		FACILITY	X		0.00	4,282.71	4,282.71

Exhibit 32 Summary of claims activities nuclear energy liability policies 1957 through 1997 (continued)

Inc. no.	Date of incident or receipt of claim	Closed	Active	Prop. damage	Bodily injury	Loss of life	Policy type	In suit	No coverage	Paid indemnity	Paid expense	Paid total
125	09/06/84	X			X		FACILITY	X		0.00	74,779.66	74,779.66
126	01/01/84	X			X		FACILITY	X		0.00	89,083.51	89,083.51
127	01/01/84	X			X		FACILITY	X		0.00	170,020.98	170,020.98
128	03/01/85		X		X		FACILITY	X	X	0.00	1,644,833.70	1,644,883.70
129	11/22/87	X		X			FACILITY			61,139.11	3,284.75	64,423.86
130	12/31/87	X		X			FACILITY			78,718.47	13,251.34	91,969.81
131	02/10/85	X			X		FACILITY	X		0.00	60,869.31	60,869.31
132	01/01/79	X			X		FACILITY	X		0.00	45,669.59	45,669.59
133	01/01/85	X			X	X	FACILITY	X		0.00	13,563.64	13,563.64
134	09/25/87	X			X		FACILITY	X		0.00	66,535.84	66,535.84
135	11/01/87	X		X			FACILITY			12,217.68	0.00	12,217.68
136	05/21/87	X			X		FACILITY	X		0.00	554,310.15	554,310.15
137	01/01/80	X			X	X	FACILITY	X		0.00	306,879.54	306,879.54
138	09/28/89	X		X**	X**	X	S&T	X		0.00	4,288,401.04	4,288,401.04
139	04/11/88	X			X		FACILITY	X	X	0.00	27,792.61	27,792.61
140	10/24/89	X		X			S&T		X	0.00	0.00	0.00
141	02/09/90	X		X			FACILITY			0.00	18,337.00	18,337.00
142	03/24/89	X			X		MW	X		0.00	292,173.36	292,173.36
143	01/01/74	X			X		FACILITY	X		0.00	42,395.38	42,395.38
144	06/13/94		X	X**	X**	X	FACILITY	X		0.00	7,940,477.35	7,940,477.35
145	01/01/73	X					FACILITY		X	0.00	0.00	0.00
146	09/01/90	X			X	X	S&T	X	X	0.00	0.00	0.00
147	08/27/91	X		X			FACILITY			219,629.70	3.00	219,632.70
148	01/01/90	X		X			FACILITY		X	0.00	0.00	0.00
149	06/03/89	X			X	X	FACILITY	X	X	0.00	28,116.03	28,116.03
150	09/25/89	X			X		FACILITY	X		0.00	426,884.49	426,884.49
151	01/01/72		X		X	X	FACILITY	X		0.00	1,687,090.24	1,687,090.24
152	03/26/90		X		X		FACILITY	X	X	0.00	0.00	0.00
153	04/06/90	X			X		S&T	X	X	0.00	177,040.68	177,040.68
154	03/04/92	X		X			FACILITY		X	0.00	0.00	0.00
155	01/01/72	X			X		FACILITY	X		0.00	135,947.54	135,947.54

Exhibit 32 Summary of claims activities nuclear energy liability policies 1957 through 1997 (continued)

Inc. no.	Date of incident or receipt of claim	Closed	Active	Prop. damage	Bodily injury	Loss of life	Policy type	In suit	No coverage	Paid indemnity	Paid expense	Paid total
156	01/01/74	X			X		FACILITY	X		0.00	125,166.79	125,166.79
157	08/28/92	X			X	X	FACILITY	X		0.00	16,279.35	16,279.35
158	06/12/91	X		X	X		S&T	X	X	0.00	0.00	0.00
159	10/21/91	X			X		FACILITY, MW		X	0.00	44,486.36	44,486.36
160	02/28/90	X			X		MW	X		0.00	41,600.16	41,600.16
161	07/05/90	X			X		FACILITY	X		0.00	432,116.14	432,116.14
162	10/25/89	X			X		FACILITY	X		0.00	148,740.40	148,740.40
163	07/01/85		X		X		FACILITY	X		0.00	2,680,165.59	2,680,165.59
164	08/20/90	X			X		S&T	X		0.00	13,125.95	13,125.95
165	01/01/82	X			X		FACILITY	X		0.00	57,438.89	57,438.89
166	01/01/73		X		X	X	FACILITY	X	X	0.00	133,104.28	133,104.28
167	01/01/72	X			X		FACILITY	X		0.00	19,024.27	19,024.27
168	09/01/59		X		X	X	FACILITY	X	X	0.00	262,693.39	262,693.39
169	06/17/85		X		X	X	FACILITY	X	X	0.00	1,079,387.62	1,079,387.62
170	02/01/85	X			X		FACILITY	X		0.00	6,949,568.52	6,949,568.52
171	10/01/74	X			X		FACILITY	X	X	0.00	8,453.86	8,453.86
172	10/01/81	X			X		FACILITY	X		0.00	21,897.78	21,897.78
173	01/01/79	X			X		FACILITY	X		0.00	250,000.00	250,000.00
174	01/01/73		X		X	X	FACILITY	X	X	0.00	507,355.60	507,355.60
175	04/01/90	X			X		MW	X		0.00	234,285.83	234,285.83
176	10/11/94	X			X		FACILITY	X		0.00	190,741.66	190,741.66
177	01/01/83	X			X		FACILITY	X		0.00	17,927.64	17,927.64
178	01/01/83	X			X		FACILITY	X	X	0.00	38,241.20	38,241.20
179	01/01/82		X		X	X	FACILITY	X	X	0.00	132,060.39	132,060.39
180	10/07/94		X		X		MW	X		0.00	538,386.88	538,386.88
181	01/01/82		X		X	X	FACILITY	X	X	0.00	103,998.81	103,998.81
182	01/01/66		X		X		FACILITY	X		0.00	343,297.45	343,297.45
183	01/01/81		X		X	X	FACILITY	X		0.00	2,143,695.85	2,143,695.85
184	01/01/84		X		X		FACILITY	X		0.00	387,929.52	387,929.52
185	01/01/60		X		X***	X	FACILITY	X		0.00	224,194.64	224,194.64
186	01/01/83	X			X	X	FACILITY	X		0.00	2,535.48	2,535.48

Exhibit 32 Summary of claims activities nuclear energy liability policies 1957 through 1997 (continued)

Inc. no.	Date of incident or receipt of claim	Closed	Active	Prop. damage	Bodily injury	Loss of life	Policy type	In suit	No coverage	Paid indemnity	Paid expense	Paid total
187	01/01/85	X			X		FACILITY	X		0.00	11,071.42	11,071.42
188	01/01/63		X	X	X		FACILITY	X	X	0.00	488,930.57	488,930.57
189	06/24/96		X	X			FACILITY	X	X	0.00	0.00	0.00
190	12/20/96		X	X			FACILITY	X	X	0.00	0.00	0.00
191	03/18/97		X	X	X**	X**	FACILITY	X	X	0.00	1,121,164.83	1,124,164.83
192	01/01/79		X		X		FACILITY	X	X	0.00	32,649.25	32,649.25
193	06/18/97		X		X		MW			0.00	0.00	0.00
194	01/01/89		X	X			FACILITY		X	0.00	0.00	0.00
195	10/27/97		X	X	X		FACILITY	X	X	0.00	0.00	0.00
									Total	45,288,119.21	85,872,457.87	131,160,577.08

* Class action for pure economic loss unassociated with physical harm.

** Class action for physical harm to persons or property.

*** Class action for alleged non-consensual human radiation experiments.

- Personal injury lawsuits multiplied after 1979. The catalysts for the increase may have been the highly publicized TMI accident and the jury verdict and punitive damage award in Silkwood v. Kerr McGee. With the legal community's heightened awareness of the radiation risk and potential for large verdicts, legal transaction costs increased too.

- Class action lawsuits increased after the TMI accident, possibly as a device to satisfy the public demand for broader accountability.

- The class action incidents designated in Exhibit 32 by the asterisk (*) are for pure economic loss unassociated with physical harm. Those designated by the double asterisk (**) are mass tort actions for physical harm to persons and property. Finally, the incident designated by the triple asterisk (***) is a mass tort case arising out of the alleged non-consensual human radiation experiments, which have been declassified by the federal government in recent years.

- Incidents identified in Exhibit 32 for which no coverage under nuclear liability policies existed, are those in which the entire claim or a portion of the claim clearly fell outside the scope of coverage. The reasons vary, but generally fit into one or more categories: (i) "public liability," as defined, is not the subject of the claim (e.g., the claim may be for workers compensation or for damage to the insured's own facility); (ii) the nuclear energy hazard is not the subject of the claim (e.g., the claim may involve exposure to non-"nuclear material" as defined); (iii) the claim does not seek "damages" within the meaning of the insuring agreement (e.g., the action may be for injunctive or equitable relief); (iv) the claim is subject to federal indemnity; or (v) the policy was canceled and the "discovery period" expired.

- There has been no relationship between the amount of radiation exposure on which a claim is based and the expense necessary to investigate and defend it.

- Expense is especially driven by lawsuits that seek class treatment for both compensatory and punitive damages. In these cases, the drain on resources provided under the Price-Anderson compensation system is dramatic. To date, the cost of handling eight class actions approaches $50 million. In contrast, the total expense incurred to respond to all 195 claims is about $86 million. Thus, the current cost for these class actions alone represents about 60% of total expense.

- Overall, paid legal transaction expense outstrips paid loss (indemnity) by a margin of nearly two to one. This shift in allocation of financial protection commenced with the TMI personal injury claims that were first filed in 1979. More representative of the long-term trend, however, is the ratio of paid expense to paid loss (nearly 23 to 1) after subtracting the early TMI indemnity payments, which dominate the loss experience to date.

- Insurers and others believe that loss experience to date demonstrates the importance of incorporating defense costs within the policy limits.

2.3.5.2 Status of TMI Claims

The insurance pools responded rapidly to the TMI accident. They established an office within 24 hours to pay claims for the living expenses of the families with pregnant women and pre-school age children who evacuated the five-mile area around the TMI-2 reactor, at the Governor's suggestion. A total of approximately $1.4 million in claims for living expenses and lost wages was eventually paid to some 3,170 claimants.

On August 17, 1979, the NRC directed that a panel composed of principal staff be formed to assemble relevant information to determine whether or not the accident at TMI-2 constituted an ENO. As directed by the Commission, the panel made its findings by applying the explicit criteria set forth in the Commission's regulations, 10 CFR 140.84 and 140.85. The panel found that the first criterion, pertaining to whether the accident caused a discharge of radioactive material or levels of radiation offsite as defined in the regulations, had not been met. It further found that there was insufficient information to support any definitive finding as to whether or not the second criterion, relating to damage to persons or property offsite, as defined in the regulations, had been met. Because the panel could not find that both criteria had been met, it recommended that the Commission determine that the TMI-2 accident was not an ENO. The Commission accepted this recommendation and on April 16, 1980 determined that the TMI accident did not constitute an ENO.

Following the TMI-2 accident, numerous lawsuits were filed in State and Federal courts in Pennsylvania, alleging various injuries and property damages. These suits were consolidated into one suit before the Federal District Court in Harrisburg. In early September 1981, a Settlement Agreement was signed in the TMI-2 class action litigation. Under the terms of the agreement, the insurance pools paid into a Court managed fund $20 million for economic harm to businesses and individuals within 25 miles of TMI-2, and $5 million for the establishment of a Public Health Fund in the TMI-2 area.

The TMI claim appears as Incident No. 40 in Exhibit 32. ANI has paid a total of $41,657,828 for indemnity (60%) and $28,011,685 (40%) for expenses in investigating and defending TMI-related claims. The last indemnity payment of any significance was made in 1985.

In the 1985-1986 time frame - or some six years after the accident - approximately 2,200 personal injury claims were filed against the site operator and others. On June 7, 1996, summary judgment in favor of the defendants was granted by the Federal District Court for the Middle District of Pennsylvania. The plaintiffs have appealed the decision to the Third Circuit. A decision on the appeal is expected in 1998.

2.3.5.3 ANI's Emergency Response Capability

A severe nuclear incident is likely to result in an evacuation of the public in areas surrounding the affected facility. In those circumstances, the need for immediate emergency financial assistance for those so affected can be anticipated. The nuclear insurance industry has established emergency response procedures to enable it to respond quickly to emergency situations. Member insurance companies are required to furnish emergency claim personnel who can be sent to temporary claim offices in the event a nuclear incident results in an evacuation of the public.

In the one instance in which this process was initiated following the TMI accident in 1979, a claim office was opened within twenty-four hours of the Governor's advisory to certain individuals to evacuate a five mile radius of the site. Families affected by the advisory were advanced funds for their immediate out-of-pocket living expenses for food, lodging, transportation, and emergency medical care. The financial loss caused by the interruption of business and loss of wages was compensated later. The process worked as planned and helped to alleviate some of the fear and dislocation of those affected by the accident.

2.3.6 Major Changes Affecting ANI and its Insureds

There have been some significant developments affecting ANI and its policyholders since the last renewal of the Price-Anderson Act in 1988. The downward pressure on nuclear liability premiums is one such development.

As is indicated in Exhibit 31, total industry-wide premiums reached a high point in 1990 at \$75.5 million. Up to 75% of that premium becomes refundable in the year 2000 under the terms of the ICRP. (See Section 5.e) In 1991, following discussions with policyholders during the preceding year, ANI and MAELU/MAERP - ANI's mutual insurance company counterpart - agreed to reduce nuclear liability premiums by 20% and by an additional 15% in 1992. These reductions were applied to all Facility Form policies issued to power reactor licensees.

In 1995, ANI and MAELU/MAERP were asked to further reduce premiums by capping the ICRP reserve fund balance. Since the fund balance exceeded the targeted cap of two full limit losses, premium reductions would be necessary as a means of reducing new contributions to the fund, in turn lowering the balance. In addition, policyholders expressed a desire to share in the exposure by having Nuclear Electric Insurance Limited (NEIL)[116] assume a percentage share of the liability risk. It was argued that this would serve to further reduce costs since ANI would have to cede a share of the premium and related income to NEIL along with the risk.

In general terms, the arguments made for premium reductions were that loss experience has been good and loss reserve funding is sufficient to cover the remote catastrophic accident. While the Commission believes that these observations are valid, the Commission also agrees with insurers that experience to date is not necessarily predictive of the future — particularly with "long tail" exposures. Moreover, while reserve funding is adequate to cover a severe accident at current policy limits of \$200 million, nuclear liability claims can be filed in the absence of an identifiable event or even any documented radiation exposure. Such claims can involve different facilities and therefore different policies.

The proposed cession of a share of the nuclear liability risk to NEIL was also of some concern to both insurers and the Commission. It was felt by Commission staff that nuclear utilities through NEIL had already undertaken significant risk by, in effect, self-insuring the property risk. And, in the event of a severe nuclear accident resulting in public liability claims, there would undoubtedly also be significant onsite property damage for which NEIL's resources would be required.

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[116] NEIL is a nuclear utility mutual (or "captive") insurance company incorporated with limited liability under the laws of Bermuda. It has a branch office in the state of Delaware where it is licensed to do business. The company writes first party property insurance as well as coverage for replacement power and business interruption at nuclear reactors and other nuclear facilities.

These concerns notwithstanding, the decision was made to begin the process of capping the ICRP loss reserve fund by reducing premiums up to 15% annually until the target balance is achieved. If the balance falls below the target, premiums will be increased up to 10% annually until the balance is re-achieved.

The first such premium reduction under this agreement was made in 1997 when premiums under all Facility Form policies issued to power reactor licensees were reduced by 15%. Premiums were reduced by another 15% in 1998, but the reduction was partially offset by premium for the new Master Worker Policy. A third reduction is anticipated in 1999, although its extent is not known as this is written.

ANI also agreed to cede reinsurance shares of the liability program to NEIL over a three year period. A 15% share was ceded in 1997, and an additional 15% share was ceded in 1998. A third and final 15% share is slated for cession in 1999. At that point, NEIL will have a maximum reinsurance participation in the liability program of 45%. In effect, NEIL will be responsible to pay up to $90 million under each nuclear liability policy written by ANI beginning in 1999 — assuming current total policy limits of $200 million.

Primarily as a result of these changes, the mutual insurance companies represented by MAELU/MAERP voted to end their more than forty years of participation in the nuclear liability program. Mutual insurers felt that significant price concessions had been made in prior years and that further reductions would not be in their interests. They also expressed concern over the cession of business to a utility captive for the reasons noted above. The MAELU/MAERP companies made clear that their withdrawal was not in any way related to their view of nuclear power as an insurable risk, but simply reflected a business-based decision.

2.3.7 Maximum Liability Insurance Available

The Price-Anderson Act requires power reactor licensees to maintain primary financial protection equal to the maximum amount of liability insurance available from private sources and to participate in a second level industry retrospective rating plan. As noted in several places in this report, ANI currently writes primary nuclear liability limits up to $200 million and administers the Secondary Financial Protection program.

The requirement in the Act for power reactor licensees to show evidence of financial protection in an amount equal to the maximum liability insurance available from private sources is considered by insurers to be essential in terms of enabling insurers to develop and sustain quality insurance capacity from worldwide insurance sources. Evidence of this lies in the stability of limits, price, and coverage which insurers have provided in what is viewed as a very special line of business.

Indeed, after the TMI accident in 1979, limits actually increased from $140 to $160 million and prices rose only modestly. Perhaps more significantly, the normal ups and downs (or market cycles) typical in the insurance business have not affected the nuclear insurance market. In the mid-1980's, for example, when liability insurance became unavailable at almost any price for many commercial insurance buyers, nuclear liability insurers continued to provide a stable market for their limited customer base.

The stable market provided by insurers in this special line of business is a reflection of the will of Congress to preserve the nuclear option, and specifically, the Act's requirement for financial protection equal to the maximum liability insurance available from private sources. Without this provision, it is doubtful that limits at the levels written could have been sustained without interruption or fluctuation for more than forty years.

Insurers last increased maximum nuclear liability insurance policy limits from $160 million to $200 million in 1988. Since that time, there has been little demand within the nuclear industry to increase these limits. The lack of interest in higher limits appears to be primarily related to two factors, namely (1) the application of the Secondary Financial Protection layer in excess of the primary limit and (2) the industry's focus on first party property insurance[117] since the last renewal of the Act.

The pending renewal of the Act may provide a good opportunity to reexamine the need for higher primary nuclear liability insurance limits. From the standpoint of public protection, an increase would provide significant benefits for a number of reasons.

First, the actual value of the current limit has been eroded by the effects of inflation. Exhibit 33 shows the relationship between the maximum amount of nuclear liability insurance available from year to year and the amount required to keep the purchasing power of those limits equal to that of the original limit of $60 million available in 1957. This table indicates that the original limit should have increased to about $350 million by August, 1998 if only to keep pace with inflation, as measured by the Consumer Price Index (CPI).[118]

Exhibit 34 shows the same relationship as in Exhibit 33, but measures the effects of inflation beginning in 1988 when the maximum limit was increased to $200 million. This exhibit indicates that the limit available in 1988 should have increased to approximately $275 million by 1998 to reflect the effects of inflation since 1988.

Quite apart from keeping pace with inflation, an increase in the primary insurance limit could help augment protection at a time when the limit of available financial protection is expected to decrease. There are currently 110 reactors participating in the SFP program. This number was reduced from a high of 116 just a few years ago. It is likely that the number of reactors in the program will diminish further as decisions are made to permanently shut down additional reactor units. Decisions to decommission nuclear generating plants for economic reasons can be anticipated as the move toward deregulation in the U.S. accelerates.

Under the present Price-Anderson system, as reactors are permanently shut down and exempted from the system, the total amount of available financial protection will be reduced. While the reductions will be partially offset in nominal terms by inflationary adjustments in the maximum retrospective premium payable in the second layer, the net impact of reactor shutdowns will be a reduction of the total limits available in real dollars to respond to public liability claims. There are no new applications for power reactors coming into the Price-Anderson system. Reactor operators have only recently started to announce commitments to license renewal. Periodic increases in the primary insurance limit would help offset reductions in the second layer, in turn reinforcing the total protection available to the public.

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[117] Property insurance limits available from nuclear utility industry captive insurers Nuclear Mutual Limited (NML) and Nuclear Electric Insurance Limited (NEIL) have more than doubled from $1.325 billion in 1988 to $3.0 billion in 1998. The operations of NML were merged into those of NEIL in 1998.

[118] Although the costs of certain items associated with insurance loss such as medical services and legal expenses have outpaced the general rate of inflation, the CPI provides a good broad measure of inflation.

Exhibit 33 Growth in maximum primary nuclear liability insurance per nuclear incident compared with increase in consumer price index from 1957 through June, 1998 ($ in millions)

Year	Consumer price index*	Maximum insurance limit	$60 million limit adjusted for inflation	Amount by which maximum insurance limit lagged inflation
1957	100.0	60	60.0	
1958	102.8	60	61.7	-1.7
1959	103.6	60	62.1	-2.1
1960	105.3	60	63.2	-3.2
1961	106.4	60	63.8	-3.8
1962	107.5	60	64.5	-4.5
1963	108.9	60	65.3	-5.3
1964	110.3	60	66.2	-6.2
1965	112.1	60	67.3	-7.3
1966	115.3	74	69.2	4.8
1967	118.9	74	71.3	2.7
1968	123.8	74	74.3	-0.3
1969	130.6	82	78.4	3.6
1970	138.1	82	82.8	-0.8
1971	144.1	82	86.5	-4.5
1972	148.8	95	89.3	5.7
1973	158.0	95	94.8	0.2
1974	175.4	110	105.3	4.7
1975	191.5	125	114.9	10.1
1976	202.5	125	121.5	3.5
1977	215.7	140	129.4	10.6
1978	232.0	140	139.2	0.8
1979	258.4	160	155.0	5.0
1980	293.2	160	175.9	-15.9
1981	323.5	160	194.1	-34.1
1982	343.4	160	206.0	-46.0
1983	354.4	160	212.7	-52.7
1984	369.8	160	221.9	-61.9
1985	382.9	160	229.8	-69.8
1986	390.0	160	234.0	-74.0
1987	404.3	160	242.6	-82.6
1988	421.0	200	252.6	-52.6
1989	441.3	200	264.8	-64.8
1990	465.1	200	279.1	-79.1
1991	484.7	200	290.8	-90.8
1992	499.3	200	299.6	-99.6
1993	514.2	200	308.5	-108.5
1994	527.4	200	316.4	-116.4
1995	542.3	200	325.4	-125.4
1996	558.4	200	335.0	-135.0
1997	571.2	200	342.7	-142.7
June 1998	580.1	200	348.1	-148.1

* Consumer Price Index for all urban consumers (CPI-U), U. S. City Average, All Items, 1957 = 100.

Source : U.S. Department Of Labor, Bureau of Labor Statistics

Exhibit 34 Maximum primary nuclear liability insurance per nuclear incident compared with increase in consumer price index from 1988 through June 1998 ($ in millions)

Year	Consumer price index*	Maximum insurance limit	$200 million limit adjusted for inflation	Amount by which maximum insurance limit lagged inflation
1988	100.0	200	200.0	0.0
1989	104.8	200	209.6	-9.6
1990	110.5	200	221.0	-21.0
1991	115.1	200	230.3	-30.3
1992	118.6	200	237.2	-37.2
1993	122.1	200	244.3	-44.3
1994	125.3	200	250.5	-50.5
1995	128.8	200	257.7	-57.7
1996	132.6	200	265.3	-65.3
1997	135.7	200	271.3	-71.3
1998 (June)	137.8	200	275.4	-75.4

[*] Consumer Price Index for all urban consumers (CPI-U), U. S. City Average, All Items, 1988 = 100.

Source : U.S. Department Of Labor, Bureau of Labor Statistics

A higher primary insurance limit would also provide an additional buffer between loss at the primary level and retrospective premium assessments on utilities in the second level. To the extent that deregulation and restructuring take hold throughout the country, the affordability of retrospective assessments may become more problematic than in the past.

A nuclear accident anywhere in the U.S. will increase financial and competitive pressures on nuclear utilities. The ability of any nuclear utility to pass retrospective premium obligations on to the local rate base — particularly in a deregulated environment — for an accident occurring in another part of the country is untested. If these costs cannot be passed through, the potential for defaults on retrospective premium obligations increases.

A higher primary liability insurance limit would lessen the potential for retrospective assessments, in turn reducing the potential for defaults on those assessments. It would also establish a better balance between pre-funding for a nuclear accident through insurance and post-funding for that accident through assessments, in effect enhancing the protection to the public.

The insurance coverage purchased by nuclear power plant operators in other industrialized (and developing) nations in which the maximum nuclear liability insurance limit exceeds $200 million is shown below.

Country	Primary insurance limit (in U.S. dollars)*
Finland	$212.6 Million
Germany	110.0 Million **
Holland	380.5 Million
Japan	243.0 Million
Mexico	250.0 Million
South Africa	336.0 Million
Sweden	264.5 Million
Switzerland	530.0 Million

* Based on exchange rates on February 11, 1998.

** It is expected that the insurance limit required in Germany will be increased in 1998 or early 1999 by national legislation from DM 200 million ($110 million) to as much as DM 1.0 billion ($550 million).

While these countries do not have programs similar to the SFP program that applies in excess of the primary insurance limit in the U.S., each does provide varying levels of government indemnity above the insurance limit in accordance with international conventions on nuclear liability.

Higher insurance limits in the U.S. would require ANI to assemble increased capacity commitments from its member insurance companies and reinsurers. If Congress (and policyholders) desire higher insurance limits, ANI would seek to develop the additional capacity.[119] Since limits have not increased since 1988, it may be possible to increase the current limit of $200 million by a significant percentage coincident with the next renewal of the Act. In subsequent years, limits could be increased periodically by more modest percentages.

2.3.8 Insurers' Perspectives on Availability of Insurance

Insurers and other observers believe that the Price-Anderson Act has been an important element in enabling them to provide stable, high quality capacity for nuclear risks. There are certain key factors that allow them to maintain and increase their capacity commitments. Those factors are identified below:

- **Channeling of Liability**. The coverage under the Facility Form policy and indemnity under Price-Anderson are omnibus in nature. This means that the financial responsibility and insurance obligation for injury to the public are effectively channeled directly to the operator of the nuclear power plant. Channeling has significant benefits for the public and for insurers. It makes virtually certain that the public will be able to establish liability for a nuclear power plant incident which will be backed by solid financial resources to pay for damages sustained. It also provides insurers with the concentration

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[119] Neither the Act nor NRC rules specifies a dollar amount for the first layer of insurance; the mandate is simply to purchase the maximum amount commercially available. Thus, ANI does not need Commission approval or Congressional legislation to increase the primary insurance level. This decision rests solely with the insurers.

of risk and stable premium base necessary to spread the risk of potentially catastrophic loss over an extended period of time.

- **Limitation on Aggregate Public Liability**. The limitation on liability makes possible the channeling of liability to the plant operator without the need for special state or federal statutes or the creation of a federal tort. In the absence of these provisions, suppliers of products or services to the nuclear industry would seek liability protection for their own accounts. Since insurance capacity is a finite commodity, the demand for insurance from suppliers could not be filled without reducing the amount of insurance available to the plant operator. Insurers would then face the prospect of cumulation of liability under multiple policies, in turn resulting in a further reduction of available capacity as they try to avoid the risk of cumulation. The limitation on aggregate public liability encourages insurers to maximize the capacity they commit to the nuclear business. The limitation also helps avoid any crushing liabilities on utilities, the imposition of which may result in less, not more, financial protection to the public. The Price-Anderson system works because it is balanced and its financial underpinnings are solid. If the industry's economic viability is threatened with new liabilities, the solidity of the system would likely diminish.

- **Legal Costs Within the Limit**. As indicated previously, insurers believe that the amount of insurance available could not be maintained without the inclusion of legal defense costs within the policy limit.

- **Federal Court Jurisdiction in Public Liability Actions**. The Price-Anderson Act confers jurisdiction over public liability actions on the Federal District Court in which an incident occurs. Insurers believe this provision removes the confusion and uncertainties of applicable law that would otherwise result when multiple claims and lawsuits are filed in multiple courts. The provision also reduces legal transaction costs and speeds the process of compensating those injured as a result of a nuclear incident.

- **Limitation on Punitive Damages**. Insurers and other knowledgeable observers believe that punitive damages distort a system intended to provide prompt and sure compensation for damages sustained by the public from a nuclear incident - not to provide a mechanism to punish wrongdoers. In the Price-Anderson context, many observers also believe that punitive damages undercut the government's authority and responsibility to penalize non-compliance with safety regulations. The potential for these undesirable results is recognized by the provision in the Price-Anderson Act that no court may award punitive damages as respects a nuclear incident if the federal government is obligated to make payments under an agreement of indemnification. Some clarification may be needed to make certain that the prohibition on punitive damages applies to Price-Anderson claims. In addition to enhancing the protection to the public, the exemption of punitive damages from the system would also eliminate the vagaries of state law, under which insurers are prohibited from paying such damages in some, but not all, state jurisdictions.

The Price-Anderson Act has encouraged maximum levels of insurance for the nuclear risk in the face of normally overwhelming obstacles for insurers - i.e., catastrophic loss potential, lack of credible predictability, very small spread of risk, and limited premium volume. This has been accomplished over more than forty years without interruption and without the "ups and downs" (or market cycles) that have affected nearly all other lines of insurance business. The financial protection which the Price-Anderson Act provides the public far surpasses the performance of any system in place today in the U.S. or anywhere else in the world. The soundness of the program lies in its simplicity and balance in achieving a few clearly defined objectives. In that respect, the Act is viewed by many as a model for other areas of technically complex human endeavor.

PART 3: OTHER RELEVANT PRICE-ANDERSON ISSUES

The Price-Anderson Act requires NRC to consider, in reporting on the need to continue or modify its provisions, other relevant factors in addition to the condition of the nuclear industry, availability of private insurance, and the state of knowledge concerning nuclear safety. The 1983 Report to Congress addressed the issues of proof of causation and proof of damages as such other relevant issues. This report similarly addresses those issues as well as Price-Anderson issues related to international agreements.

3.1 State of Scientific Knowledge of Causality and Legal Issues as to Proof of Causation

A recurring issue related to compensating victims of radiation exposure is to identify who in fact has been harmed when releases or exposure levels are low or when evidence of harm is not contemporaneous with exposure. The probability that a nuclear incident will result in delayed or uncertain effects in the exposed population in the form of cancer, genetic effects, and birth defects gives rise to serious policy questions which must be addressed in an attempt to assure that the public will be adequately compensated in the event of a catastrophic nuclear accident. In particular, individuals with latent health effects may be denied financial protection due to the interaction of (1) the current level of scientific knowledge with regard to the biological effects of radiation and indicators of radiation exposure and (2) principles of state tort law requiring that the plaintiff establish that the defendant's action caused the plaintiff's injury. Section 3.1.1 reviews the current state of scientific knowledge for identifying radiation-induced harm and those exposed. Section 3.1.2 describes current legal issues relevant to compensation.

3.1.1 Radiation, its Biological Effects, and Indicators of Radiation Exposure

> *Because Price-Anderson is intended to compensate those harmed by certain incidents involving the release of radiation, its functioning is influenced by society's ability to identify who has been harmed by such radiation. For a variety of reasons, identifying these damages is problematic. This section reviews the scientific understanding of radiation-induced health impacts and society's ability to determine whether persons have been harmed by such radiation.*

Biological effects from exposure to ionizing radiation[120] can vary widely. As discussed in this section, these effects range from *acute* (often called *short-term* or *deterministic*), such as radiation burns, to *delayed* (or *long-term* or *stochastic*), such as cancer. Acute effects typically are associated with high doses of radiation delivered over a short period of time, while delayed effects have been detected from doses as low as about 10 rem and are postulated for even lower doses.

Some of the effects of radiation exposure—particularly those resulting from high doses—can be relatively accurate indicators of exposure, not only of whether radiation exposure actually occurred, but of how much occurred and what kind it was. Other biological effects—particularly the low-dose effects—are poor indicators, because the effects are considered to be stochastic (i.e., they may or may not actually occur following the

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[120] Use of the term "radiation" in this report refers to "ionizing radiation", unless otherwise indicated.

radiation exposure) and they are indistinguishable from the effects of a variety of both synthetic and natural chemicals, background radiation, and other natural causes. Consequently, researchers have also focused on the development of other indicators of exposure, such as fate/transport modeling and dose monitoring and sampling.

In the last 15 or so years, a large amount of information related to radiation health effects has been generated through maturation of several long-term studies (e.g., on Japanese atomic bomb survivors). To some extent, other information such as results from studies of relatively recent accidents such as Three Mile Island (TMI) and Chernobyl; advances in our understanding of natural radiation sources (e.g., radon in homes), medical uses of radiation (e.g., radiotherapy patients being treated for benign and malignant conditions), and basic biophysics; and major improvements in computational, modeling, and monitoring techniques are also of interest. This section provides only a brief overview of the most recent information on biological effects of radiation exposure, the use of these effects as indicators of exposure, and the use of other indicators of exposure. First, however, this section briefly discusses several of the key concepts of basic radiation physics and health risk assessment.

3.1.1.1 Background

Below is a background discussion of several concepts regarding the biological effects and other indicators of radiation exposure, including basic radiation physics, the effects of radiation on cells and organs (see Section 3.1.1.2, pp. 113-116, for additional discussion of such effects), the various dose measures in use today, NRC radiation exposure limits, and sources of radiation exposure (including both natural and anthropogenic).

Types of Radiation[121]

Radiation has been categorized into two basic types: ionizing and nonionizing. Conceptually, ionizing radiation interacts with atoms by stripping away electrons, thus changing neutral atoms into charged atoms, called ions, while nonionizing radiation does not remove electrons from atoms. As a practical matter, however, the distinction is not so simple. Visible light, for example, is capable of ejecting electrons from atoms but by convention, and for practical reasons, visible light, even ultraviolet light, is classified as nonionizing. Conversely, neutron radiation is considered ionizing, even at very low energies, because neutrons tend to interact with atom nuclei and thereby to create ions. Generally, subatomic particles are considered ionizing, as is electromagnetic radiation above some energy, commonly 10 keV. While nonionizing radiation can have biological effects, ionizing radiation is the focus of this report.

One source of ionizing radiation—the source most likely to be of concern to the public following a release event from a nuclear power plant—is the nuclei of unstable atoms. As these radioactive atoms, called *radionuclides* or *radioisotopes*, decay, they eject or emit two basic types of radiation: (1) *particulate radiation*, such as alpha particles (energetic, positively charged particles)[122] and beta particles (high energy electrons), which ionize matter via direct collisions with atoms; and (2) *electromagnetic radiation* (or *photons*), such as x-rays and

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[121] Much of this discussion is summarized from National Research Council, *Health Effects of Exposure to Low Levels of Ionizing Radiation: BEIR V*, Committee on the Biological Effects of Ionizing Radiation, Washington, D.C.: National Academy Press, 1990.

[122] Specifically, alpha particles are a very stable combination of two protons and two neutrons. This combination is identical to a helium nucleus.

gamma rays, which ionize matter via several other processes (depending on the photon energy). Each radionuclide (e.g., carbon-14, or ^{14}C) emits its own unique mixture of radiation.

As electrons are ejected from atoms that have been affected by radiation, they proceed through tissue and create a track of excited and ionized atoms and molecules. The amount of energy deposited per unit length of particle track, or the spatial energy distribution, is defined as the *linear energy transfer* (LET) of the radiation. X-rays and gamma rays result in electrons that have a relatively low spatial rate of energy loss. For example, gamma rays from cobalt-60 (^{60}Co), with an average energy of about 1.25 megaelectron volt (MeV), result in a low LET of about 0.25 keV/μm). A 2 MeV alpha particle, in contrast, results in a high LET of about 250 keV/μm. LET is important for determining the relative biological effectiveness of a given type of radiation. Other more refined measures of radiation in terms of its effect on biological systems are discussed below.

Effects of Radiation on Cells and Organs

Even though all biological effects of radiation can be traced back to the interaction of the radiation with atoms, there are two mechanisms by which radiation ultimately affects cells. These two mechanisms are commonly called *direct* and *indirect* effects.

- **Direct Effects**. If radiation interacts with the atoms of the DNA molecule, or some other cellular component critical to the survival of the cell, it is referred to as a direct effect. Such an interaction may affect the ability of the cell to reproduce and, thus, survive. If enough atoms are affected such that the chromosomes do not replicate properly, or there is a significant alteration in the information carried by the DNA molecule, then the cell may be destroyed by "direct" interference with its life-sustaining system.

- **Indirect Effects**. The probability of the radiation interacting with the DNA molecule is very small, since these critical components make up such a small part of the cell. But each cell, just as is the case for the human body, is mostly water. Therefore, there is a much higher probability of radiation interacting with the water that makes up most of the cell's volume. When radiation interacts with water, it may break the bonds that hold the water molecule together, producing fragments such as hydrogen (H) and hydroxyls (OH). These fragments may recombine or may interact with other fragments or ions to form compounds, such as water, that would not harm the cell. However, they could combine to form toxic substances, such as hydrogen peroxide (H_2O_2), which can contribute to the destruction of the cell.

Notwithstanding these modes of action, however, not all living cells are equally sensitive to radiation. Those cells that are actively reproducing are more sensitive than those that are not, since dividing cells require that the DNA information be correct in order for the cell's offspring to survive. A direct interaction of radiation could result in the death or mutation of such a cell, whereas a direct interaction with the DNA of a dormant cell would have less of an effect or no effect at all. As a result, living cells can be classified according to their rate of reproduction, which also indicates their relative sensitivity to radiation. This means that different cell systems have different sensitivities. For example, lymphocytes (white blood cells) and cells that produce blood are constantly regenerating and thus are the most sensitive; reproductive and gastrointestinal cells do not regenerate as quickly and thus are less sensitive; and nerve and muscle cells are the slowest to regenerate and thus are the least sensitive.

Similarly, organs differ in their sensitivity to radiation. This sensitivity correlates with the relative sensitivity of the cells from which the organs are composed, as well as other factors (e.g., oxygen supply). For example, since the blood-forming cells are one of the most sensitive cells (because of their rapid regeneration rate), the blood-forming organs are some of the most sensitive organs to radiation. Muscle and nerve cells are relatively insensitive to radiation, and therefore so are the muscles and the brain.

How the various sensitivities of cells and organs to radiation affect the risk of adverse health effects is discussed in Section 3.1.1.2.

Radiation Dose Measures

Various limitations in the concept of LET and dose in subcellular tissue volumes have led to the introduction and refinement of microdosimetric concepts. These concepts take into account the fact that energy deposition by ionizing radiation is a stochastic (random) process, and that a dose can occur from an external source (e.g., contaminated soil that irradiates those passing over it) or an internal source (e.g., radionuclides inhaled and taken up by cells). Thus, radiation dose is a generic term today that can have a number of different specific definitions, depending on the type of dose being estimated. Many of these definitions, as well as several related concepts, are defined in Exhibit 35.

Radiation Exposure Limits

Radiation exposure limits to individual members of the public from NRC-licensed operations are as follows:

- a total effective dose equivalent of 0.1 rem (1 millisievert (mSv)) in a year to individual members of the public from the licensed operation, exclusive of the dose contributions from background radiation, any medical administration the individual has received, voluntary participation in medical research programs, and the licensee's approved disposal of radioactive material into sanitary sewerage; and
- a dose in any unrestricted area of 0.002 rem (0.02 mSv) in any one hour.

These dose limits can be found in 10 CFR 20.1301.

Average Radiation Exposure Compared to Dose Limits from NRC-licensed Operations

The U.S. average radiation exposure from natural and anthropogenic (primarily medical) sources is approximately 3.6 mSv/yr (360 mrem/yr) in effective dose equivalent (EDE), while the maximum annual radiation exposure limit to members of the public from NRC-licensed operations is only 1 mSv/yr (100 mrem/yr) (10 CFR 20.1301). Thus, average radiation exposure—most of which is from natural sources—is almost four times the NRC exposure limit. Furthermore, average radiation exposure from the nuclear fuel cycle is less than 0.01 mSv/yr (less than 1 mrem/yr), which is less than 1 percent of the exposure limit.

Exhibit 35 Key concepts and terms for radiation dose measurement

Absorbed dose means the energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the gray (Gy).

Becquerel (Bq) is the SI* unit for activity, or disintegrations (transformations) per unit of time. 1 Bq=1 disintegration per second.

Committed dose equivalent ($H_{T,50}$) means the dose equivalent to organs or tissues of reference (T) that would be received from an intake of radioactive material by an individual during the 50-year period following the intake if the individual's metabolism remains consistent with the models.

Committed effective dose equivalent ($H_{E,50}$) is the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues ($H_{E,50}=\sum w_T H_{T,50}$).

Curie (Ci) is the special unit for activity, disintegrations (transformations) per unit of time.
1 Ci=$3.70\text{x}10^{10}$ disintegrations per second=$3.70\text{x}10^{10}$ Bq.

Deep-dose equivalent (H_d), which applies to external exposure, is the dose equivalent at a tissue depth of 1 cm (1,000 mg/cm^2).

Dose equivalent (H_T) means the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and sievert (Sv).

Gray (Gy) is the SI* unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule/kilogram (100 rads).

Quality factor (Q) means the modifying factor that is used to derive dose equivalent from absorbed dose.

Rad is the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram (0.01 gray).

Rem is the special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem=0.01 sievert).

Sievert is the SI* unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv=100 rems).

Total effective dose equivalent (TEDE) means the sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Weighting factor, w_T, for an organ or tissue (T) is the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly.

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[*] International System of Units (abbreviated SI from the French Le Systeme Internationale d'Unites).

Source: 10 CFR 20.1003-1005.

Sources of Radiation Exposure

Radiation is ubiquitous in our environment and is an integral part of our lifestyle. As seen in Exhibits 36 and 37, approximately 82 percent of the U.S. average exposure to radiation is from natural background sources, while the remainder is from medical uses (15 percent), consumer products (3 percent, almost all from naturally radioactive material), and other sources (less than 1 percent).[123] Natural radiation varies depending on the area where people live, the type of housing construction they live in, and what they eat. For instance, Colorado has relatively high radiation levels because of its high altitude (which means less atmosphere is available to screen out cosmic rays); brick homes have higher natural radiation levels than homes made of other building materials; and certain foods contain higher levels of radiation than other foods. Similarly, radiation exposure from the nuclear fuel cycle (e.g., nuclear power plants) varies also, although dose limits are in place to protect the public from excessive exposure.

Exposure of the public to radiation from a nuclear accident would most likely be from radionuclides released into the air as gasses and fine aerosols. These releases then would be spread by prevailing winds. Exposure would occur via two main pathways: (1) direct radiation "shine" (i.e., external radiation) from plume immersion and ground, skin, and other deposition: and (2) internal dose from ingestion, inhalation, and dermal absorption. (See text box at right for examples of nuclear accidents that resulted in exposure to the public.) In the remainder of this section, the effects of these types of exposures, as well as how these exposures can be measured, are discussed.

A Range of Exposures: A Comparison of Two Case Studies

As seen from TMI and Chernobyl data, radiation exposure following a nuclear power plant accident can range from less than the allowable dose limit (TMI) to many times the limit (Chernobyl). One measure of the intensity of the Chernobyl accident—and of the mildness of the TMI accident—is that levels of iodine-131 around TMI were three times as high after Chernobyl than they were after the TMI accident. (See: NRC, 1996, *A Short History of Nuclear Regulation, 1946-1992*, NUREG/BR-0175, Washington, D.C.; also available on the Web at HTTP://WWW.NRC.GOV/SECY/SMJ/SHORTHIS.HTM.)

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[123] NCRP, *Ionizing Radiation Exposures of the Population of the United States*, Report No. 93, Washington, D.C., 1987. Updates have been made of some sources, although the proportions described above have remained essentially the same. See: NCRP, *Public Radiation Exposure from Nuclear Power Generation in the United States*, Report No. 92, Washington, D.C., 1988; NCRP, *Exposure of the Population in the United States and Canada from Natural Background Radiation*, Report No. 94, Washington, D.C., 1988; NCRP, *Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources*, Report No. 95, Washington, D.C., 1988; NCRP, *Exposure of the U.S. Population from Diagnostic Medical Radiation*, Report No. 100, Washington, D.C., 1989; and NCRP, *Exposure of the U.S. Population from Occupational Radiation*, Report No. 101, Washington, D.C., 1989.

Exhibit 36 Average amounts of ionizing radiation received yearly by a member of the U.S. population[a]

Source	Dose[b]	
	(mSv/yr)	(%)
Natural		
Radon	2.0	55[c]
Cosmic	0.27	8
Terrestrial	0.28	8
Internal	0.39	11
Total Natural	3.0	82
Anthropogenic		
Medical		
X-ray diagnosis	0.39	11
Nuclear medicine	0.14	4
Consumer products[d]	0.10	3
Occupational	< 0.01	< 0.3
Nuclear fuel cycle	< 0.01	< 0.03
Nuclear fallout	< 0.01	< 0.03
Miscellaneous[e]	< 0.01	< 0.03
Total Anthropogenic	0.63	18
Total Natural and Anthropogenic	3.6	100

[a] Based on National Research Council *BEIR-V* (1990), and NCRP, Report No. 93 (1987).

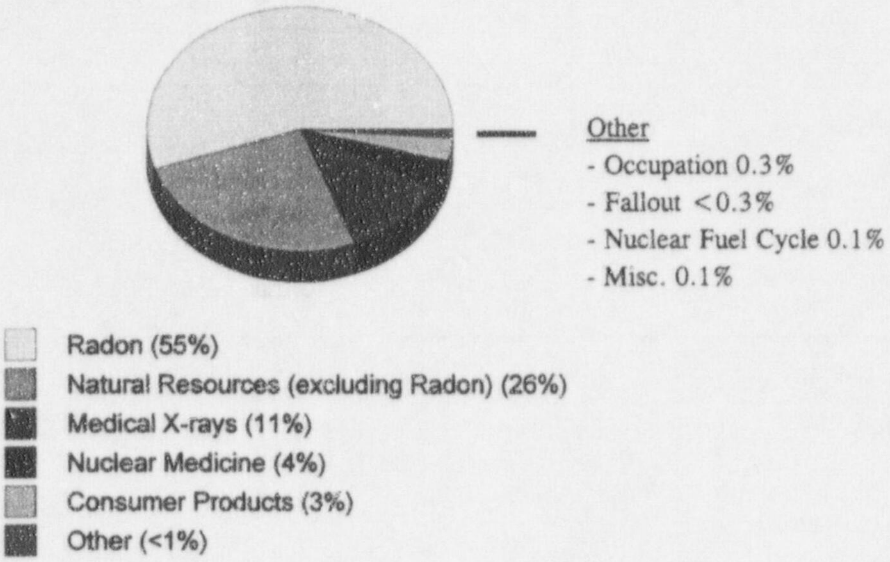
[b] Average effective dose equivalent.

[c] Dose to bronchial epithelium alone.

[d] For consistency with BEIR-V, consumer products are listed under the anthropogenic heading although essentially all the consumer product dose comes from naturally radioactive materials, specifically radium and radon in water supplies; radium, thorium, etc. in building materials; and the same nuclides in mining and agricultural products.

[e] DOE facilities, smelters, transportation, etc.

Exhibit 37 Pie chart of exhibit 36: sources of radiation exposure from NCRP report no. 93



3.1.1.2 Biological Effects of Radiation Exposure[124]

The biological effects of radiation on living cells can result in three basic outcomes: (1) cells repair themselves, resulting in no damage; (2) cells die (much like millions of body cells do every day), being replaced through normal biological processes; or (3) cells change, resulting in no effect or in cancer or other effects. These effects can be prompt (e.g., within minutes of exposure) or delayed (e.g., years after exposure).

Prompt Effects

Prompt effects from radiation exposure can appear in a matter of minutes to as long as a few weeks after exposure to very high doses of radiation. The higher the dose, the sooner the effects will appear, and the higher the probability of severe effects and death. Exhibit 39 summarizes the types of prompt effects from varying radiation exposure levels. Because radiation affects different people in different ways, it is not possible (except for extremely high doses) to indicate what dose is needed to be fatal for a given individual. Nevertheless, it is estimated that approximately 50 percent of an exposed population would die within 30 days of receiving a dose ranging from about 3.2 to 11 Gy (320 to 1,100 rad).[125] This rate would depend on the health of the individuals before the exposure and the medical care received after the exposure. Also, note that these doses are acute whole body doses, which means that the whole body is exposed to the radiation in a very short period of time (minutes to hours). Exposure of only parts of the body will likely lead to more localized effects, such as skin burns or tissue damage in the exposed area.

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[124] Except where noted, much of this information was summarized from NRC's web page at HTTP://WWW.NRC.GOV/NRC/EDUCATE/REACTOR/06-BIO/RADBIOEFFECTS.HTML.

[125] NCRP, *Guidance on Radiation Received in Space Activities*, Report No. 98, Washington, D.C., 1989.

Exhibit 38 Acute whole-body radiation syndromes

Syndrome	Acute dose (Gy)	Characteristics/sequelae
Subclinical syndrome	< 2	No or slight blood changes may be detected by medical evaluation
Hematopoietic syndrome	2-4	Blood changes (granulocytopenia, thrombocytopenia), hemorrhage, infection, electrolyte imbalance
Gastrointestinal syndrome	6-10	Lethargy, diarrhea, dehydration, degeneration of intestinal lining, death (if it occurs) in 10-14 days
Central nervous syndrome	> 10	Agitation, apathy, disorientation, disturbed equilibrium, vomiting, convulsions, prostration, coma, death (if it occurs) in 1-2 days

Source: NCRP, *Guidance on Radiation Received in Space Activities*, Report No. 98, Washington, D.C., 1989.

Delayed Effects[126]

As discussed previously, ionizing radiation affects cells and organs by depositing energy in body tissue, which can then cause cell damage. In some cases, the cell may survive but the DNA may be damaged, increasing the chance—although not the severity—of a long-term or delayed effect.

Delayed health effects from radiation exposure generally appear many years (usually between 5 and 20 years) after exposure, if they appear at all. For leukemia, the minimum period of time between the radiation exposure and the appearance of disease (latency period) is 2 years. For solid tumors, the latency period is more than 5 years. The primary delayed effects of concern include somatic (e.g., carcinogenic) effects, genetic (or heritable) effects, and teratogenic (e.g., in utero) effects. The approximate risks for these three principal delayed effects are shown in Exhibit 39.

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[126] NRC maintains a Web page—HTTP://WWW.NRC.GOV/NRC/EDUCATE/REACTOR/06-BIO/RADBIOEFFECTS.HTML—that provides additional detail regarding NRC views on delayed (as well as prompt) effects. One of the most recent major scientific assessments of the data on delayed effects, and the source from which most of the discussion in this section is summarized, is National Research Council, *Health Effects of Exposure to Low Levels of Ionizing Radiation: BEIR V*, Committee on the Biological Effects of Ionizing Radiation, Washington, D.C.: National Academy Press, 1990.

Exhibit 39 NRC estimates of radiation effects

Effect	Excess cases per 10,000 exposed per rad
Genetic	1 to 2
Somatic (cancer)	2 to 10
In-Utero (cancer)	2 to 6
In-Utero (all effects)	10 to 100

Source: HTTP://WWW.NRC.GOV/NRC/EDUCATE/REACTOR/06-BIO/RADBIOEFFECTS.HTML.

Genetic Effects

The genetic effects of radiation are well known in animal models, but they have yet to be clearly demonstrated in humans. Nevertheless, by extrapolation from animal studies, BEIR V estimates that the "doubling dose" (i.e., the dose required to double the mutation rate in humans) is at least 1 Gy (100 rad) of low dose rate, low LET radiation. NRC concurs and estimates that 1 rem (0.01 Sv) (1 rad (0.01 Gy) of low LET radiation) exposure to the reproductive organs is approximately 50 to 1,000 times less than the spontaneous risk for various anomalies.

Somatic Effects

Carcinogenicity is the most significant somatic effect typically assessed. The population-weighted average lifetime excess risk of death from cancer following an acute dose equivalent to all body organs of 0.1 Sv (10 rem; 0.1 Gy (10 rad) of low LET radiation) is estimated by BEIR V to be about 0.8 percent. The lifetime risk varies considerably with age at the time of exposure, however. For example, the risk from exposure during childhood is estimated to be about twice as large as the risk for adults. Risk also varies depending on dose rate. For example, there is a two or more fold decrease in risk when the dose is spread out over weeks or months. Thus, actual risk can vary considerably depending on several factors. NRC uses this variability and several other assumptions to estimate that a 10 rad (0.1 Gy) dose (or 0.1 Sv (10 rem) of low LET radiation) results in a 0.2 to 1 percent increase in cancer cases. Because only about half of all cancers result in death, the actual risk of death is expected to be about half of this range.

In-Utero/Teratogenic Effects

Fetal brain damage is just one type of potential teratogenic effect from *in utero* radiation exposure. According to BEIR V, the magnitude of risk for this effect is approximately a 4 percent chance of occurrence per 0.1 Sv (10 rem) exposure during the 8 to 15 week gestational age. NRC estimates that spontaneous risks of fetal abnormalities are about 5 to 30 times greater than the risk of exposure to 1 rem (0.01 Sv)

Attributing a particular delayed effect in an individual to a radiation dose that occurred at some point in the past is very difficult if not impossible. Contrary to most prompt effects from radiation exposure, delayed effects generally are indistinguishable from those that develop spontaneously or as a result of exposure to other carcinogens, mutagens, or teratogens. Furthermore, although radiation is known to cause cancer at high doses, currently there are no data to unequivocally establish the occurrence of cancer following exposure to low doses (see text box at right). Notwithstanding this possibility of a "threshold" in the dose-response curve for radiation, however, the radiation protection community conservatively assumes that, in the absence of sufficient data to the contrary, any amount of radiation may pose some risk for causing cancer and hereditary effects, and that the risk is higher for higher level doses. NRC's dose limits for both radiation workers and members of the public were developed on that basis. (NRC regulations and radiation exposure limits are contained in 10 CFR Part 20.)

A Question of Thresholds

Although radiation is known to cause cancers at high doses, currently there are no data to unequivocally establish the occurrence of cancer following exposure to low doses—below about 30,000 mrem (300 mSv). Recently, activity has increased regarding the question of whether radiation dose thresholds exist below which no carcinogenic effects occur. The International Commission on Radiological Protection (ICRP) recently reported on their investigations into the possibility of thresholds (Roger H. Clarke, in comments to the Uranium Institute 1996 Symposium). The Health Physics Society (McLean, VA) recommends against quantitative estimation of health risk below specific doses, based on evidence that the linear, no-threshold dose-response model is an over-estimation of health risks. EPA recently published a draft cancer assessment guideline document (Proposed Guidelines for Carcinogen Risk Assessment, Office of Research and Development, EPA/600/P-92/003C, April 1996) that allows for the possibility of thresholds, or non-linearity, in the dose-response of carcinogens (although not necessarily for radiation). Given these activities and statements, NRC recently contracted with NCRP to conduct a critical evaluation of the issues surrounding the validity of the non-threshold model.

3.1.1.3 Indicators of Radiation Exposure

As discussed above, there are few health effects—particularly delayed effects—that provide a clear and certain indicator of radiation exposure. Consequently, much of the recent focus on indicators has been on refining techniques to assess exposure based on observations of subtle cellular and subcellular effects, measurements of radiation in the environment and in tissues, and the use of calculations (models) to estimate exposure. These approaches individually can often produce highly uncertain results, but when used in combination with each other they can provide an accurate picture of a population's or an individual's exposure to radiation following a release event.

Biological Effects as Indicators of Exposure

The biological effects that follow high, short-term radiation doses are fairly unique and occur soon after the exposure (i.e., promptly). Thus, prompt effects can be good indicators of the type and amount of radiation exposure. This is especially true when the effects are considered in combination with each other (e.g., radiation burns and blood cell changes) and with other indicators of exposure (e.g., the results of monitoring devices and exposure models; see below).

The biological effects that follow low doses of radiation, however, are quite the opposite in terms of being able to attribute the effect to an exposure. Such effects can be caused by any number of other factors. Furthermore, these effects are considered stochastic (i.e., their probability increases with dose) and, if they do occur, are seen many years following the exposure. To address these problems, in 1983 Congress amended the

Orphan Drug Act (Public Law 97-414) requiring the National Institutes of Health to produce *probability causation* or *PC* tables.[127] The legislative intent was to help during the compensation of people with cancer that may have been caused by radiation from nuclear weapons tests.

PC tables are useful in that they address not only the direct link between dose and effect, but also consider many of the additional factors (e.g., age, gender, smoking habits, latency period of the effect) that may have influenced the development of the specific effect in that particular individual. Nevertheless, PC tables do have their problems, which need to be considered as they are refined or used. For example, one author[128] describes several generic sources of statistical uncertainty in PC tables that prevent accurate quantification of assigned shares. He claims that there are many hidden, debatable policy judgments in PC tables such that probability of causation cannot in general be quantified with sufficient precision to be useful. Nevertheless, in 1990, the Presidential Commission on Catastrophic Nuclear Accidents recommended the use of PC tables to aid in deciding the question of cause and effect between a malignancy or related effect and a specified previous exposure to ionizing radiation.[129] The Commission also recommended that the full award be paid when PC indicates that it is "more likely than not" that a particular illness occurred as a result of the accident. And that a level be established on the other end of the scale where it is "extremely unlikely." In 1992, NCRP announced that it also recommended the use of PC tables.[130]

Electronic Personnel Dosimeters

Electronic personnel dosimeters (EPDs) are presently in the research and development phase and could in the future provide a more comprehensive way of assessing the dose to which a person is exposed. EPDs record not only the size of the exposure, but the energy spectra, LET spectra, and other qualitative factors that are not possible to assess with passive dosimeters. Although in use as secondary and supplemental dosimeters for several years, EPDs are currently under review by NRC for use as primary dosimeters. This research aims to determine the impact that radio frequencies, microwaves, electric fields, and various other environmental conditions can have on the accuracy and reliability of these devices (60 *Federal Register* 42629, August 16, 1995, "Performance Testing of Electronic Personnel Dosimeters: Availability").

An established yet still rapidly developing area in the use of biological effects as indicators of radiation exposure is cellular and molecular *biomarkers*. For example, changes in cell membranes, proteins, DNA, and even tooth enamel are increasingly being studied or used for assessing not only the amount of radiation that an individual was exposed to, but also the type of radiation (e.g., high vs. low LET). A thorough review of the use

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[127] NIH, *Report of the National Institutes of Health Ad Hoc Working Group to Develop Radioepidemiology Tables*, NIH Publication No. 85-2748, Washington, D.C., 1985.

[128] Cox, LA, Jr, 1987, "Statistical issues in the estimation of assigned shares for carcinogenesis liability", *Risk Analysis* 7:1, 71-80.

[129] See *Report to Congress of the Presidential Commission on Catastrophic Nuclear Accidents*, 1990.

[130] NCRP, *The Probability That a Particular Malignancy May Have Been Caused by a Specified Irradiation*, Statement No. 7, Bethesda, MD., 1992.

of biomarkers is beyond the scope of this report; however, numerous recent review articles describe in detail the state of the science for these promising techniques.[131]

Other Indicators of Exposure

Other potential indicators of exposure to radiation include two distinct, yet often combined, methodologies: (1) dose monitoring/sampling; and (2) release, transport, and exposure modeling. Both methodologies are continuously evolving and have been used for many years to reconstruct doses following various release events.

Dose Monitoring/Sampling

There are four basic types of dose monitoring/sampling:

(1) individual monitoring
(2) population/area monitoring
(3) environmental sampling from the exposed media, and
(4) bioassays

NRC defines individual monitoring as "the assessment of dose equivalent by the use of devices designed to be worn by the individual."[132] This monitoring is required for employees and visitors of licensed facilities who are likely to receive a dose equivalent exceeding 10 percent of any applicable threshold.[133] Individual monitoring devices are typically small devices, such as film badges, that are designed to be worn by a single individual. These devices record doses by the reaction of a medium to radiation. A recent NCRP report,[134] however, notes that in many external exposure circumstances, dose equivalent estimates obtained from personal monitors significantly overestimate dose, particularly when the body is not uniformly irradiated due to the irradiation conditions or due to protective shielding of portions of the body. Specifically, in these cases, the numerical relationships between monitoring data and dose need to be better understood so that appropriate monitoring practices are selected and monitoring data are properly evaluated. That report explores these numerical

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[131] For example, see numerous articles in *Stem Cells (Dayt)*, 1995 (May), 13 Supplement 1, including: Baranov, AE, Guskova, AK, Nadejina, NM, and Nugis, VYu, "Chernobyl experience: biological indicators to exposure to ionizing radiation," pp. 69-77; Dainiak, N and Tan, BJ, "Utility of biological membranes as indicators for radiation exposure: alterations in membrane structure and function over time," pp. 142-52; Plappert, U, Raddatz, K, Roth, S, and Fliedner, TM, "DNA-damage detection in man after radiation exposure—the comet assay—its possible application for human biomonitoring," pp. 215-22; Densow, D, "Are there 'common denominators' in different radiation exposure scenarios as a target for predictive assessment?", pp. 307-17; and Ziegler, BL, Weiss, M, Thoma, S, Lamping, C, and Fliedner, TM, "Biologic indicators of exposure: are markers associated with oncogenesis useful as biologic markers of effect?," pp. 326-38.

[132] 10 CFR 20.1003, "Definitions."

[133] 10 CFR 20.1502, "Conditions requiring individual monitoring of external and internal occupational dose."

[134] NCRP, *Use of Personal Monitors to Estimate Effective Dose Equivalent and Effective Dose to Workers For External Exposure to Low-LET Radiation*, Report No. 122, Washington, D.C., 1995.

relationships for external exposure from low-LET radiation and gives recommendations for estimating doses in practice, using personal monitors. In the future, more accurate electronic dosimeters are expected to replace the existing monitors (see text box above). The use of personal monitors may not be feasible in reactor accident scenarios.

Unlike individual monitoring, which provides information only for persons wearing dosimeters, area/population monitoring refers to monitoring and sampling that takes place in designated locations. It is aimed at assessing the dose to which nearby populations may be exposed. Under federal regulations, all licensed U.S. nuclear power plants are required to monitor radiation levels beyond facility boundaries. This monitoring is performed by the facility to ensure that accurate records are kept when radiation levels outside of the facility exceed the natural background level. In the event of an accidental release of radiation into the environment, these monitoring stations would provide important data in terms of the magnitude and distribution of the release.

In addition to constant monitoring outside the boundaries of licensed facilities, power plants are required to periodically measure samples from environmental media (soil, air, surface and ground water, and biota) outside the facility boundaries to verify that radiation levels are not higher than is allowed or expected. Several guidance documents are available for use during these sampling events.[135]

Bioassays are another type of monitoring for radiation exposure. A bioassay is the determination of the kinds, quantities, or concentrations, and, in some cases, the locations, of radioactive material in the human body, whether by direct measurement (*in vivo* counting) or by analysis and evaluation of materials excreted or removed (*in vitro*) from the human body. NRC has published numerous guides on the use of bioassays.[136]

Release, Transport, and Exposure Modeling

Modeling the release, transport, and exposure of radionuclides is another way of estimating the dose to an individual. Modeling is a method that estimates or takes a given release and computes, using meteorological, topographical, and hydrogeological data, the distribution of the released constituents over space and time. Once the spatial and temporal distributions of the material are determined, geographical and behavioral data can be used to estimate doses for individuals in particular locations.

There are numerous sophisticated and well-tested models available for assessing the release of radionuclides and radiation from catastrophic release events. This report describes only a few of these.

- MELCOR. This model is the most recent and complete of the models developed by NRC. It can model the initial accident, the release of radionuclides into the environment, and the transport of these radionuclides into environmental media. This

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[135] For example, see NCRP, *Calibration of Survey Instruments Used in Radiation Protection for the Assessment of Ionizing Radiation Fields and Radioactive Surface Contamination*, Report No. 112, Washington, D.C., 1991.

[136] For example, see NRC, *Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program*, Regulatory Guide 8.9, Revision 1, 1993.

model was specifically designed for nuclear power plant accidents with the goal of preparing and responding to accidents.[137]

- RASCAL. This is the primary model used by the NRC to conduct an independent assessment of dose projections during a power plant accident. It contains tools to estimate radioactive source term, atmospheric transport, and dose from a radiological accident. It can also estimate dose from field survey measurements of radionuclide concentrations.

- SPEEDI. Another example package is the SPEEDI package developed by the Japan Atomic Energy Research Institute (JAERI). This package was designed to provide real-time dose assessments for radiological emergencies and consists of an atmospheric transport model, a meteorological data processor, and graphical software.

- RESRAD. This is a U.S. DOE and EPA model designed to analyze the radiological doses resulting from the remediation and occupancy of buildings and land contaminated with radioactive material. It considers external exposure, the inhalation of dust and radon, and the ingestion of soil/dust as exposure pathways. Although not designed specifically as an accidental release model, RESRAD could be useful for estimating the doses associated with remediation and cleanup of areas following an accident.

- CAP88-PC. For low-level chronic releases, U.S. EPA also has a radiological dose assessment model known as CAP88-PC.[138] The model calculates the magnitude and distribution of radionuclides in air, the deposition of radionuclides to ground surfaces, and the concentration of radionuclides in foods, and then estimates, using inhalation and ingestion intake rates, the dose received by the individual. Although this model was designed for low-level, chronic releases, it nevertheless may be useful for some short-term accidental releases.

- Screening Models. For rapid assessment, NCRP developed a two-volume report that seeks to meet the need for simple, authoritative, screening techniques to address release of radioactive materials to the atmosphere, surface water, or ground.[139] Work sheets are included that allow the user to easily carry out a screening process for a release through a few multiplicative calculations using a minimum of site-specific data and decisions.

Fate and transport models involve a level of uncertainty that is more difficult to assess than that of monitoring and sampling. This uncertainty is largely dependent on the quality of the input data to the models. Because there are so many forces at work on radionuclides as they move through the different environmental media, the accurate specification of input parameters is crucial. For example, the form of the radionuclide release

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[137] NRC, *RadioNuclide (RN) Package Reference Manual*, Washington, D.C., 1997.

[138] EPA, *User's Guide for CAP88-PC*, No. 402-B-92-001, Washington, D.C., 1992.

[139] NCRP, *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground* (two volumes), Report No. 123, Washington, D.C., 1996.

(elemental gas, molecular form, etc.) plays a significant role in determining the transport, uptake, and organ specificity of the radionuclides. Thus, without a complete and accurate picture of the composition of the release, the models begin with a high degree of uncertainty that is compounded throughout the simulation. Today's nuclear power plants, however, utilize sufficiently high levels of monitoring, inventory practices, and quality control such that any release would likely be adequately characterized within the level of precision inherent within the models. Furthermore, several tools exist for evaluating and reducing the uncertainty associated with such models.[140]

Notwithstanding most of the uncertainties associated with modeling, an important benefit of modeling is that, unlike sampling and monitoring, it provides the user with a general overview of the severity of the release to the entire area, instead of being restricted to the limited amount of sampling and monitoring data available.

Prior Experience with Monitoring/Sampling and Modeling

Through experience with the monitoring, sampling, and modeling of the results of large-scale releases of radionuclides—such as the atomic bomb explosions in Hiroshima and Nagasaki, Japan, the releases from military testing at Hanford, WA, Oak Ridge, TN, Dugway, UT, and Los Alamos, NM, and the core meltdowns at Chernobyl, Ukraine and Three Mile Island, PA—the methodologies of release assessment processes have been well developed, tested, and refined. Furthermore, there has been an increased use in recent years of probabilistic risk assessment (PRA) for evaluating nuclear power plants. For example, NRC requested in 1988 that all licensees perform a plant-specific search for vulnerabilities to severe accidents; virtually all licensees used PRA for this task. NRC also has conducted several of its own PRAs, the most recent being a large-scale study of five different reactors using the then-current methodology and experience data available.[141] In addition, NRC recently adopted a new policy to promote the use of PRA.[142] PRAs can include not only a detailed probabilistic analysis of events leading up to a release, but also a detailed and complex analysis of the transport and fate of the released radionuclides. Thus, this focus on PRA has translated into significant developments in modeling and other techniques for assessing exposure. (See Section 2.2.2 for a review of PRA and nuclear safety.)

Conclusion

Since the last NRC Report to Congress on the Price-Anderson Act, the knowledge base for identifying biological effects and other indicators of radiation exposure has expanded. This expansion is due to numerous factors.

- New and Updated Epidemiologic Studies and Techniques. Several long-term studies (e.g., on Japanese atomic bomb survivors) have matured such that more specific and

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[140] NCRP, *A Guide for Uncertainty Analysis in Dose and Risk Assessments Related to Environmental Contamination*, Commentary No. 14; and IAEA, 1996, *Evaluating the Reliability of Predictions Made Using Environmental Transfer Models*, Safety Series No. 100, 1989.

[141] U.S. Nuclear Regulatory Commission, *Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants*, NUREG-1150, 1991.

[142] U.S. Nuclear Regulatory Commission, "Use of Probabilistic Risk Assessment Methods in Nuclear Regulatory Activities; Final Policy Statement," 60 *Federal Register* 42622, August 16, 1995.

definite conclusions can be made about the long-term effects of radiation. Also, studies of relatively recent accidents (e.g., Three Mile Island, Chernobyl) and medical uses of radiation (e.g., radiotherapy for cancer patients) have begun to produce results that aid our understanding, especially when these results are combined with those of older studies.

- Better Understanding of Mammalian Physiology and Underlying Biological Effects of Radiation. Significant advances have occurred in recent years in our understanding of the molecular mechanisms of carcinogenesis and genetic disorders in mammals. These advances have led to refinements in several of the assumptions used to develop radiation risk estimates. Similarly, a wealth of data on development of the mammalian brain has emerged in recent years, which has helped scientists better understand the effects of radiation on the mental development of the fetus.

- Better Understanding of Background Radiation Exposure. Newer studies of natural and other background radiation sources (e.g., radon) have helped to refine the estimates of risk from ionizing radiation by providing a better accounting of background exposures and risks.

Several other important advances have occurred over the years, most notably in the areas of computing, modeling, and monitoring.

Overall, these improvements have resulted in a narrowing of the uncertainties surrounding dose-response estimates for radiation. For example, progress made in our understanding of the genetic mutation process significantly reduces the uncertainties inherent in the current animal-to-human extrapolation models that have been used to estimate heritable risks from radiation. Notwithstanding the overall reduction in uncertainties over time, however, our confidence in other areas may have decreased somewhat. For example, assumptions about whether the existing low-dose extrapolation model for radiation cancer risk should remain a linear non-threshold model have come under increased scrutiny lately.

A significant change that has occurred since publication of the 1983 Report to Congress is the overall increase in the estimate of lifetime cancer risk attributable to a given radiation dose, in the high dose, high dose rate regime. This increase is due primarily to reassessments of radiation dosimetry at the Hiroshima and Nagasaki atomic bomb sites. Another significant change—attributable both to new studies of the atomic bomb survivors and to advances in biological science—is the ability now to generate estimates of the effects of radiation on the mental development of the fetus.

Notwithstanding these gains in the knowledge base, however, NRC recognizes that much still is unknown about the biological effects of radiation, particularly at low dose and low dose rates. For example, we do not know exactly how a given individual will react to a given type and amount of radiation. Nevertheless, more information probably has been gained on the biological mechanisms and resulting dose-response measures of radiation in the last 15 years than in all previous years combined, at least in terms of relevance to the Price-

Anderson Act. NRC expects that this trend will continue for some time. Additional studies, such as the BEIR update,[143] may provide additional insights into the health effects of low level radiation.

3.1.2 Legal Issues Relating to Proof of Causation

The 1988 Amendments committed Congress to providing "full compensation" to those injured as a result of a nuclear accident or precautionary evacuation. However, the Amendments left the resolution of the extent of proof required to establish compensable injury to state law. As it may often not be possible to establish by a preponderance of the evidence that later appearing health effects were caused by exposure during the accident (as opposed to other environmental or genetic factors), state tort law governing the degree of proof of causation required to establish entitlement to compensation may result in the denial of compensation to individuals with latent health effects. Whether stress may be treated as a compensable injury varies under state law.

Any resolution of the issues of timing of compensation and burden of proof requires judgments on three related questions of policy: (1) whether to provide compensation immediately following the accident to all those exposed or to defer compensation until it can be determined which of the individuals exposed actually develop health problems related to the incident, (2) what degree of proof claimants should be required to meet to establish the requisite causation between their injuries and the incident, and (3) what constitutes compensable injury within the meaning of full compensation.

The current Price-Anderson scheme has resolved many, but by no means all, of these fundamental issues. While it leaves to state tort law the basic question of whether a legally cognizable injury has occurred, this policy is tempered by the waivers of defenses, which effectively impose strict liability and nullify statutes of limitations which would bar latent health effect claims. It leaves to state law, however, the issues of the nature of the injuries to be compensated, the degree of proof required to establish the requisite causation, and the nature and extent of damages recoverable (except to the extent that the 1988 Amendments imposed a prohibition on the payment of punitive damages).[144] For example, not all states recognize emotional distress as a compensable injury, and most state tort laws require the plaintiff to establish causation by a preponderance of the evidence. Recovery under state tort law is generally limited to recovery of money damages; provision of non-pecuniary damages such as medical monitoring for those exposed as a result of the incident is not ordinarily available.

While the present Act provides no specific authorization for the compensation of claims arising out of latent heath effects, it does assume that latent injury will be included in public liability. Under Section 170(o)(1)(C) the Commission must submit to the court having jurisdiction over an action where public liability may exceed the limitation of liability, a plan for disposition of funds which

> . . . include[s] an allocation of appropriate amounts for personal injury claims, property damage claims, <u>and possible latent injury claims which may not be discovered until a later time</u> and shall include establishment of priorities between claimants and classes of claims, as necessary to insure the most equitable allocation of available funds. [Emphasis added]

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[143] See footnote 126.

[144] See Section 1.2.2 above for discussion of punitive damages.

In recognition of the need to address these issues, Congress included in the 1988 Amendments a requirement that the President establish a commission "to study means of fully compensating victims of a catastrophic nuclear accident that exceeds the amount of aggregate public liability." That commission was charged with addressing the following three issues:

(1) recommendations for any changes in the laws and rules governing the liability or civil procedures that are necessary for the equitable, prompt, and efficient resolution and payment of all valid damage claims, including the advisability of adjudicating public liability claims through an administrative agency instead of the judicial system

(2) recommendations for any standards or procedures that are necessary to establish priorities for the hearing, resolution, and payment of claims when awards are likely to exceed the amount of funds available within a specific time period, and

(3) recommendations for any special standards or procedures necessary to decide and pay claims for latent injuries caused by the nuclear incident

The report of the Commission was published in August, 1990.[145] Its conclusions and recommendations are summarized below.

The Presidential Commission considered a full range of options to address the issue of causation of latent illness. These included: (1) making immediate but small payments following the incident to everyone exposed based on a theory of increased risk; (2) relaxing traditional requirements as to proof of causation and permitting payment to any one exposed who later developed cancer; (3) retaining current law requiring the claimant to prove causation by a preponderance of the evidence, and (4) adopting a probability of causation approach, which would allow full recovery if probability was established by a preponderance of the evidence, and partial recovery based on a lesser evidentiary standard as to causation.

Increased Risk

The Presidential Commission rejected this option as a comprehensive solution because it would result in small payments both to individuals who never developed cancers and to those who did, resulting in a windfall to the former and a shortfall to the latter, who would not be compensated fully. It did conclude that certain immediate non-monetary relief, such as counseling and medical monitoring of those exposed at a certain level, would be appropriate.[146]

Relaxation of Requirements of Proof of Causation

Citing the proportion of the U.S. population which eventually develops some form of cancer, the Presidential Commission concluded that this option would be excessively expensive unless benefits were capped at a level that would fail to cover the costs of medical treatment. It also concluded that relaxation of requirements of

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[145] *Report to the Congress of the Presidential Commission on Catastrophic Nuclear Accidents*, Volume One (the "*Presidential Commission Report*").

[146] *Presidential Commission Report* at pp. 9, 74, 82, 88-91, 102, and 107.

proof would be contrary to the policy underlying amendments to the Price-Anderson Act beginning in 1975.[147] That policy is that the costs of nuclear power should be internalized by putting responsibility for absorbing the actual costs of producing nuclear power on the industry and its rate payers.[148] Relaxation of the degree of proof required to establish causation would result in the industry's absorption of costs for cancers it had not caused, thereby artificially inflating, rather than internalizing, the cost of producing nuclear power.

Retention of Current Law

Retention of current law, on the other hand, would not, in the opinion of the Presidential Commission, be consistent with the charge contained in the 1988 Amendments that it recommend special standards or procedures necessary to decide and pay claims for latent injuries.

The Presidential Commission concluded that application of existing law would lead to the rejection of many deserving claims.[149] Under the law of most states the plaintiff must sustain two burdens of proof: that of going forward with the evidence and that of persuasion. The first burden is not difficult to meet; the plaintiff must merely allege sufficient facts to make out a *prima facie* case. The second burden, however, generally requires the plaintiff to establish the case by a preponderance of the evidence, that is to show it is more likely than not that the facts were as alleged. The elements of a tort claim for personal injury include establishing the injury itself and that the defendant's conduct was the cause of the injury. Individuals suffering latent health effects would have great difficulty in establishing the latter requirement of causation by a preponderance of the evidence.[150]

Probability of Causation Approach

To avoid the problem of establishing causation under current law, some commentators have suggested that the plaintiff's burden of proof be modified by shifting the burden to the defendant after the plaintiff has introduced all the facts which he can reasonably be expected to have access to, or through the use of presumptions.[151] After reviewing various of these alternatives, the Presidential Commission concluded that the method best suited to carry out the purposes of the Act was application of a technique which has come to be known as probability of causation. Under this technique, causation is attributed by weighing such factors as level of exposure, age, sex, personal habits, the type of cancer, and the latency period. Tables have been prepared by the National Institutes of Health of the Department of Health and Human Services pursuant to unrelated legislation but with the anticipation that they would be used to implement later enacted legislation relating to injury caused by

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[147] Id. at 107-108.

[148] See, Rockett, Laurie R., *Issues of Financial Protection in Nuclear Activities* at 4-6 through 4-7 (Columbia University 1973); Rockett, Laurie R. *Financial Protection Against Nuclear Hazards; Thirty Years' Experience under the Price-Anderson Act* at 80-82.(Columbia University 1984).

[149] *Presidential Commission Report* at 108.

[150] These issues are discussed more fully in the NRC's Report to Congress published in December 1983 prior to the enactment of the 1988 Amendments. See *The Price-Anderson Act - The Third Decade* at D-12 through D-15

[151] Ibid.

radiation exposure.[152] These tables could be used to establish the probability that a certain cancer was caused by the nuclear incident. Recovery would then be made on the basis of the degree of probability established; below a certain level of probability no recovery would be allowed, above that level awards would be made at a level proportionate to the degree of probability assigned. The Presidential Commission acknowledged that adoption of a plan of compensation incorporating a probability of causation approach would require a departure from common law tort principles and adoption of a federal standard to be applied consistently to all claims.[153]

3.2 Issues Raised by International Agreements: The Convention on Supplementary Compensation for Nuclear Damage

The Convention on Supplementary Compensation for Nuclear Damage (the Convention) is a new international convention on civil nuclear liability that in large part is modeled after the Paris and Vienna Conventions on Nuclear Liability, which were in turn rooted in the earlier Price-Anderson Act. The subject matter of the new Convention overlaps and has provisions that replicate many of those in Price-Anderson. Thus, if the U.S. intends to ratify the new Convention, the terms of that Convention are relevant to the subject of continuing or modifying the Price-Anderson Act. The Convention does not conflict with Price-Anderson provisions in any significant way.

The Convention was adopted, after extensive negotiations in which the U.S. actively participated, by a Diplomatic Conference convened by the International Atomic Energy Agency (IAEA) in September 1997 and was opened for signature on September 29, 1997 during the IAEA General Conference. The U.S. led the way in signing the Convention at that time. The Convention provides for entry into force after ratification by five States with at least 400,000 megawatts of installed nuclear capacity among them. The entry-into-force requirements were deliberately drafted to allow the Convention to enter into force if the U.S., Russia, and Ukraine, along with any two other States ratify the Convention.

3.2.1 Summary of Provisions

The Convention, which covers only civilian nuclear matters, establishes a framework for member parties to address legal issues that would arise if a significant nuclear accident occurs. In sum, the Convention designates a single legal forum for suit (except in certain specified and unusual circumstances, the courts of the Party within which the incident occurs), channels financial and legal responsibility to a single source (the "operator"), establishes a minimum level of funds (which the U.S. far exceeds under the Price-Anderson Act) that each Party which is the "installation" State of one or more nuclear facilities must ensure is available in the event of a nuclear incident in that State, and provides the mechanism for the Parties to contribute to a contingent international fund to be constituted if needed to supplement compensation available to victims pursuant to the incident nation's domestic law in the event of a nuclear accident. The accidents covered are essentially those that take place within a member nation or, for example, in a transportation accident when the operator is a national of a member nation.

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[152] See the *Presidential Commission Report*. at p. 109 and fns. 27 and 28.

[153] Id. at pp. 3, 10.

The Convention establishes two legal criteria that must be met in order for a nation to be eligible to join. One criterion is that the country, if it has any nuclear facilities, must be a Party to the Convention on Nuclear Safety. The other criterion pertains to the country's domestic nuclear liability system and is designed to ensure that all Parties to the Convention incorporate into their domestic nuclear liability systems the three fundamental principles of international nuclear liability law, which were spawned by the Price-Anderson Act, namely (1) channeling to the facility operator the obligation to compensate in damages; (2) ensuring the availability of funds (by public funds if necessary) to fulfill the operator's obligations up to the allowed limit of liability, and (3) dispensing with the need to prove fault (i.e., strict liability) on the part of the operator. A State may satisfy this criterion by being a Party to and in compliance with either the IAEA's 1963 Vienna Convention on Civil Liability for Nuclear Damage or the OECD's 1960 Paris Convention on Third Party Liability in the Field of Nuclear Energy, or by having in place domestic nuclear liability statutes that conform to the provisions set forth in the "Annex" to the Convention. To preserve the indemnification system of channeling liability to the operator under the Price-Anderson Act which neither the Vienna nor the Paris Conventions have incorporated, the U.S. would necessarily become a Party to the Convention through the Annex. The Annex contains a "grandfather clause" that was specifically designed to allow the U.S. to join the Convention without altering the Price-Anderson Act as it currently exists (Non-nuclear nations must accept the jurisdictional provisions, limits of liability, and the like, but need not legislate provisions that would be meaningless in the absence of nuclear facilities.)

Other significant aspects of the Convention include the following:

- The Parties' obligations to contribute to the supplementary international fund are triggered only if the incident State's funds are insufficient for compensation of the nuclear damage. The contribution amounts are determined pursuant to a formula relating to each Party's installed nuclear capacity and the United Nations rate of assessment. The potential contribution of the U.S. is "capped" (except for accidents within the U.S.) to prevent a disproportionate burden being placed on the U.S., especially in the early phases before there is a broad membership by the large nuclear nations.

- The international supplementary fund is tilted toward transboundary damage: half of the international supplementary fund would be made available to compensate claims for nuclear damage suffered both in and outside the incident State without discrimination, and the other half would be available for compensation of claims only for nuclear damage suffered outside the territory of the incident State(i.e., transboundary damage).

- There is no provision in the Convention that would require U.S. civil nuclear operators to bear any financial burden. The Convention leaves the Parties, including the U.S., free to determine through domestic legislation how each would provide for the international supplementary fund if the obligation were triggered. It is anticipated that the Executive Branch will submit implementing legislation with the Convention that provides the means to raise the funds if needed. A likely approach will seek to place the burden chiefly on the U.S. firms benefitting from the Convention (i.e., those engaged in the sale of nuclear power generating equipment and technology outside the U.S.), perhaps through insurance requirements.

3.2.2 Significance to the Price-Anderson Act

As noted above, the Convention contains a "grandfather" provision that permits the U.S. to become a Party without amending the Price-Anderson Act's idiosyncratic provisions, designed to accommodate our federal system. Thus, virtually no changes in the Price-Anderson Act are required for the U.S. to join the Convention. The Convention does introduce a few conceivable, potential U.S. obligations with respect to nuclear incidents over which the U.S. courts would have jurisdiction but which would not currently be covered by the Price-Anderson Act because they would occur in areas outside the U.S. territorial limits (e.g., the U.S. Exclusive Economic Zone). In the absence of Price-Anderson Act coverage, U.S. nuclear incidents in such areas would be covered by self-executing nuclear liability provisions set forth in the Convention's Annex. Thus, there may be some incentive for the Congress to consider adopting and including new provisions for this coverage in any amendment to the Price-Anderson Act in order to have codified in one place the entire legal system for U.S. civil nuclear liability. On the other hand, Congress could await ratification to consider whether it would prefer to amend Price-Anderson or to accept the Annex's self-executing provisions.

Any modifications to the Price-Anderson Act would necessarily have to take into account the U.S. obligations under the Convention. However, so long as Congress renews Price-Anderson's overarching principles, joining the Convention would not restrict Congressional action. The Convention generally permits great flexibility in the specific terms of national law and even greater flexibility to the United States under the "grandfather" clause. The U.S. leadership in reaching a diplomatic conference as well as the signing of the Convention by the U.S. sent a clear message to the international community that the U.S. intends to take actions leading to the Convention's ratification. Failure to extend the Price-Anderson Act to cover future as well as existing plants would be inconsistent with ratification and disturbing to other signatories and the interested international community.

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PART 4: CONCLUSIONS AND RECOMMENDATIONS

Protection of the public has been a principal purpose of Price-Anderson along with permitting the nuclear energy option as a private commercial endeavor. The statutory scheme of indemnification and/or insurance has been intended to ensure the availability to the public of adequate funds in the event of a catastrophic, yet unlikely, nuclear incident. Other benefits to the public include such features as emergency assistance payments, consolidation and prioritization of claims in one court, channeling of liability through the "omnibus" feature, and waiver of certain defenses in the event of a large accident. The system has removed the deterrent to private sector participation in nuclear power programs by reducing the probability of financial catastrophe for industry participants due to liability resulting from a nuclear accident. The structured payment system of billions of dollars created to meet the two objectives stated in the Act has been successful. It has operated for over 40 years with minimal cost to the taxpayer.

If a large accident were to occur, Congress recognized initially in 1957 and throughout the various extensions of the Act that a single utility reactor licensee probably could not meet the costs of such an accident. During consideration of the last extension, the Senate Energy Committee summarized this point as follows:

> In general, failure to extend the Price-Anderson Act would result in substantially less protection for the public in the event of a nuclear incident. In the absence of the Act, compensation for victims of a nuclear incident would be less predictable, less timely, and potentially inadequate compared to the compensation that would be available under the current Price-Anderson system.[154]

Further, the Price-Anderson Act has since 1975 specifically provided that, in the event of a nuclear incident involving damages in excess of the statutory liability limit, Congress would thoroughly review the particular incident and take whatever action is deemed necessary and appropriate to protect the public from the consequences of a disaster of such magnitude. This Congressional commitment was reiterated and strengthened in 1988.

As was discussed in detail in this report, the Price-Anderson system has functioned well in connection with the payment of claims arising out of the Three Mile Island accident in 1979, the only major accident situation where it was called upon. Because of the 1975 Amendments, government indemnity has been essentially phased out for large power reactors. The principal changes brought about by the 1988 Amendments related to an increase in the overall limitation of liability, coverage for "precautionary evacuations," and some clarification of costs for investigating, settling, and defending claims. These 1988 Amendments substantially increased the limits of liability and also indexed the retrospective premium to inflation.

4.1 Continuing Industry and Public Need for Price-Anderson

When the Act was first enacted in 1957, nuclear power was in its early stages of conversion from a federal government monopoly to government-encouraged private enterprise. The Act was intended to overcome reluctance to participate by the nascent industry worried by the possibility of catastrophic, uninsured claims resulting from a large nuclear accident. Congress was also concerned with the prospect of delays or failures in providing compensation to the public for injuries and damages caused by such accidents. By 1965, when the first

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[154] 1987 Senate Energy Committee report, at 18.

10-year extension of the Act was being considered, a handful of nuclear power reactors was coming into operation, and the nuclear industry considered itself on the verge of expanding into large-scale nuclear power generation. Thus, the need for continued operation of the Price-Anderson system for the forthcoming 10 years was believed to be critical for the unrestricted development of nuclear power.

By the time the second extension of the Act was being considered in 1974 and 1975, the construction and operation of utility-owned nuclear power was in large-scale development with dozens of plants in operation or under construction and with hundreds more being contemplated to be in operation by the end of the century. The industry urged not only that the Act be extended but also that this action be taken by Congress as early as possible so that any uncertainty about extension would not disrupt nuclear power development.

Another key element in the decisions to extend the Price-Anderson Act in 1965, in 1974-1975, and in 1988, was the belief that the Act provides an essential mechanism for ensuring the prompt availability and equitable distribution of funds to pay public liability claims in the event of a nuclear accident.

With respect to future power plants, the nuclear industry in the mid-1990s contrasts greatly with the industry in the periods of the earlier extensions of Price-Anderson. Industry views of its financial situation are mixed. Some feel that although there have been recent gains in efficiency, the industry faces long-term difficulties in load growth and regulatory and political climate. Many nuclear suppliers express the view that without Price-Anderson coverage, they would not participate in the nuclear industry. Given industry perception of the continuing need for Price-Anderson and in view of the lack of new orders in plants, the situation is in some respects similar to what it was when Congress saw the need for enactment of the original Price-Anderson Act. A primary difference, however, is that in 1957, the nuclear industry was in the development stages of the technology whereas it is now well beyond those stages.

It cannot be said at this point that a failure to extend the Price-Anderson Act for new facilities beyond August 1, 2002, would, in and of itself, foreclose construction that would otherwise be undertaken. It is also uncertain whether extension of Price-Anderson would be necessary to a renewal of utility interest in nuclear technology. However if additional plants are constructed after August 1, 2002, a failure to extend the Act would deny the public protection benefits of the Act for those plants.

In considering the future direction of the Price-Anderson Act, the Congress has before it a range of possible actions from termination of the Act (which would not terminate Price-Anderson coverage in connection with currently licensed facilities) to its extension unchanged. Modifications could be made to the system for existing facilities and for new units for which no financial commitments have yet been made. Alternatively, Congress could leave the present program intact for existing and future licensees. Congress also has the option of waiting to take action for future licensees until such time as renewed nuclear power programs develop. The present situation regarding future nuclear power plant development allows ample time to permit congressional review of the future direction of the Act. However, the Commission believes that in view of the strong public policy benefits in ensuring the prompt availability and equitable distribution of funds to pay public liability claims, the Price-Anderson Act should be extended to cover future as well as existing nuclear power plants. The Commission believes that the same amount, type, and terms of public liability protection should be provided for future and existing plants. Regardless of the degree of early retirement of nuclear reactors, Price-Anderson will continue to make a large sum of funds available to victims of nuclear incidents for at least the next decade.

4.2 Current Knowledge of Nuclear Safety

During the consideration of the Price-Anderson Act in the 1950s and its two extensions in the 1960s and 1970s, new studies of nuclear safety and the probability and consequences of nuclear accidents were produced. Reports such as WASH-740 and WASH-1400 (Reactor Safety Study) entered the nuclear and even the public jargon, as these and other safety studies were used both to support and to refute the need for the Price-Anderson system.

By the mid-1980s, the technology for analyzing the physical processes of severe accidents evolved to the point that researchers developed a new computational model of severe accident physical processes, the Source Term Code Package. Meanwhile, the NRC developed general procedures for performing probabilistic risk assessments (PRAs) and approved policy guidance on how the NRC was to assess severe accident risks. The Commission also established safety goals as a general guide for assessing these risks and analytical methods by which to evaluate potential safety improvements.[155]

In 1990, the NRC issued NUREG-1150[156] as an update of the Reactor Safety Study. In NUREG-1150, the NRC used improved PRA techniques to assess the risk associated with five nuclear power plants, including the two plants originally evaluated in WASH-1400. The study was a significant turning point in the use of risk-informed concepts in the regulatory process and enabled the Commission to greatly improve its methods for assessing containment performance after core damage and accident progression. The methods developed for and the results produced by NUREG-1150 provided a valuable foundation in quantitative risk techniques.

While, in general, the central estimates (means, medians) of the accident frequency distributions reported in NUREG-1150 are lower in magnitude than those predicted in earlier studies such as WASH-1400, the uncertainty ranges remained large. In fact, NUREG-1150 advised readers to view the core damage frequencies below 1×10^{-5} per reactor year with caution because of the remaining uncertainties (e.g., events not considered) in PRA itself.

At this point, the interaction between nuclear accident risk and Price-Anderson can still be summarized as follows: Although the two layers of insurance should provide sufficient liability protection for most postulated nuclear power plant accidents, there remains a very low probability of a very high-consequence accident that could result in public liability claims well in excess of the present and projected amounts of nuclear liability insurance. The postulated release of radiation from nuclear cores under various accident situations is under active study. Whether resolution of this core release fraction, or "source term," issue will change this statement about risk and Price-Anderson (with respect to any accident having major offsite radiological consequences) is not now established.

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[155] U.S. Nuclear Regulatory Commission, "Safety Goals for the Operation of Nuclear Power Plants: Policy Statement," 51 FR 30028, August 21, 1986.

[156] U.S. Nuclear Regulatory Commission, *Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants*, NUREG-1150, December 1990.

4.3 Causality and Proof of Damages

Since the last NRC Report to Congress on the Price-Anderson Act, the knowledge base for identifying biological effects, including latent effects, and other indicators of radiation exposure has expanded enormously. Overall, these developments have resulted in a narrowing of the uncertainties surrounding dose-response estimates for radiation, particularly in the high dose, high dose rate regime. For example, progress made in our understanding of the genetic mutation process significantly reduces the uncertainties inherent in the current animal-to-human extrapolation models that have been used to estimate heritable risks from radiation. Notwithstanding the overall reduction in uncertainties over time, however, our confidence in other areas may have decreased somewhat. For example, assumptions regarding whether the existing low-dose extrapolation model for radiation cancer risk should remain a linear non-threshold model have come under increased scrutiny lately.

A significant change that has occurred since publication of the 1983 Report to Congress is the overall increase in the estimate of lifetime cancer risk attributable to a given radiation dose in the high dose, high dose rate regime. This increase is due primarily to reassessments of radiation dosimetry at the Hiroshima and Nagasaki atomic bomb sites. Another significant change—attributable both to new studies of the atomic bomb survivors and to advances in biological science—is the ability now to generate estimates of the effects of radiation on the mental development of the fetus.

Notwithstanding these gains in the knowledge base, however, NRC recognizes that much still is unknown about the biological effects of radiation, particularly at low doses and low dose rates. For example, we do not know exactly how a given individual will react to a given type and amount of radiation. Nevertheless, more information probably has been gained on the biological mechanisms and resulting dose-response measures of radiation in the last 15 years than in all previous years combined, at least in terms of relevance to the Price-Anderson Act. NRC expects that this trend will continue for some time. Additional studies, which are underway, may provide additional insights into the health effects of low level radiation exposure.

As discussed in Part 3, the system as it exists today is well able to provide ample and prompt compensation for public injuries and other economic losses directly connected to a serious nuclear accident. The NRC expects that, if a serious accident should occur where latent effects are scientifically shown to be probable, the courts would do their best to satisfy the requirements of Section 170o(1)(C) of the Act that funds be allocated for latent injury claims. Nonetheless, to sustain a claim for damages, there may be difficulties in establishing sufficient proof that latent injuries are, in fact, caused by the nuclear accident.

It is possible to legislate — partially or completely — the allocation of funds for latent injury claims in advance, either by imposing binding criteria on the courts or by removing the issue entirely from the judicial process and establishing a separate administrative system for compensating such injuries. Legislative proposals along these lines have been introduced in recent years for activities not covered by the Price-Anderson Act. Initial efforts are underway in at least one area — possible latent injuries resulting from U.S. atmospheric tests of nuclear weapons — to determine the feasibility of an administrative compensation system utilizing a probability approach for establishing causation. Until additional information is available from these and other efforts, the Commission believes that it is premature to recommend modification of the causation and proof of damages provisions of the Price-Anderson Act.

4.4 Recommendations

(1) The Commission recommends renewal of the Price-Anderson Act because the Act provides a valuable public benefit by establishing a system for the prompt and equitable settlement of public liability claims resulting from a nuclear accident. The Commission further recommends extending the Act for only 10 years to allow Congress to be better able to take account of substantial changes that have begun and will continue within the nuclear power industry. While existing nuclear power plants would remain covered in any event, the Act should be extended to cover future nuclear power plants, and the existing limit of liability provisions should be maintained. Any changes in the Act should also apply to existing nuclear power plants.

(2) The Commission recommends that the Congress consider amending the Price-Anderson Act to raise the maximum retrospective premiums that can be charged from the present $10 million per reactor per incident per year to $20 million per reactor per incident per year. An increase in the size of the annual retrospective premiums to $20 million would substantially increase the amount of funds available shortly after a nuclear accident to pay public liability claims but should not jeopardize the financial viability of the participating utilities. However, deregulation and restructuring within the industry may have some impact on certain licensees' ability to cover such assessments. The total retrospective premium per reactor per incident would remain unchanged.

(3) The Commission does not recommend changes to the causation and proof of damages provisions of the Price-Anderson Act at this time.

(4) The Commission recommends that the Congress consider investigating with nuclear liability insurers the potential for increasing the private insurance capacity made available through the insurance pools for the basic layer of insurance. The Commission notes that this capacity has not kept pace in recent years with inflation.

(5) The Commission recommends that the Congress clarify its intent on the following issues that have been or can be sources of uncertainty in implementing Price-Anderson: The clarification should ensure that:

(a) A nonprofit NRC licensee may not be indemnified for legal costs incurred in connection with the settlement of a claim

(b) The prohibition on payment of punitive damages extends to every case where a defendant is indemnified under Price-Anderson not just where damages would exceed the financial protection and would actually involve the government paying for punitive damages.

(6) The Commission recommends that the Congress should determine whether a public liability lawsuit arising or resulting from a nuclear incident may be filed in a tribal court. Further judicial developments relating to this issue may avoid or suggest consideration in connection with Price-Anderson renewal legislation.

(7) The Commission recommends that any modifications to the Price-Anderson Act should take into account any potential U.S. obligations under the Convention on Supplementary Compensation for Nuclear Damage

(8) The Commission recommends that Price-Anderson implications of any new regulatory responsibility for DOE activities or facilities which Congress may assign to the Commission be addressed by a provision in the enactment creating the Commission's specific authority for that regulation

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APPENDIX A: POTENTIAL FINANCIAL BURDEN OF INCREASING RETROSPECTIVE PREMIUM ASSESSMENTS

When Congress enacted legislation in 1957 to limit liability and indemnify the nuclear power industry, it anticipated a time when its indemnification would no longer be necessary. Requiring reactor units to be insured to the maximum available level of primary insurance, Congress gradually reduced its indemnification. A more dramatic reduction occurred in 1975 when Congress required utilities to implement retrospective, or "secondary," insurance in addition to the maximum available level of primary insurance. As a consequence, Congress reduced indemnification and provided for increased insurance coverage. However, retrospective insurance poses a potential expense for utilities that might significantly affect a company's finances. In 1982, Congress recognized this and limited the maximum annual payment to a non-inflation adjusted $10 million.[157]

In past Reports to Congress, NRC studied different levels of retrospective assessments and utilities' ability to afford such assessments. A report prepared by Professor Melicher of the University of Colorado in 1976 established a template that has been updated at regular intervals, including 1979, 1983, and, most recently, 1998. This appendix presents the results of the 1998 analysis.

A.1 Background Explanation of Melicher Study

In 1976, NRC published a research report prepared by Professor Ronald W. Melicher of the University of Colorado entitled "Financial Implications of Retrospective Premium Adjustments on Electric Utilities."[158] The report evaluated the possible financial consequences if utilities were required to pay retrospective premiums for nuclear liability insurance. Using four utilities producing electricity from nuclear power, Professor Melicher estimated the financial impacts of assessing retrospective premiums of $3 and $5 million during 1975. He concluded that each utility would have been able to pay either of the retrospective premiums without suffering undue financial stress. This finding substantiated the viability of the retrospective insurance program, because the utilities would be able to meet their financial obligations. Furthermore, during hearings before the Joint Committee on Atomic Energy in 1976, a Vice President and Division Executive of the Public Utilities Department, Chase Manhattan Bank, testified that he would feel at ease even with a $10 million per reactor unit retrospective premium.[159]

In 1979, NRC staff applied Melicher's methodology to 1978 operating data from the same four utilities that were used in the 1976 report. The NRC had three reasons for the update:

(1) to test Professor Melicher's conclusions using 1978 utility operating results;

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[157] Restricting annual payments to a non-inflation adjusted $10 million spreads retrospective assessments over longer time periods thereby lengthening the payment period and mitigating the annual financial effects of the total assessment.

[158] NR-AIG-003, September 1976.

[159] "To Consider Whether Financial Risk to Utilities Under the Price-Anderson Act Should Be Increased," Hearings before the Joint Committee on Atomic Energy, March 3, 1976, 94th Congress, 2nd Session, p. 14.

(2) to reflect the number of operational reactors owned by each of the four utilities;[160] and
(3) to determine the financial effects of larger retrospective insurance premiums.

The 1979 NRC update of the Melicher study corroborated many of the original report's conclusions. Specifically, the update concluded that assessments of $3, $5, and even $10 million per incident, per reactor unit could be absorbed without significant hardship. The update questioned, however, the ability of some nuclear utilities to pay substantial assessment levels without resorting to capital markets. Furthermore, the NRC staff study observed that "On balance, it appears that although a $10 million assessment could be managed by the four respective utilities, a $20 million assessment might be marginal."[161]

The 1983 Report to Congress further evaluated when retrospective assessment levels become financially burdensome. It reapplied the Melicher method using 1981 operating data from the same four utilities previously studied. The 1983 analysis evaluated retrospective assessment levels of $5, $10, $20 and $50 million. It found that a $5 or $10 million assessment had little measurable impact; the $20 million level had some significant impacts; and $50 million would pose difficulties, especially for Commonwealth Edison.

The 1998 analysis similarly evaluates the affordability of retrospective assessment levels (i.e., when a utility experiences either financial distress or is unable to meet its financial obligations). It also examines whether current retrospective assessment levels (i.e., total and maximum annual) are too low and could be increased to provide enhanced liability protection, without causing any undue financial burdens. These questions are answered by using:

- data from 1996 SEC 10-K financial statements
- the Melicher method, as updated in 1983.

This analysis is intended solely to update the previous analyses as a way to estimate the affordability of alternative retrospective insurance premiums.

A.2 Analysis of 1996 Financial Data Using of Professor Melicher's Methodology

The 1998 analysis considers larger retrospective insurance premiums than were evaluated in earlier analyses. The amounts range from a lower bound of $5 million, as used in 1983, to an upper bound of $150 million. This range brackets the levels used in previous analyses, tests utilities' ability to meet the existing maximum annual assessment of $10 million, and determines whether utilities might be able to afford larger maximum annual premiums.

The following utilities were included in the 1983 and prior analyses:

- Duquesne Light
- Public Service Company of Colorado

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[160] Melicher's original study assumed each utility was responsible for a single power reactor unit.

[161] *1983 Report to Congress*, Appendix H, p. 2

- Northern States Power of Minnesota
- Commonwealth Edison.

However, since the 1983 Report to Congress, three changes occurred with these four utilities: (1) Public Service of Colorado is no longer a licensee; (2) Duquesne Light is now a wholly-owned subsidiary of DQE, has announced a merger with Allegheny Energy, and is separating its generation business from its transmission and distribution businesses; and (3) Commonwealth Edison is now a wholly-owned subsidiary of Unicom. When the Fort St. Vrain reactor unit finished decommissioning in 1996, Public Service Company of Colorado no longer owned an operating nuclear power reactor unit. This analysis includes instead Duke Power, which helps provide a more representative sample of the nuclear power industry. In addition, because Commonwealth Edison is now part of Unicom, with the greatest percentage of Unicom's holdings being the old Commonwealth Edison, Unicom's financial data have been substituted for those of Commonwealth Edison because Unicom is the new owner. Similarly, the analysis used financial data for DQE, with Duquesne Light providing the majority of the revenues and earnings.

Exhibit A-1 presents selected data from SEC 10-K financial statements for the four utilities included in this analysis. The Melicher method focuses on three financial indicators: earnings per share, interest coverage, and return on equity. Earnings per share is calculated by dividing earnings available to common stock shareholders (i.e., after preferred stock dividend payments) by the number of common stock shares outstanding. Interest coverage is the sum of net income and interest expense divided by interest expense.[162] Return on common equity is earnings available to common stock shareholders divided by common equity.

Exhibit A-2 shows the effects of different assessment levels on the financial indicators for the four utilities. The results in Exhibit A-2 are calculated as follows:

- Earnings before taxes are reduced by the assessment level (e.g., \$5, \$10, \$20, \$50, \$80, \$100, \$120, and \$150 million) multiplied by the number of reactor units owned by the utility.

- Effective taxes are the product of the 1996 effective tax rate and earnings before taxes.

- Net income is calculated by reducing earnings before taxes in proportion to the utility's effective tax rate. Net income is calculated for each assessment level and determines the financial impacts shown in Exhibit A-2.

Exhibits A-3 and A-4 present the information in Exhibit A-2 in terms of the percent reduction in earnings and interest coverage. As shown, the latter is a less sensitive indicator than the former. In terms of impacts on earnings, substantial effects appear at the \$50 million level of assessment.

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[162] Typically, interest coverage ratios are calculated by dividing *earnings before interest and taxes* by *interest expense*. This analysis, in order to be consistent with previous NRC studies, has instead used *net income plus interest expense* divided by *interest expense*.

Exhibit A-1 Selected data from 1996 sec 10-k financial statements ($ millions)

	Duquesne Light	Duke Power	Northern States Power (MN)	Unicom
Total operating revenue	1176.83	4757.97	2654.21	6937
Earnings before interest and taxes	327.58	1362.21	592.51	1651.94
Interest expense	88.86	156.55	141.96	488.48
Earnings before taxes	237.58	1205.66	450.55	1163.46
Income taxes	87.72	475.69	176.01	497.36
Net income	149.86	729.97	274.54	666.1
Preferred stock dividends	4.05	44.25	12.245	64.42
Earnings available to common shareholders	145.81	685.72	262.295	601.68
Common equity	989.42	4888.72	2135.88	6104.38
1996 effective income tax rate	37%	39%	39%	43%
Number of common stock shares outstanding (millions)	90	201.59	68.68	216.11
Earnings per share*	1.62	3.40	3.82	2.78
Interest coverage (net income plus interest/interest)	2.69	5.66	2.93	2.36
Return on common equity	15%	14%	12%	10%
Number of reactors currently owned	0.75	5.13	3	11.5

* Earnings per share in dollars.

Exhibit A-2 Financial impacts of different amounts of assessments (i.e., pre-tax expense)

Assessments	Duquesne Light	Duke Power	Northern States Power (MN)	Unicom
$5 million per reactor				
earnings per share	1.59	3.32	3.69	2.63
interest coverage	2.66	5.56	2.87	2.30
return on common equity	14%	14%	12%	9%
$10 million per reactor				
earnings per share	1.57	3.25	3.55	2.48
interest coverage	2.63	5.46	2.81	2.23
return on common equity	14%	13%	11%	9%
$20 million per reactor				
earnings per share	1.52	3.09	3.29	2.17
interest coverage	2.58	5.27	2.68	2.09
return on common equity	14%	13%	11%	8%
$50 million per reactor				
earnings per share	1.36	2.63	2.49	1.26
interest coverage	2.42	4.67	2.29	1.69
return on common equity	12%	11%	8%	4%
$80 million per reactor				
earnings per share	1.20	2.17	1.69	0.35
interest coverage	2.26	4.08	1.90	1.29
return on common equity	11%	9%	5%	1%
$100 million per reactor				
earnings per share	1.09	1.86	1.16	-0.26
interest coverage	2.15	3.68	1.65	1.02
return on common equity	10%	8%	4%	-1%
$120 million per reactor				
earnings per share	0.99	1.55	0.63	-0.87
interest coverage	2.05	3.28	1.39	0.75
return on common equity	9%	6%	2%	-3%
$150 million per reactor				
earnings per share	0.83	1.09	-0.17	-1.79
interest coverage	1.89	2.69	1.00	0.34
return on common equity	8%	5%	-1%	-6%

Exhibit A-3 Percent reduction in earnings per share after assessing retrospective premiums[*,]**

Assessments ($ millions)	Duquesne Light	Duke Power	Northern States Power (MN)	Unicom
5	1.62%	2.26%	3.48%	5.47%
10	3.24%	4.53%	6.97%	10.94%
20	6.49%	9.05%	13.94%	21.89%
50	16.22%	22.63%	34.85%	54.71%
80	25.95%	36.20%	55.76%	87.54%
100	32.44%	45.25%	69.69%	>100%
120	38.92%	54.30%	83.63%	>100%
150	48.65%	67.88%	>100%	>100%

[*] The percentage reduction in earnings per share is derived by subtracting the initial earnings per share in Exhibit A-1 from the post-assessment earnings per share in Exhibit A-2 and dividing the resulting number by the initial earnings per share in Exhibit A-1. This number is then multiplied by 100.

[**] These percentages affected by rounding error.

Exhibit A-4 Percent reduction in interest coverage after assessing retrospective premiums[*,]**

Assessments ($ millions)	Duquesne Light	Duke Power	Northern States Power (MN)	Unicom
5	0.99%	1.75%	2.19%	2.85%
10	1.98%	3.50%	4.39%	5.70%
20	3.96%	7.00%	8.78%	11.40%
50	9.91%	17.50%	21.95%	28.51%
80	15.85%	28.00%	35.11%	45.62%
100	19.81%	35.00%	43.89%	57.02%
120	23.77%	42.00%	52.67%	68.43%
150	29.72%	52.50%	65.84%	85.54%

[*] The percentage reduction in interest coverage is derived by subtracting the initial interest coverage in Exhibit A-1 from the post-assessment interest coverage in Exhibit A-2 and dividing the resulting number by the initial interest coverage in Exhibit A-1. This number is then multiplied by 100.

[**] These percentages affected by rounding error.

The 1983 Report to Congress demonstrated financial distress at assessment levels between $10 and $20 million (i.e., between $16 and $32 million in 1996 dollars). By comparison, this analysis shows that three of the four utilities face minimal financial stress up to a $50 million assessment, using the 1983 Report to Congress criteria. All utilities but Unicom maintain acceptable returns on common equity and interest coverage up to $50 million in annual premium assessments. At an $80 million assessment level Duquesne Light and Duke Power maintain interest coverage ratios in excess of a minimally acceptable 2.0. At assessment levels of $150 million, both the interest coverage and earnings per share impacts are at levels probably considered unacceptable for three of the four utilities.

In Exhibit A-5, cash flow data[163] from SEC 10-K financial statements are presented for each of the four utilities. Net cash flow is the difference between the sources of funds from operations and the application of funds. Net cash flow is calculated for each assessment level using the net income associated with that assessment level (consistent with Exhibit A-2). Cash flow per share is net cash flow divided by number of common stock shares outstanding.

These data are used in Exhibit A-6 to evaluate how the net cash flow and cash flow per share indicators are affected by different retrospective assessment levels. Because Unicom owns and operates 11.5 reactor units, its cash flow is the most affected of the four utilities. In total dollars, Unicom's cash flow declines the furthest (i.e., $37.5 million) when assessed the $5 million premium.[164] But Unicom is also the utility with the greatest cash flow and is therefore best able to meet its financial obligations within a fiscal year.

Exhibit A-7 extends the results from Exhibit A-6 by presenting the percentage changes in net cash flow associated with the different levels of assessments. Exhibit A-7 demonstrates that while Duquesne Light may be stressed by a $5 million premium, Unicom can cover a premium assessment thirty times higher. Exhibit A-7 shows that when comparing the effect of a $5 million premium across utilities, only Duquesne Light would see a reduction of more than two to three percent in net cash flow. Of the three utilities well able to pay premium assessments in excess of $5 million out of net cash flow, Northern States Power experiences a larger percentage reduction in net cash flow than does either Duke Power or Unicom. Three (i.e., Duke Power, Northern States Power, and Unicom) of the four utilities examined could meet a $150 million annual premium assessment without exhausting net cash flow.

Exhibit A-8 shows for each assessment level the number of reactor units that could be covered by net cash flow. Generally, the number of reactor units that can be covered by each utility is approximately halved with each doubling of the assessment. Except for Duquesne Light, the utilities would be able to cover a substantial number of additional reactors at the $5 million assessment. At levels up to $150 million, the three utilities have sufficient net cash flow to more than cover their pro rata shares, based on reactor ownership.

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[163] A utility's cash flow is one indicator of its ability to pay retrospective premiums. If a utility has sufficient cash flow, it can theoretically pay an assessment in cash rather than resorting to capital markets to finance the assessment. The NRC is mandated by 10 CFR 140.21 to review annually each licensee's ability to guarantee payment of retrospective premiums. In this process, the most common supporting evidence supplied by licensees is the ability to generate sufficient cash flow.

[164] The premium is a "before-tax expense" thus even though 11.5 multiplied by $5 million is $57.5 million, the net effect on the utility is $37.5 million.

Exhibit A-5 Selected cash flow data from 1996 SEC 10-K financial statements*

	Duquesne Light	Duke Power	Northern States Power (MN)	Unicom
Sources of Funds from Operations:				
Net income	149.86	729.97	274.54	666.10
Depreciation and amortization	216.34	667.71	335.61	990.78
Capital lease, nuclear fuel and other amortization	24.00	57.64	45.77	-20.78
Deferred income taxes and investment tax credits	-98.87	-27.64	-39.91	129.77
Changes in working capital other than cash	-20.87	7.60	-71.54	126.19
Other	11.18	47.38	0.00	67.80
Net cash provided by operating activities	281.64	1482.66	544.47	1959.86
Application of funds:				
Preferred stock dividends	4.05	44.25	12.25	64.42
Common stock dividends	276.00	419.31	187.52	344.55
Total dividends on capital stocks	280.05	463.56	199.77	408.97
Estimated net cash flow (i.e., sources less applications)	1.59	1019.10	344.70	1550.89
Cash flow per share	0.02	5.06	5.02	7.18
Number of common stock shares outstanding (millions)	90.00	201.59	68.68	216.11

* Data in the exhibit do not include cash flows that are generally of a non-recurring nature (e.g., cash flows from property sales, construction, investments, and issuance of securities).

Exhibit A-6 Cash flow impacts of retrospective premium assessments

Assessments	Duquesne Light	Duke Power	Northern States Power (MN)	Unicom
$5 million per reactor				
Net cash flow	-0.77	1003.59	335.56	1517.97
Cash flow per share	-0.01	4.98	4.89	7.02
$10 million per reactor				
Net cash flow	-3.14	988.07	326.42	1485.05
Cash flow per share	-0.03	4.90	4.75	6.87
$20 million per reactor				
Net cash flow	-7.87	957.04	308.14	1419.21
Cash flow per share	-0.09	4.75	4.49	6.57
$50 million per reactor				
Net cash flow	-22.06	863.95	253.30	1221.69
Cash flow per share	-0.25	4.29	3.69	5.65
$80 million per reactor				
Net cash flow	-36.25	770.87	198.46	1025.72
Cash flow per share	-0.40	3.82	2.89	4.75
$100 million per reactor				
Net cash flow	-45.71	708.81	161.90	892.50
Cash flow per share	-0.51	3.52	2.36	4.13
$120 million per reactor				
Net cash flow	-55.61	646.75	125.34	760.82
Cash flow per share	-0.61	3.21	1.82	3.52
$150 million per reactor				
Net cash flow	-69.35	553.66	70.50	563.30
Cash flow per share	-0.77	2.75	1.03	2.61

Exhibit A-7 Percent reduction in net cash flow after assessing retrospective premiums[*]

Assessments ($ millions)	Duquesne Light	Duke Power	Northern States Power (MN)	Unicom
5	>100%	1.52%	2.65%	2.12%
10	>100%	3.04%	5.30%	4.25%
20	>100%	6.09%	10.61%	8.49%
50	>100%	15.22%	26.52%	21.23%
80	>100%	24.36%	42.43%	33.86%
100	>100%	30.45%	53.03%	42.45%
120	>100%	36.54%	63.64%	50.94%
150	>100%	45.67%	79.55%	63.68%

[*] The percentage reduction in net cash flow is derived from Exhibit A-5 by subtracting the net cash flow after the assessment from the initial estimated net cash flow and dividing the resulting number by the initial estimated net cash flow. This number is then multiplied by 100.

Exhibit A-8 Possible number of reactors covered by cash flow at various assessments[*]

Assessments per reactor ($ millions)	Duquesne Light	Duke Power	Northern States Power (MN)	Unicom
5	0.5	336.64	113.14	541.78
10	0.25	168.32	56.57	270.89
20	0.13	84.16	28.28	135.45
50	0.05	33.66	11.31	54.18
80	0.03	21.04	7.07	33.96
100	0.03	16.83	5.66	27.09
120	0.02	14.03	4.71	22.57
150	0.02	11.22	3.77	18.06
Number of reactors owned	0.75	5.13	3.00	11.50

[*] Estimated net cash flow of the utility from Exhibit A-5 divided by the after-tax assessment of a single reactor unit.

A.3 Methodology and Data Limitations

When Congress assigns the financial assessment level that reactor units must meet, it is concerned with balancing the need to compensate the American public while not overburdening the utilities owning nuclear power reactor units. Professor Melicher's method is one way to determine the level of assessments that can be borne by utilities without undue financial stress. However, the Melicher method has significant limitations. Its primary limitations include the following:

- representativeness of the sample;
- use of single year versus multi-year assessment test
- appropriate affordability/financial indicators

A.3.1 Representativeness of the Sample

The Melicher method uses only four utilities to characterize the nuclear industry. The original Melicher sample included only three of the 47 utilities currently licensed to operate nuclear power reactors, accounting for 15.25 of the 110 reactors currently licensed. Data readily at hand indicated that the Melicher sample was not representative of utilities that own nuclear power units. Exhibit A-9 below presents selected 1994 financial data for DQE Inc. (which owns Duquesne Light Company), Public Service Company of Colorado, Northern States Power Company, and Unicom Corporation, compared to summary data for 35 additional investor-owned utilities.

Exhibit A-9 Selected financial data as of December 31, 1994 (millions of 1994 dollars)

	DQE Inc.	Public Service CO	Northern States Power	Unicom
Total assets	4,149.9 (30)*	4,207.8 (29)	5,953.6 (25)	23,121.0 (3)
Total operating revenues	1,180.3 (32)	2,057.4 (24)	2,486.5 (21)	6,278.0 (5)

* Numbers in parentheses indicate rank among the 39 utilities in the sample, with a rank of 1 indicating the highest value in the sample. Data for Entire Sample (N = 39)

	Total assets	Total operating revenues
Mean	9,607.3	3,263.7
Minimum	1,205.2	409.7
Lower Quartile	4,178.8	1,483.2
Median	8,143.5	2,725.1
Upper Quartile	12,578.2	4,329.9
Maximum	27,809.1	10,447.4

In total, these 39 utilities own the equivalent of approximately 77 operating nuclear power reactors. These data indicate the following:

- Three of the four Melicher utilities fall below both the median and the mean for both total assets and total operating revenues. The remaining utility, however, ranks among the top utilities for each of these financial indicators.
- DQE Inc. ranks 30th in terms of assets and 32nd in terms of operating revenues. The company's assets and operating revenues each fall in the bottom 25 percent of the distribution.
- Public Service Company of Colorado ranks 29th in terms of assets and 24th in terms of operating revenues. The company's assets and operating revenues each fall between the lower quartile and the median for the distribution (i.e., between the 25th and 50th percentiles).
- Northern States Power Company ranks 25th in terms of assets and 21st in terms of operating revenues. The company's assets and operating revenues each fall between the lower quartile and the median for the distribution.
- Unicom Corporation ranks 3rd in terms of assets and 5th in terms of operating revenues. The company's assets and operating revenues each fall in the top 25 percent of the distribution.

These data indicate that the Melicher utilities did not represent all quartiles of the industry. In fact, Professor Melicher acknowledged in 1976 that the four investor-owned utilities he selected represented at the time two relatively small, one medium, and one large utility in terms of revenues. In addition, he stated that an analysis of affordability should include public non-federal systems and cooperatives.[165] Because Public Service Company of Colorado no longer owns an operating nuclear plant, and in order to make the sample more representative, NRC has substituted Duke Power in the analysis. Duke Power ranked 10th in both total assets and total operating revenues in 1994.

A.3.2 Use of Single Year Versus Multi-Year Assessment Test

The Melicher method tests single-year affordability, rather than multi-year affordability. If a utility can afford a $50 million one-time assessment, then it likely can afford five yearly assessments of $10 million. The converse is not necessarily true. A utility that can afford a series of five $10 million annual assessments may not be able to afford a one-time $50 million assessment. Similarly, a utility may be able to afford three yearly payments of $20 million, but not a fourth.

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[165] See *Financial Implications of Retrospective Premium Assessments of Electric Utilities*, U.S. Nuclear Regulatory Commission, May 1976 (NTIS PB-257 657).

A.3.3 Appropriate Indicators of Affordability

Finally, the Melicher method may not use the most appropriate indicators and thresholds for assessing affordability to utilities. For example, earnings per share is an arbitrary basis on which to compare utilities because the number of common stock shares issued varies arbitrarily by utility. Similarly, the Melicher method does not state a minimum threshold for acceptable cash flow, return on equity, or earnings per share. A threshold for interest coverage (2.0) has been applied but was not supported with a discussion of how or why it was selected. The task of selecting appropriate indicators and thresholds for utilities is inherently difficult for two reasons.

- First, the majority of research on corporate financial distress has focused on predicting bankruptcy and/or other types of default that are largely inapplicable to today's electric utilities. Regulatory oversight has not only eliminated most of these types of risks from utility operation, but it has also helped shape the evolution of utilities' financial characteristics, which are substantially different than those considered by most studies of financial distress. Other financial distress research that may be more applicable to utilities considers risks associated with movements in stock prices or bond rating changes.

- Second, the effect of ongoing deregulation on utilities' financial characteristics remains uncertain. Consequently, thresholds of financial viability that apply today may not apply in the near future. For example, following restructuring, some licensees will have smaller asset bases, if they are separated from transmission/distribution and possibly other generating assets. Cash flow also will be reduced for such licensees. The need to compete will put pressure on earnings. Whereas indicators and threshold values distinct from other manufacturing industries have historically been applied to power utilities, different indicators and/or threshold values may be more appropriate for nuclear power units that cease to be utilities.

While it may be very difficult to adequately address the second issue, it should be more feasible to overcome the first issue. Appropriate indicators and thresholds can be identified based on past studies specifically applicable to electric utilities and on statistical analysis of historical financial data. Indicators identified in this way could overlap some of those used in the Melicher study (e.g., return on equity), but might also include ratios such as return on assets or assessments divided by revenue.

A.4 Conclusions

The purpose of this analysis was to use the Melicher method in order to assess the affordability of various amounts of retrospective insurance premiums. The conclusions reached in this analysis parallel those found during the first analysis done by Professor Melicher in 1976 when he concluded that, "Evidence suggests that current cash flows for investor-owned electric utilities (entering into nuclear reactor ownership arrangements) seem adequate to meet possible retrospective premium assessments."[166] Given that the current maximum annual

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[166] 1983 Report to Congress, Appendix. H, p. 11

assessment level is $10 million, the general conclusions Professor Melicher reached in 1976 remain the same in 1998 (i.e., utilities will be able to make retrospective assessment payments).

The 1979 NRC staff study determined that assessments at the $10 million level were manageable but that problems might arise at the $20 million, and higher, assessment levels. The 1983 Report to Congress, using financial data from 1981, demonstrated that assessments at the $50 million level per reactor could pose major problems for all four of the utilities and especially for the two with more than one reactor each. It also showed how utilities began to evidence financial distress at assessment levels ranging between $10 and $20 million. That finding supported the 1979 NRC staff study's findings that recommended limiting the maximum assessments to $10 million per year, because higher assessments could cause financial distress.

Using the Melicher method to evaluate the four utilities, this analysis concludes that the maximum annual assessment that all four utilities could afford seems to range between $20 and $50 million. This is consistent with the previous analyses' findings concluding that the maximum assessment level utilities could afford was between $10 and $20 million, which equal $16 and $32 million, respectively, in 1996 dollars when adjusted for inflation. However, the current deregulatory environment, which may lead to restructuring within the nuclear power industry, may impact the ability of some nuclear power entities to handle a $20 million annual retrospective premium assessment.

NRC FORM 335
(2-89)
NRCM 1102,
3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

1. REPORT NUMBER
(Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)

NUREG/CR-6617

2. TITLE AND SUBTITLE

The Price-Anderson Act - Crossing the Bridge to the Next Century: A Report to Congress

3. DATE REPORT PUBLISHED

MONTH	YEAR
October	1998

4. FIN OR GRANT NUMBER

W6294

5. AUTHOR(S)

P. Bailey, K. Blake, M. Brown,
P. Duback, S. Krill, J. Laurenson
J. Saltzman

6. TYPE OF REPORT

Report to Congress

7. PERIOD COVERED *(Inclusive Dates)*

8. PERFORMING ORGANIZATION – NAME AND ADDRESS *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

ICF Inc.
9300 Lee Highway
Fairfax, VA 22034

9. SPONSORING ORGANIZATION – NAME AND ADDRESS *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)*

Division of Reactor Program Management
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

This report fulfills the mandate of Subsection 170p. of the Atomic Energy Act of 1954, as amended, which requires that the Commission submit to the Congress by August 1, 1998, a detailed report on the need for continuation or modification of Section 170 of the Act, the Price-Anderson provisions. Part 1 presents an overview of the Price-Anderson system. Part 2 examines the issues that the Commission is required by statute to study (i.e., condition of the nuclear industry, state of knowledge of nuclear safety, and availability of private insurance). Part 3 covers other issues of interest and importance to the Congress and to the public, such as proof of causation and international agreements relevant to Price-Anderson. Part 4 of the report contains conclusions and recommendations. Part 5 is the list of references. Appendix A is an evaluation of the affordability of certain Price-Anderson assessments.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

Price-Anderson, Indemnity, Public Liability,
Nuclear Liability Insurance, Financial Protection

13. AVAILABILITY STATEMENT

Unlimited

14. SECURITY CLASSIFICATION

(This Page)

Unclassified

(This Report)

Unclassified

15. NUMBER OF PAGES

16. PRICE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, DC 20555-0001

120555154486 1 1AN
US NRC-OCIO
DIV-INFORMATION MANAGEMENT
TPS-PDR-NUREG
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