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REPORT OF THE COMPTROLLER GENERAL OF THE UNITED STATES

Selected Aspects Of Nuclear Powerplant Reliability And Economics

Information on nuclear powerplant operating experience from 1960 through 1974 was obtained and analyzed by GAO. Generally, nuclear powerplants showed an upward performance trend during their first 7 years of commercial operation. Only three small, first-generation powerplants have been operating for more than 7 years, and their performance has been erratic. Data from these three plants is not a reliable predictor of future nuclear powerplant performance.

Considerable Government assistance to nuclear power enterprises exists in the form of indirect subsidies for atomic energy insurance and indemnity, management of radioactive waste, and uranium enrichment. Reprocessing used commercial nuclear fuel and decommissioning nuclear powerplants are the responsibility of private industry, and little or no Federal involvement exists.

RED-76-7

AUG. 15, 1975

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-164105

The Honorable Lee Metcalf
Chairman, Subcommittee on Reports,
Accounting, and Management
Committee on Government Operations
United States Senate

Dear Mr. Chairman:

In response to your February 17, 1975, request and subsequent discussions with your office, we obtained information on specific areas of concern to your subcommittee relating to the economics and reliability of current-generation nuclear powerplants. This information is discussed in detail in the attached appendixes.

Generally, we learned:

1. Nuclear powerplants showed a general upward performance trend during the first 7 years of commercial operation. Only three nuclear powerplants have been operating for more than 7 years and, therefore, the average performance factors after 7 years are strongly influenced by extremely good or poor performance by a single plant. The experience of these three plants beyond 7 years cannot be used to reliably project the future performance of other nuclear powerplants. (See app. I, p. 1.)

2. Three Government-owned plants represent the only capability in the United States for enriching uranium for commercial nuclear powerplant fuel. These plants were built in the 1940s and 1950s to produce enriched uranium for national defense purposes and utilize the gaseous diffusion enrichment process. The Energy Research and Development Administration believes that a private and competitive domestic enrichment industry is highly desirable to support the forecasted growth in nuclear power. In June 1975 the President submitted to the Congress a legislative proposal which would authorize the Energy Research and Development Administration to enter into cooperative arrangements with private firms to provide such Government assistance as necessary to encourage the development of a competitive

private uranium enrichment industry. That same month the Energy Research and Development Administration issued a request for proposals from private industry to design, construct, and operate, with Government cooperation, uranium enrichment plants using the gas centrifuge enrichment process to produce fuel for nuclear powerplants. The prices for enrichment services have been based on full recovery of the Government's costs. However, in June 1975, the Energy Research and Development Administration proposed that future prices be on a basis which would reduce or eliminate the differential between the Government's charges for enriching services and those of potential domestic private enrichment companies. (See app. I, p. 4.)

3. The Nuclear Regulatory Commission is responsible for approving plans for shutting down nuclear powerplants and maintaining them in a safe condition--a process called decommissioning--and for periodically inspecting reactor sites to determine that the decommissioning is performed according to regulations. The powerplant owner is responsible for the decommissioning and for paying the costs associated with decommissioning, including subsequent protection and surveillance. As of June 1975 only seven commercial nuclear powerplants had been decommissioned; however, all seven were substantially smaller and differed in design from the nuclear powerplants in operation or under construction today. The Commission estimates that, depending on the alternative chosen by the reactor owner, decommissioning a modern nuclear powerplant will cost between $3 million and $60 million initially, with possible additional costs for subsequent surveillance. More refined estimates will be available in November 1975 when a privately financed study by the Atomic Industrial Forum is to be completed. (See app. I, p. 7.)

4. High-level radioactive wastes originate from fuel removed from a nuclear reactor. The spent reactor fuel cores can be dissolved in acids, the reusable products chemically removed and refabricated into new fuel elements, and the resulting wastes separated and stored. This process is called reprocessing. There are no commercial spent-fuel reprocessing plants operating in the United States today. The Commission recently stated that commercial reprocessing plants might not be licensed until questions over safeguarding plutonium can be resolved. The final Commission view on interim licensing actions for facilities related to plutonium recycling should be established in late 1975. A Commission decision on widespread plutonium recycling is not expected until 1978. Delays in the startup of reprocessing plants suggest the

possibility that a serious shortage in spent-fuel storage capacity could develop. (See app. I, p. 9.)

5. The Price-Anderson Act, as amended (P.L. 85-256), which was enacted on September 2, 1957, provides a combination of private financial protection and Government indemnity amounting to a maximum of $560 million to cover public liability claims that might arise from an accident at a commercial nuclear powerplant. The act was regarded as temporary legislation covering a 10-year period. In 1966 the act was extended an additional 10 years so that a more accurate assessment could be made of the accident potential and the insurance requirements of the nuclear industry. Legislation has been proposed to continue and expand the indemnity coverage. (See app. I, p. 14.)

We have discussed this report with Energy Research and Development Administration and Nuclear Regulatory Commission officials and included their comments where appropriate. We will contact your office in the near future to arrange for the release of this report so that copies can be provided to other congressional committees and interested Members of Congress.

Sincerely yours,

Elmer B. Staats

Comptroller General
of the United States

CONTENTS

ABBREVIATIONS

AEC	Atomic Energy Commission
ERDA	Energy Research and Development Administration
NRC	Nuclear Regulatory Commission
RDT	Reactor Development and Technology

SELECTED ASPECTS OF NUCLEAR POWERPLANTS RELIABILITY AND ECONOMICS

THE RELIABILITY OF NUCLEAR POWERPLANTS

As of June 1975, 53 nuclear powerplants were licensed for commercial operation in the United States and accounted for about 7.7 percent of the United States' electrical capacity. Another 76 were under construction. Plans have been announced for constructing 115 more powerplants. Most of these powerplants are to be operating before 1985.

The Energy Research and Development Administration (ERDA),[1] the successor agency to the Atomic Energy Commission (AEC), and others believe that nuclear power can provide more than half of the Nation's electricity by the end of the century. According to the proponents of nuclear power, this power source is more economical than other energy sources.

On the other hand, critics of nuclear power expansion have maintained that nuclear powerplants are not as reliable as its proponents have claimed and, therefore, may not be the most economical source of energy.

Nuclear powerplant reliability is measured by two related statistical factors--plant capacity and plant availability. The plant capacity factor is the percentage of total electric energy actually produced by a powerplant during a specified time compared to the energy it might have produced had it operated at its licensed power level for the entire period. The plant availability factor measures the percentage of time in a given period that a nuclear powerplant was capable of operating and producing electricity. Neither factor is a perfect measure of plant reliability, although the plant capacity factor is generally regarded as the closest indicator.

The following table shows the average capacity and availability factors for 37 of the nuclear powerplants presently in full commercial operation. We did not review powerplants that were rated at less than 100 megawatts (electric) because they are not typical of commercial nuclear powerplants.

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[1]The Energy Reorganization Act of 1974 (Public Law 93-438) abolished AEC and established ERDA and the Nuclear Regulatory Commission (NRC) effective January 19, 1975.

Average availability and capacity factors were calculated by adding the average reliability and capacity factors that all reactors experienced during their first year of operation, their second year, third year, etc. and then dividing those sums by the number of reactors with 0 to 1 year of service, 1 to 2 years of service, 2 to 3 years of service, etc.

Average availability and capacity factors as an expression of years in commercial operation

Years of service	Number of reactors	Average availability (percent)	Average capacity (percent)
0 to 1	37	65.2	52.1
1 to 2	28	70.3	60.1
2 to 3	19	64.6	56.7
3 to 4	13	80.1	69.4
4 to 5	9	75.2	65.0
5 to 6	6	72.1	64.3
6 to 7	5	91.2	81.3
7 to 8	3	77.9	66.7
8 to 9	3	57.4	47.3
9 to 10	3	74.8	62.2
10 to 11	3	89.3	73.8
11 to 12	3	39.4	25.9
12 to 13	2	74.6	65.4
13 to 14	2	71.2	46.3
14 to 15	1	35.5	20.1

As indicated above, the average plant capacity and availability factors show a general upward trend during the first 7 years of commercial operation. Only three nuclear powerplants have been operating for more than 7 years and, therefore, extremely good or poor performance by one plant strongly influences the annual average capacity and availability factors above 7 years. These three plants were built in the early 1960s to demonstrate the feasibility of nuclear power generation and to provide an engineering basis for moving to larger nuclear plant designs with higher power ratings. One of the manufacturers of the nuclear reactors used in the three plants attributed their lower performance to their being out of service periodically to modernize equipment and their lack of certain improvements subsequently developed and incorporated into newer powerplants. (See apps. II, III, and IV for detailed information on powerplant operating experience.)

According to ERDA, capacity and availability factors are affected by other events besides failure of the nuclear portion of the plant. These events include failure of non-nuclear components, licensing restrictions, economic considerations, fluctuations in demand, special tests, and refueling.

Generally a nuclear reactor is designed to achieve 80-percent capacity and availability factors for its entire operating life, which is considered to be about 35 years.

ERDA officials told us that before licensing a nuclear reactor, NRC must prepare an environmental impact statement, in which NRC prepares for each reactor a benefit-cost analysis. We reviewed 58 environmental statements prepared during 1972-75 for 98 nuclear power reactors. More than half (33) of the statements contained an 80-percent capacity factor in the benefit-cost sections. However, NRC has recognized that the 80-percent objectives may be optimistic and has provided benefit-cost information on a range of plant capacity factors (60, 70, 80 percent) in many recent environmental impact statements. For example, 8 of the 11 statements we examined that were prepared in 1975 had information on a range of capacity factors.

Different methods used in calculating plant capacity and availability factors

AEC's Division of Reactor Development and Technology (RDT) calculated plant capacity and availability factors for nuclear powerplants during 1960 to 1973. AEC's regulatory organization collected the data for 1972 and 1973, and NRC compiled the data for 1974. Each organization used slightly different methods in calculating the plant capacity and availability factors.

According to NRC, the different methods translate to an average 3-percent difference in the capacity and availability factors. NRC's and the regulatory organization's calculations, assuming no other changes to the methods employed, are lower than RDT's by about 3 percent.

In April 1975 NRC revised its method of calculating plant capacity factor to conform to the method most generally used by electric power companies and the Edison Electric Institute.[1] The new method gives capacity factors, on the average, which are greater than the AEC regulatory organi-

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[1] A trade association representing 181 electric operating companies, 11 holding companies, and 26 affiliate members.

zations by about 2.3 percent and which are very close to that of previous RDT calculations. Appendix V shows how AEC's regulatory organization and NRC calculated plant capacity factors.

URANIUM ENRICHMENT

The production of nuclear fuel consists of a series of operations: uranium mining and milling, converting uranium feed material into uranium hexafluoride, enriching the uranium, and fabricating the enriched uranium into fuel elements which can be placed into nuclear reactors. Private industry performs all of these operations except uranium enrichment.

Nuclear fuel ore contains essentially two forms, or isotopes. One isotope, uranium-235, constitutes about 0.7 percent of the uranium found in nature. Since the fuel for current nuclear reactors requires about 3-percent uranium-235, the percentage in the fuel must be increased from 0.7 to 3 percent. Increasing this percentage is the purpose of enrichment.

ERDA's enrichment plants are located at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio. These plants use a process called gaseous diffusion to enrich uranium. The plants were built at a cost of about $2.4 billion in the 1940s and 1950s to supply enriched uranium for national defense purposes. They are now operated primarily to supply enriched uranium for commercial nuclear powerplants. The plants are operated by private firms under cost-plus-fixed-fee management contracts.

ERDA expresses the production capacity of its plants in terms of "separative work" units. A separative work unit is not a quantity of material but rather a measure of the effort expended in the plants to separate a given quantity of uranium feed into two streams--one having a higher percentage of uranium-235.

The Private Ownership of Special Nuclear Materials Act of 1964 (Public Law 88-489) authorized AEC to offer, beginning in January 1969, services for enriching privately owned uranium. The act also provided that AEC set forth the terms and conditions under which enriching services would be made available, including the requirement that prices be established on the basis of providing reasonable compensation to the Government.

The act was amended by P.L. 91-560 on December 19, 1970, to state that prices would be established on a basis of recovery of the Government's cost over a reasonable period. On May 9, 1973, AEC established a new type of enrichment contract--fixed-commitment. Under fixed-commitment contracts, customers must specify delivery leadtime of at least 8 years for initial delivery and 10 years for subsequent deliveries and make a substantial down payment. Before this type of contract was established, AEC offered requirements contracts in which AEC agreed to provide the enrichment services for a stated nuclear reactor on an "as needed" basis, up to a limit, with only 120 days' advance notice.

The establishment of fixed-commitment contracts created a dual pricing structure--one price for requirements contracts and a lower price for fixed-commitment contracts. AEC justified this difference by pointing to its experience with requirements contract holders that have shown that actual sales have fallen short of projected sales.

In June 1975 the Administrator of ERDA forwarded to the Congress draft legislation which would revise the pricing criteria for enriching uranium used to fuel nuclear powerplants. The proposed legislation would amend the Atomic Energy Act of 1954, as amended, to (1) obtain fair value for enriching service and (2) eliminate or reduce the differential between the Government's charges for enriching services and those of potential domestic private enrichment projects. The price for a separate work unit under the new basis would include charges' in lieu of insurance and Federal, State, and local taxes plus a factor to cover economic risks.

ERDA estimates that the increase in the cost of nuclear power due to the new legislation will add about 0.49 mills per kilowatt hour (or 2.9 percent) to the cost of nuclear power for those electric utilities which procure their enrichment services under fixed-commitment contracts. Utilities with requirement-type contracts would not be affected. When averaged over all electric generation in the United States this would amount to a 0.05-percent increase in the cost of electric power to the ultimate consumer in fiscal year 1977. The proposed legislation will increase enrichment costs from $53.35 per separative work unit to about $76.00. The $22.65 difference is roughly equivalent to the Federal subsidy[1] for enrichment services.

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[1]Defined to include direct or indirect payments, economic concessions, and privileges or benefits provided to any enterprise by the Government to promote its policy.

This subsidy represents a benefit to the nuclear power industry because the price charged by the Government to enrich uranium has not included profit, taxes, and insurance. If a taxpaying, profit-maximizing company were selling uranium enrichment services to the nuclear power industry, these items would be included in the price.

The following table shows the quantity of enriched uranium sold by the Government in terms of separative work units and revenues received through fiscal year 1974.

	Separative work units	Revenues
	(000 omitted)	
Domestic	21,433	$ 633,672
Foreign	21,837	694,030
Total	43,270	$1,327,702

In addition to these revenues, ERDA has received, through fiscal year 1974, $181.3 million in advance payments for fixed-commitment contracts.

ERDA efforts to encourage commercial enriching

ERDA believes that a private and competitive domestic enrichment industry is highly desirable to support the forecasted growth in nuclear power. In support of this belief, ERDA has made classified enriching technology available to qualified U.S. organizations. During fiscal year 1976, ERDA will spend about $2 million for these domestic access programs.

One group of private companies--Uranium Enrichment Associates--has actively sought to establish a project to construct a new gaseous diffusion plant. The association has determined that, due to the unique nature of the project, it cannot be financed and operated commercially without certain forms of Government assistance and assurance.

On February 7, 1975, the Administrator of ERDA established a project board to evaluate the association's request for several forms of Government assistance. The project board has completed its work, and ERDA has prepared a proposed legislative package to provide Government assistance to encourage and facilitate the establishment of a competitive private enrichment industry. On June 26, 1975, the President forwarded to the Congress proposed legislation which would provide Government assistance and temporary assurance to private firms interested in entering the uranium enrichment industry (Senate bill 2035).

ERDA also has a research and development program investigating another process for enriching uranium called gas centrifuge. On June 26, 1975, ERDA requested proposals from industry to design, construct, own, and operate gaseous-centrifuge enrichment plants. It is likely, since the initial output of such facilities may not be economical, that the Government will have to provide assistance for a number of years.

DECOMMISSIONING COMMERCIAL NUCLEAR POWERPLANTS

Nuclear powerplants are licensed to operate up to 35 years. At the end of this term, the powerplant owner must renew the license from NRC or apply for termination and authorization to shut down the plant and dispose of its components. The owner may also apply for termination before the expiration of the license if technical, economic, or other factors are unfavorable to continued plant operation.

Termination activities, including shutting down the facility and maintaining it in a safe condition, are generally referred to as decommissioning. Three primary methods can be used to decommission a commercial nuclear powerplant--entombment, dismantling, or mothballing. A fourth method, called conversion, is also available but is essentially a combination of using some of the facility's equipment and one of the other alternatives. For example, a nuclear powerplant could be partially dismantled and converted to a coal-fired plant. NRC believes that this method is not as likely to be used as the other three methods.

Mothballing involves placing the nuclear powerplant in protective storage. The facility is generally left intact except that all nuclear fuel and the radioactive fluids and wastes are removed from the site and transported elsewhere for burial or reclamation. An exclusion area is established around the remaining structure.

Entombment consists of sealing the remaining radioactive components in a concrete and/or steel structure after removing all reactor fuel, surface contamination, and radioactive fluids and waste from the reactor site. The components and wastes that are removed are transported by the reactor owner or its agent to commercial burial grounds in Nevada, New York, or Washington or to Federal repositories.[1]

Dismantling involves removing the nuclear fuel, superstructure, reactor vessel, and all contaminated equipment, fluids, and wastes from the reactor site and transporting them elsewhere for burial or reclamation. At the owner's option, the site could be restored to prereactor conditions.

Under the entombment and mothballing methods, the facility owner will be required to provide adequate radiation monitoring, environmental surveillance, and an active or passive security system. These activities would be required until (1) the remainder of the facility is dismantled or (2) radiation decreases to an acceptable level where the health and safety of the public is not endangered--which may take 50 years or more.

The Federal Government, under the auspieces of NRC, is responsible for approving the decommissioning plan[2]--which the nuclear plant owner must submit before decommissioning can begin--and periodically inspecting the reactor site to determine that the decommissioning is being performed in accordance with regulations protecting the health and safety of the public. The powerplant owner is responsible for the decommissioning and the costs associated with decommissioning, including subsequent surveillance and protection.

Decommissioning costs

There are no firm estimates of decommissioning costs for large-scale nuclear powerplants in operation or under construction. The seven reactors that have been decommissioned were small and differed substantially in design from modern reactors.

We obtained several rough estimates from NRC regarding the three alternative ways to decommission a nuclear powerplant. NRC representatives said that more refined estimates

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[1]Radioactive material may be accepted at Federal repositories if private burial grounds do not have the capability to properly dispose of the material. If radioactive materials are deposited on Federal land, ERDA charges the depositor for the service.

[2]Not required for minor disassembly or mothballing because this can be done by the existing operating and maintenance procedures under the license in effect.

should be available in November 1975 when a privately funded study by the Atomic Industrial Forum is completed.

The least expensive method initially to decommission a nuclear powerplant is mothballing. A very small nuclear powerplant in Saxton, Pennsylvania, was mothballed for about $500,000 in 1973. In addition, approximately $10,000 will be spent annually to monitor and protect the remaining structures.

About $3 million was spent to decommission the Hallam Nuclear Power Facility in Hallam, Nebraska, under the entombment option. Security and protective surveillance costs about $2,500 per year. Also, in 1973, the Elk River Power Plant at Elk River, Minnesota, which was about twice as large as the Saxton facility, was dismantled for about $6 million. There is no subsequent surveillance.

According to NRC, the larger, modern nuclear powerplants will incur costs to decommission on the order of 6 to 10 times the costs for the smaller reactors mentioned above. The following chart, which is based on NRC's assumptions, shows estimated costs to decommission a large nuclear powerplant.

Alternative	Initial cost (millions)	Annual surveillance and protection
Mothballing	$ 3 to 5	$60,000 to 100,000
Entombment	18 to 30	15,000 to 25,000
Dismantling	36 to 60	none

As mentioned above, all of these expenses are to be borne by the powerplant owner.

MANAGEMENT OF RADIOACTIVE WASTE FROM COMMERCIAL NUCLEAR POWERPLANTS

Commercial nuclear powerplant operation results in radioactive wastes containing varying degrees of contamination. Some low-level radioactive wastes, such as slightly contaminated air and water, may be safely discharged to the environment after treatment. Three types of radioactive wastes, however, must be isolated from the environment--high-level radioactive wastes, transuranium-contaminated wastes, and other solid contaminated wastes.

High-level radioactive wastes

These wastes originate from the fuel taken from a nuclear reactor after it has been operating a year or two and needs new fuel. This so-called "spent fuel" contains substantial quantities of unburned, reusable uranium-235 and plutonium and radioactive byproducts. The spent reactor fuel cores can be dissolved in acids, the reusable products chemcially removed and fabricated into new fuel elements, and the resulting wastes separated and stored. This is called reprocessing.

No commercial spent-fuel reprocessing plants operate in the United States today. The only one that has operated in the past is owned by Nuclear Fuel Services, Incorporated. Operations at this plant, located in West Valley, New York, began in 1966 and were suspended in late 1971 to modify and expand the plant. Operations are scheduled to resume in 1979. About 600,000 gallons of highly radioactive liquid waste were generated during this plant's operation. This waste is being stored by Nuclear Fuel Services in underground tanks located on State-owned land in West Valley.

Allied General Nuclear Services is constructing a plant at Barnwell, South Carolina, which is scheduled to begin operating in mid-1976. The General Electric Company was scheduled to open a plant in Morris, Illinois, in 1974; however, several problems were encountered and in July 1974 General Electric announced that the plant was not operable in its current configuration and that more than $100 million and several years would be required to make the plant operable. A decision on whether to modify the plant is expected in late 1975 or early 1976.

ERDA operates three spent-fuel reprocessing plants and one standby plant for reprocessing fuels for Navy reactors and fuels from ERDA's research and production reactors. None of these plants, however, handle spent fuels from commercial power reactors, and there are no plans for them to do so.

The economics of commercial reprocessing are dependent on plutonium recycling. NRC recently stated that commercial reprocessing plants might not be licensed until questions over safeguarding plutonium can be resolved. The establishment of a commercial reprocessing industry and the consequent production and transportation of large quantities of plutonium may increase the possibility of diversion of plutonium from legitimate channels. The final NRC view on interim actions for facilities related to plutonium recycling should be established in late 1975. An NRC environmental impact statement, including detailed safeguards considerations, concerning the use of recycled plutonium in light-water reactors is expected in 1978. This statement will be the vehicle used to decide the future of widespread plutonium recycling and commercial fuel reprocessing.

Because there are no operating commercial reprocessing plants, spent fuels are being temporarily stored in water filled, reinforced concrete basins at the reactors and at the sites where the reprocessing plants are being constructed. As of January 1, 1975, the total inventory of spent fuels in onsite reactor basins was 927 metric tons. The total inventory of spent fuel at reprocessing plant sites was 152 metric tons.

Delays in the startup of reprocessing plants suggest the possibility that a serious shortage in spent-fuel storage capacity could develop because about five reactor site storage basins will be completely filled by the end of 1976 and several others will be completely filled soon thereafter. The industry is studying plans to expand basin storage capacity at reactor sites as an interim measure to alleviate this situation. Reactor operation could be affected if storage capacity is not expanded.

With the exception of NRC's role in licensing storage facilities, the private sector is responsible for the temporary storage of spent fuel. The Federal Government, through ERDA, is responsible for providing permanent storage for or disposal of future high-level radioactive wastes generated by commercial reprocessing plants. ERDA has a two-phase program to develop repositories for commercial high-level radioactive wastes. The first phase is to develop a repository for fully retrievable surface storage, using existing technology, at a large ERDA nuclear site. The second phase is to develop a repository for permanent disposal of the waste in a deep, stable geological formation.[1]

The current status of ERDA's programs is as follows:

1. ERDA is studying several alternative formations (such as salt and granite) and attempting to identify specific sites where permanent disposal will be acceptable. ERDA's fiscal year 1976 budget requests $3.5 million for geologic disposal, which includes preliminary work to design a pilot disposal facility. This type of repository would

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[1]A December 18, 1974, GAO report entitled "Isolating High-Level Radioactive Waste from the Environment: Achievements, Problems, and Uncertainties" (RED-75-309) discussed many of the aspects of the retrievable surface storage facility and the permanent disposal facility.

have as its purpose the resolution of questions about the safety of permanent disposal at that site by actual observations with high-level waste. The waste could be removed completely in the event an unfavorable consensus is reached by the scientific community, subject to approval by ERDA.

2. In April 1975 ERDA announced its intention to issue a broad generic environmental statement, in which NRC would be invited to participate, on Federal options to manage spent fuel and high-level waste. This statement would replace one of more limited scope issued by AEC in September 1974. Construction of a retrievable surface storage facility has been deferred pending completion of the expanded statement. During the interim period the need for this facility might be reduced if good results are obtained in the permanent disposal program.

The cost of managing commercial high-level radioactive waste

According to ERDA, it is not possible at this time to accurately estimate the total cost of safely managing commercial radioactive waste from the time the spent fuel is removed from a reactor until the waste products are placed into their ultimate resting place. ERDA says this is because of the considerable uncertainties in future waste management processes. These uncertainties include (1) the methods for, and location of, interim storage, extended storage, and final disposal have not yet been selected and (2) the processes which may be used to reduce the volume of waste and convert it to the form in which it will be stored and disposed of are still being developed. In view of these uncertainties, the cost of constructing and operating the facilities associated with storage and final disposal can only be approximated.

Based on experimental work and engineering design studies, however, ERDA did predict the upper limits for the total cost of management of commercial high-level radioactive waste:

--For the 60 trillion cumulative kilowatt hours of electricity expected to be produced by commercial nuclear plants by the year 2000, it will cost industry $2.5 to $3 billion (4 to 5 cents per 1,000 kilowatt hours) to treat, store, and ultimately dispose of all the radioactive waste generated in the course of producing this power.

--In the event permanent disposal in geological formations is not developed, and indefinite retrievable surface storage is used, the cost will be in the same range as above.

At the time of transferring the waste to Federal custody, the Government will collect a fee, which will be established in a trust fund, from the waste generator. This fee, together with interest on unexpended balances in the fund, will pay all of the cost of retrievable storage, if used, plus the projected cost of later transferring the waste to a permanent disposal site, including surveillance of the site. This fee has not been established yet. As discussed earlier, the "full-recovery-of-cost" policy provides a subsidy to the nuclear power industry in that allowances for taxes, insurance, and profits are not included in any fee charged to the industry.

Transuranium-contaminated wastes

Transuranium-contaminated wastes are usually solid materials contaminated with substantial amounts of radiation. These wastes can include such items as rags, paper, plastics, and equipment.

All transuranium-contaminated wastes produced by the nuclear industry, expect those which have substantial amounts of penetrating radiation,[1] are disposed of at commercial burial grounds. Through 1972 about 7.5 million cubic feet of transuranium-contaminated waste was buried at these grounds. AEC has estimated that the volume of transuranium-contaminated waste generated in 1974 was 2 million cubic feet and will increase to 4 million cubic feet in 1980.

Six licensed burial grounds are in operation. These include a West Valley, New York, site operated by Nuclear Fuel Services, Incorporated, and a site at Barnwell, South Carolina, operated by Chem-Nuclear Company, Incorporated. The four other sites (Beatty, Nevada; Maxey Flats, Kentucky; Richland, Washington; and Sheffield, Illinois) are operated by Nuclear Engineering Company, Incorporated. In addition, other organizations collect, store, and repackage solid radioactive wastes but do not have licenses to bury the wastes.

In 1974 AEC's regulatory organization published a proposed regulation which would prohibit further burial of commercial transuranium-contaminated waste in soil and would

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[1]Presently buried at reprocessing plants.

require this waste to be transferred to Federal custody. In the event this regulation becomes effective, ERDA plans to expand its permanent disposal program for commercial high-level wastes to include commercial transuranium-contaminated solid waste. For the interim, ERDA plans to store most of the material at one of its larger nuclear sites.

ERDA also anticipates implementing a "full-cost recovery" policy for transuranium-contaminated waste disposal. When the waste is transferred to ERDA for disposal, ERDA will collect a fee which, with interest on unexpended balances, will pay the cost of interim storage and the eventual costs of permanent disposal and perpetual surveillance. AEC has stated that, if the regulation becomes effective, retrievable storage and eventual permanent disposal could cost up to $30 per cubic foot, whereas the present charge for burial at a commercial burial ground is about $1 per cubic foot. NRC believes that this cost increase will decrease the volume of waste generated as industry becomes more careful about their activities.

Other solid contaminated wastes

Solid radioactive-contaminated wastes which are neither high-level nor transuranium-contaminated are often called "low-level solid" wastes. These wastes consist of a wide variety of solid objects which are not usually radioactive themselves but which have radioactive materials present within them or on their surfaces. The nuclear industry sends all of these wastes to commercial burial grounds.

Certain solid high-level wastes, such as fuel hulls and highly contaminated equipment, are generated at fuel reprocessing plants. These wastes are buried at the reprocessing plant site.

ATOMIC ENERGY INSURANCE AND INDEMNITY

Section 170 of the Atomic Energy Act of 1954, as amended (42 U.S.C. 2210), called the Price-Anderson Act, provides a combination of private financial protection and Government indemnity amounting to a maximum $560 million to cover public liability claims that might arise from any nuclear accident at commercial nuclear facilities. The following sections discuss the reasons for, the essential features of, the proposed amendment to, and the subsidy provided by, the Price-Anderson Act for commercial nuclear powerplants.

Reasons for the Price-Anderson Act

The Atomic Energy Act of 1954 made possible for the first time the private production, possession, and use of fissionable nuclear materials. However, this change in national policy had little effect in spurring private investment to develop nuclear powerplants. The threat of potential enormous liability associated with a nuclear incident and the inability to obtain adequate commercial liability insurance in connection with the operation of nuclear reactors were the major obstacles to private sector participation.

Following a detailed congressional study of these problems, the Price-Anderson Act was enacted on September 2, 1957. The objectives of this act were to (1) assure the availability of adequate funds to satisfy third party liability claims in the event of a catastrophic nuclear accident and (2) remove the deterrent of possible enormous liability claims.

Essential features of the act

Nuclear powerplants must be licensed by NRC. NRC requires owners of power reactors of 100 electrical megawatts of capacity or more to have the maximum amount of liability insurance available from private industry. The amount of financial protection required of reactors of less than 100 megawatts is established in accordance with a formula that takes into account the population near the reactor.

The private insurance industry has provided nuclear liability insurance through policies issued by the Nuclear Energy Liability Insurance Association and the Mutual Atomic Energy Liability Underwriters. In 1957, $60 million per powerplant was the total insurance available. Nuclear liability insurance capacity has since increased to $125 million and all powerplants required to furnish financial protection have done so by purchasing insurance policies from these two organizations.

To date 27 claims have been filed against these organizations under the nuclear liability insurance plan. However, none of the claims filed can be attributed to nuclear accidents at a commercial nuclear reactor. Instead claims have resulted from such incidents as transportation accidents and spillage of radioactive material.

The act further requires that the reactor owner must execute and maintain an indemnity agreement with NRC. Pursuant to this agreement, NRC will indemnify the reactor owner for all public liability claims exceeding his required private insurance coverage up to $560 million per nuclear incident. If the reactor owner is required to have the maximum available liability insurance of $125 million, the Government indemnity agreement will be for $435 million.

The act authorizes NRC to collect fees in return for the indemnity. The fee is $30 per year per thousand kilowatts of thermal energy authorized in the reactor's license[1], with a minimum fee of $100 per year. By August 1, 1977, almost $10 million in indemnity fees will have been collected since 1957. No claims have ever been made against the Government for indemnity liability.

Since 1957 the act has limited the amount of liability protection to $560 million, even though the possibility exists that damages, as a consequence of a nuclear incident, could exceed this amount. However, it is NRC's opinion that in such a case the Congress would have the opportunity to reassess the situation and appropriate additional funds. At the 1965 hearings on the act, the Joint Committee on Atomic Energy expressed the view that the $560 million limit would serve as a device for facilitating further congressional review rather than set an ultimate limit of relief.

As originally enacted in 1957, the act was regarded as temporary legislation and was written for only a 10-year term. In 1965 the act was extended an additional 10 years by P.L. 89-210 so that data could be accumulated to enable a more accurate assessment of the likelihood of a major nuclear accident and the insurance requirements of the nuclear industry. The act is now to expire on August 1, 1977.[2]

<u>Proposed amendment to the act</u>

On April 22, 1974, AEC forwarded to the Congress proposed legislation which would amend the act. Following hearings before the Joint Committee on Atomic Energy in May of 1974, a revised bill was passed by the House and Senate.

According to NRC, the Congress passed the bill dependent upon the results of an NRC study assessing the risks to the public of nuclear powerplant accidents. The final study is

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[1]The annual fee for a 1,000 megawatt (electric) powerplant would be about $90,000.

[2]Reactors covered under the Price-Anderson Act at this time would remain covered until their licenses expire and all radioactive materials are removed from the reactor site.

expected in early 1976. Since the final study had not been prepared, the President vetoed the bill.

Some major purposes of the proposed legislation were to

--extend through July 31, 1987, the authority of NRC to indemnify powerplant owners,

--phase out Government indemnity for most licensed commercial facilities as private insurance is increased and nuclear utilities provide retrospective insurance obligations,[1]

--gradually raise the $560 million liability ceiling by permitting an increase, without any upper limit, in the amount of financial protection available from private sources, and

--extend indemnity coverage to certain nuclear incidents occurring outside the territorial limits of the United States (for example, for offshore, floating power stations).

Insurance and indemnity subsidies

The Federal Government has never paid a direct subsidy to the nuclear industry for atomic energy insurance and indemnity. Subsidy contributions are in the form of (1) limiting the licensees' liability to $560 million and (2) the value of the $435 million Government indemnity to each reactor owner.

The subsidy to the nuclear industry arising from the fact that all liability is limited to $560 million is not quantifiable. It is uncertain how much damage a nuclear powerplant accident could cause, although several groups have attempted to estimate these consequences. In 1957 AEC's Brookhaven National Laboratory concluded that the maximum consequences of a nuclear accident could range up to about 3,400 fatalities, 43,000 injuries, 460,000 persons required to be evacuated, and $7 billion in property damage. In 1974 a draft AEC study, using some different assumptions, stated that maximum consequences would be 92 deaths, 200 injuries, and $1.7 billion in property damage.

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[1]Contingency insurance premiums payable to the insurance pool by all licensees when losses occur in excess of the financial protection required.

A subsidy question also arises on the $435 million in indemnity coverage provided by the Federal Government. For this coverage NRC collects a fee that is not a premium, has no actuarial basis, and is assessed on a flat basis of $30 per thousand kilowatts of thermal energy authorized in the reactor's license.

If commercial insurance were available for this additional coverage, the difference between the annual indemnity fee and the additional annual net insurance premium would represent the Government's annual subsidy. According to NRC, this difference would be insignificant because about two-thirds of the insurance premiums collected in the years 1957 to 1963 have been returned to the policy holders after a 10-year duration.[1] The reactor owner also receives from the insurance companies discounts on the second and third reactors on a site. As of January 1, 1975, the annual premium for each $1 million of coverage exceeding $100 million for a single reactor at a site is $800 and for two reactors at a site it is $1,000.

Taking these above mentioned factors into consideration, we computed the annual indemnity subsidy to be no more than $145,480 for a utility with one 1,000 megawatt (electric) reactor at a site and no more than $114,350 for a utility with two 1,000 megawatt (electric) reactors at a site.

The following table shows how we arrived at these amounts.

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[1]These rebates are not required and may fluctuate in amount.

The value of government indemnity to the nuclear powerplant owner

	Additional annual cost of liability insurance, if available		Annual indemnity fee		Annual subsidy
One reactor rated at 1,000 MWe	$348,000[a]		$90,000		
	less 112,520[b]				
	$235,480	-	$90,000	=	$145,480
Two reactors each rated at 1,000 MWe	$435,000[a]		$180,000		
	less 140,650[c]				
	$294,350	-	$180,000	=	$114,350

[a]Computation based on current premium per $1 million of atomic energy insurance.

[b]The present value of the two-thirds insurance rebate ($232,000) after 10 years, discounted at the average rate of return on investment for appropriate electric utilities from 1970 through 1973 (7.5 percent).

[c]The present value of the two-thirds insurance rebate ($290,000) after 10 years, discounted at the average rate of return on investment for appropriate electric utilities from 1970 through 1973 (7.5 percent).

NUCLEAR POWERPLANTS IN COMMERCIAL OPERATION AS OF 12/31/74

	Reactor type	Design electrical rating MWe net	Date of commercial operation	Unit capacity factor to date (note a)	Unit availability factor to date
Browns Ferry-1	[b]BWR	1098	8/74	50.7	72.9
Connecticut Yankee	[c]PWR	575	1/68	78.8	79.7
Cooper Station	BWR	778	7/74	54.0	75.4
Dresden-1	BWR	200	7/60	49.5	67.1
Dresden-2	BWR	809	6/72	47.4	69.1
Dresden-3	BWR	800	11/71	53.7	70.4
Ginna	PWR	490	3/70	65.9	74.3
Indian Point-1	PWR	265	10/62	[d]65.7	[d]76.4
Indian Point-2	PWR	873	8/73	33.2	48.9
Kewaunee	PWR	560	6/74	62.2	75.2
Maine Yankee	PWR	790	12/72	49.6	72.4
Millstone Point-1	BWR	690	3/71	52.6	62.7
Monticello	BWR	545	7/71	66.2	73.0
Nine Mile Point-1	BWR	610	12/69	53.9	65.2
Oconee-1	PWR	886	7/73	53.3	64.4
Oconee-2	PWR	886	7/74	58.2	68.5
Oyster Creek	BWR	650	12/69	74.0	76.5
Palisades	PWR	821	12/71	27.9	35.4
Peach Bottom-2	BWR	1065	5/74	81.8	90.6
Peach Bottom-3	BWR	1065	12/74	76.5	100.0
Pilgrim-1	BWR	655	12/72	52.3	63.6
Point Beach-1	PWR	497	12/70	70.1	79.9
Point Beach-2	PWR	497	4/73	63.9	86.4
Prairie Island-1	PWR	530	12/73	30.3	42.4
Quad Cities-1	BWR	809	2/73	48.9	58.9
Quad Cities-2	BWR	809	3/73	53.2	65.7
Robinson-2	PWR	707	3/71	70.1	74.3
San Onofre-1	PWR	450	1/68	70.0	73.0
Surry-1	PWR	823	12/72	49.5	58.6
Surry-2	PWR	823	5/73	49.4	57.3
Three Mile Island	PWR	819	9/74	86.0	88.2
Turkey Point-3	PWR	745	12/72	59.2	73.8
Turkey Point-4	PWR	745	9/73	73.1	78.5
Vermont Yankee	BWR	514	11/72	46.9	67.7
Yankee-Rowe	PWR	175	7/61	68.2	79.3
Zion-1	PWR	1050	12/73	45.0	57.1
Zion-2	PWR	1050	9/74	43.9	59.8

[a]Calculated by using maximum dependable capacity.
[b]Boiling water reactor.
[c]Pressurized water reactor.
[d]As of October 1974.

CAPACITY FACTORS FOR 37 NUCLEAR POWERPLANTS 1960-74

Powerplant	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973 (note a)	1974 (note b)
Dresden-1	21.8	33.0	73.0	53.8	56.2	55.4	80.2	46.4	52.4	47.5	77.7	35.3	62.9	33.1	20.1
Yankee-Rowe	[c]25.0	76.0	55.0	69.0	79.8	64.7	85.9	85.7	81.5	75.3	78.8	95.4	42.5	68.0	59.5
Indian Point-1			27.7	38.0	24.6	46.4	50.3	68.3	64.9	72.1	14.1	60.4	48.4	[b]0	
Connecticut Yankee								[c]29.8	73.4	75.0	71.3	83.9	86.0	48.3	92.0
San Onofre-1								[c]21.3	33.6	69.2	81.0	87.5	74.5	60.3	83.5
Oyster Creek										92.7	74.4	77.5	80.0	64.0	67.6
Ginna										[c]19.6	57.8	65.6	64.1	87.4	51.7
Point Beach-1											30.0	76.3	69.4	64.5	76.2
Nine Mile Point											42.4	63.4	60.5	65.0	61.7
Millstone-1											[c]25.9	63.2	54.9	33.6	63.1
Dresden-2											[c]23.3	[c]37.7	47.4	73.7	48.2
Dresden-3												35.7	72.8	54.5	45.7
Robinson-2												40.7	80.4	81.9	82.6
Monticello												49.2	74.5	67.7	62.0
Palisades													57.0	41.1	1.3
Pilgrim-1													29.3	71.0	33.6
Surry-1													47.3	57.0	48.1
Turkey Point-3													7.6	68.2	62.1

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APPENDIX III

Powerplants	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973 (note a)	1974 (note b)
Vermont Yankee													37.9	43.5	56.2
Point Beach-2													[c] 14.8	66.8	76.9
Quad Cities-1													[c] 64.0	70.6	50.8
Quad Cities-2													[c] 39.4	75.3	63.8
Surry-2														73.4	38.2
Turkey Point-4														61.7	74.1
Zion-1														22.4	45.1
Indian Point-2														23.6	43.5
Maine Yankee														57.8	51.6
Oconee-1														57.4	52.4
Oconee-2														[c] 27.1	58.2
Browns Ferry-1														[c] 22.0	55.4
Prairie Island-1														[d] 12/73	31.5
Kewaunee															62.2
Peach Bottom-2															81.8
Peach Bottom-3															76.5
Cooper Station															54.0
Three Mile Island															86.0
Zion-2															43.9

a/ Source of data 1960-73--AEC's RDT.
b/ Source of data--NRC.
c/ Capacity factors before commercial operation.
d/ Date of actual commercial operation indicating no capacity factors for the remaining months of that year.

APPENDIX IV

AVAILABILITY FACTORS FOR 37 NUCLEAR POWERPLANTS
1960-74 (note a)

Powerplant	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Dresden-1	32.9	38.1	78.6	75.6	80.9	78.3	94.9	53.9	62.2	61.3	92.7	63.0	78.2	72.8	35.5
Yankee-Rowe		87.0	67.6	78.9	91.1	75.7	89.6	92.1	87.2	83.0	79.9	96.5	55.2	71.0	69.6
Indian Point-1			60.5	71.4	48.4	64.0	67.5	80.9	91.7	92.8	26.9	83.3	78.7	[b]0	
Connecticut Yankee								[c]44.3	78.7	86.5	78.7	86.6	87.7	50.5	91.2
San Onofre-1								[c]36.4	41.4	75.8	83.0	93.4	77.4	62.8	86.1
Oyster Creek										95.4	77.0	80.4	81.3	[b]73.1	70.4
Ginna										[c]34.3	69.4	75.9	69.2	95.0	62.4
Point Beach-1											67.6	88.3	72.5	75.9	81.5
Nine Mile Point											48.9	68.1	70.2	76.0	70.5
Millstone-1											[c]39.6	70.9	59.0	45.4	79.1
Dresden-2											[c]47.4	[c]65.0	59.8	87.6	64.1
Dresden-3												54.6	85.9	68.1	65.0
Robinson-2												48.7	85.2	75.2	83.3
Monticello												59.1	79.4	[b]71.2	74.9
Palisades													57.0	43.8	5.5
Pilgrim-1													42.3	86.7	39.2
Surry-1													47.3	57.0	54.8
Turkey Point-3													27.5	81.3	69.9
Vermont Yankee													70.0	61.1	74.1

APPENDIX IV

Powerplant	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Point Beach-2													[c]81.8	92.4	81.0
Quad Cities-1													[c]69.6	84.9	61.9
Quad Cities-2													[c]55.0	84.5	82.6
Surry-2														73.4	44.8
Turkey Point-4														77.0	77.1
Zion-1														34.4	57.2
Indian Point-2														23.1	59.4
Maine Yankee														75.8	68.7
Oconee-1														73.7	60.1
Oconee-2														[c]27.1	68.5
Browns Ferry-1														[c]76.7	74.5
Prairie Island-1														[d]12/73	43.9
Kewaunee															75.2
Peach Bottom-2															90.6
Peach Bottom-3															100.0
Cooper Station															75.4
Three Mile Island															88.1
Zion-2															59.8

a/ Source of 1974 data--NRC; source of 1960-73 data--AEC's RDT.
b/ Source of data--NRC.
c/ Availability factor before commercial operation.
d/ Date of actual commercial operation indicating no availability factors for the remaining months of that year.

TWO METHODS USED BY AEC AND NRC TO CALCULATE PLANT CAPACITY FACTOR

The AEC regulatory organization and NRC through April 1975 calculated capacity factor as follows:

$$\text{Capacity factor} = \frac{\text{net electrical output (MWHe)} \times 100}{\text{design electrical capacity (net)} \times \text{time (hours)}}$$

Design electrical capacity (net) was defined by AEC as the nominal net electrical output of the plant (unit) used for the purpose of plant design.

Since April 1975, NRC has been calculating capacity factor as shown below:

$$\text{Capacity factor} = \frac{\text{net electrical output (MWHe)} \times 100}{\text{maximum dependable capacity (MWe-net)} \times \text{time (hours)}}$$

The difference in the new calculation--maximum dependable capacity--is defined by NRC and the Edison Electric Institute as the smaller of winter or summer dependable main-unit capacity. According to NRC, maximum dependabale capacity often differs from the design electrical rating, which is a nominal value, because the turbine generator output may vary during the year with the temperature of the condenser cooling water.