A Roll of the Dice

NRC's Efforts to Renew Nuclear Reactor Licenses

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Public Citizen's Critical Mass Energy Project
April 1995

We would like to thank the Deer Creek Foundation for providing some of the funding that made this report possible.

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ISBN **0-937188-89-1**

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Executive Summary

For the second time in four years, the U.S. Nuclear Regulatory Commission has issued a "final" rule that would allow utilities to operate nuclear power plants beyond the 40 year term of the current license. The nuclear industry's first attempt to renew a nuclear reactor license resulted in the shutdown of Yankee Atomic's Rowe reactor, a perennial industry leader. In the wake of the Rowe debacle, the nuclear industry pressed the Commission to change the license renewal rule. Acquiescing to industry demands, the NRC's rewrite of the rule concluded that the existing regulatory process will continue to mitigate the effects of aging to provide an acceptable level of safety in the period of extended operation. However, if that were actually the case, Yankee Rowe would still be splitting atoms rather than being decommissioned. The NRC's reliance on "current regulatory processes" to ensure the safety of nuclear reactors in the absence of any criteria, inspection or licensee submittal of a reactor's current licensing basis constitutes an abrogation of the Commission's statutory responsibility. Merely declaring that all reactors meet their current licensing basis does not make it so.

License renewal has proven to be a high stakes gamble. Nuclear utilities can gain 20 more years of operation, and the commensurate economic benefit, while shifting the risk of future operation from the stockholder to the ratepayer. The decision either to retire a nuclear reactor or renew its license will be based on a combination of economic, safety and political considerations. As the experience of Yankee Rowe demonstrated, the existing regulatory process may not mitigate the effects of aging and even the best run reactors may have difficulty proving they can operate safely for an additional 20 years. Furthermore, the Rowe experience demonstrates that examination of the licensing basis for extended operation could jeopardize the remaining years on the current license.

Yankee Atomic's efforts to extend Rowe's license raised the issue of the strength of the reactor pressure vessel, the steel crucible that holds the radioactive fuel rods. Bombarded by radiation, the reactor vessel becomes embrittled, which increases its susceptibility to cracking. If the vessel cracks a meltdown is virtually inevitable. The NRC has attempted to get ahead of the embrittlement curve by allowing reactors that are becoming severely embrittled to justify continued operation. While other utilities have pencil whipped their embrittlement calculations to conform with regulations, the public can take little solace in these computations. Although NRC estimates indicated that Rowe would not be in danger of embrittlement until 2029, the reactor is now being decommissioned because Yankee Atomic could not prove that its reactor pressure vessel was sound.

The reactor vessel is not the only component of a nuclear reactor susceptible to premature degradation. The steam generators used in Westinghouse and Combustion Engineering designs have experienced rapid degradation, necessitating lengthy reactor shut downs for repair and replacement. Steam generator tube failure is both a safety and economic problem for utilities. The rupture of as few as ten steam generator tubes could result in the meltdown of the reactor fuel rods, releasing catastrophic amounts of radiation into the environment. Steam generator tube degradation has led NRC Commissioner Kenneth Rogers to conclude that "in essence, we have a 'loaded gun,' an accident waiting to happen."

Whether steam generator tubes are sleeved, plugged or replaced altogether, the solution is an expensive one for the utility and ultimately the consumer. After fending off numerous voter referenda calling for the shutdown of the Trojan reactor in Oregon, the utility decided to close the nuclear reactor and sue Westinghouse rather than replace the steam generators at a cost of at least $200 million. Considering the steep cost of steam generator replacement and the uncertainty of recouping the investment, some utilities may decide not to replace their steam generators and forgo the opportunity to renew their operating licenses. However, the prospect of reactors limping along with degraded steam generators is neither in the interests of the nuclear utilities nor in the interests of public health and safety.

The NRC has long recognized that reactor vessels can crack precipitating a Chernobyl-like catastrophe. However, regulators have been slow to acknowledge that radiation-induced damage to other parts of the nuclear reactor could be just as catastrophic. More than a dozen General Electric designed nuclear reactors in the U.S. and abroad have evidence of cracking in the reactor core shroud—a metal cylinder surrounding the reactor fuel rods. The owners of these boiling water reactors have contended that the core shroud is of little safety significance. However, the NRC has acknowledged that cracking of the core shroud could damage the radioactive fuel rods, prohibit the insertion of control rods and lead to a meltdown of the reactor.

The problem of core shroud cracking is now believed to affect most, if not all, older General Electric reactors. However, "older" is a relative term. Cracking has been found in reactors that have operated for less than 10 years, only one quarter of a reactor's operating license. Replacement of the core shroud will cost millions of dollars and calls into question the economic viability of many of these nuclear reactors. While the issue of the core shroud cracking has not yet resulted in the permanent shutdown of a reactor, it does indicate that extended operation of boiling water reactors is anything but certain. It is doubtful whether any reactor could economically justify the two year down time estimated for core shroud replacement. Even if reactors can operate with hastily repaired core shrouds, the degradation of other reactor internals will pose both safety and economic problems. The degradation of reactor internals, including the core shroud, may lead boiling water reactors to shutdown prior to any renewal term.

The economics of license renewal are problematic at best. Increased competition in the wholesale electricity market is already placing serious economic pressure on nuclear utilities.

As nuclear reactors age, utilities will be forced to spend large amounts of capital to repair or replace components such as steam generators and core shrouds. Absent the ability to amortize or write off these large capital additions over an additional 20 year period, nuclear utilities will be forced by economics and safety to retire nuclear reactors prior to license expiration. Early shutdown of nuclear reactors may result in stranding large utility investments and under-funding utility commitments such as decommissioning and waste disposal. Utilities do not want to make their investors swallow these costs. Through license renewal, they can shift the risk of the bad investment in nuclear power from the investor to the ratepayer.

However, if utilities can not recoup their investments after nuclear reactors are retired, they may continue to operate unsafe and uneconomical reactors. If nuclear reactors are too expensive to operate but utilities are reluctant to close them down due to stranded investments, we could have an economic recipe for disaster. More than half of the nuclear reactors in the US. are already more expensive to operate than the cost of replacement power. If nuclear reactors can not compete in the current market, the prospects for license renewal would appear dim and fading. Even if nuclear utilities can bring O&M costs under control and reverse historic trends, the combination of cheap replacement power, large capital additions and a growing high-level waste problem will likely doom many renewal efforts.

Extending the licenses of operating reactors will only increase the amount of high level waste with which future generations will have to contend. Neither the nuclear industry nor the government has developed the means to isolate high-level radioactive waste from the environment for the duration of its hazardous life. Coping with the wastes that result from any proposed license extension looms as an unknown cost and possible taxpayer liability of the NRC's license renewal rule.

Serious doubt exists as to whether a geologic repository, once expected in 1998 but now envisioned by optimistic timetables in 2010, will ever be available. In fact, the feasibility of "disposing" of this nation's nuclear waste in an underground storage facility has never been more in doubt. Scientists at Los Alamos National Laboratory in New Mexico, fear that high level radioactive wastes stored in the proposed repository at Yucca Mountain could eventually explode. Even nuclear scientists are beginning to understand what environmentalists and public interest advocates have been arguing for decades, that one can not merely "dispose" of radioactive wastes that have a hazardous life of over 240,000 years.

In the absence of either a repository or interim facility, many utilities are running out of space in their spent fuel pools. As many as **14** reactor fuel pools will reach capacity by the year 2000. Faced with the politically unsavory task of attempting to site additional dry cask storage at the reactor site, utilities with reactors nearing the end their licenses may opt to avoid the political and economic costs and decide instead to retire the nuclear reactor.

No nuclear reactor has yet operated for the 40 year term of its operating license. It appears increasingly unlikely that older reactors will remain competitive with alternative sources of electricity. Given the myriad safety problems facing aging reactors, many nuclear power plants will have difficulty even lasting to the end of their current licenses. When one also considers the utilities' ever growing high-level radioactive waste problem and dismal economics, operation of nuclear reactors beyond 40 years seems like a pipe dream. The NRC's attempt to extend the operating licenses of nuclear reactors is little more than a regulatory "slight of hand." License renewal would allow utilities to shift the financial risk of nuclear power from the investor to the ratepayer by amortizing the costs of continued operation over an additional 20 year period.

The new license renewal rule has no foundation in safety. Merely relying upon the current regulatory process to protect the public while failing to require that reactors document compliance with the current licensing basis is an abdication of the Commission's responsibility. Absent any enforceable standard for renewal, the NRC's new license renewal rule appears to be little more than a rubber stamp. If the Commission were truly concerned with safety, it would ensure that aging, unsafe and uneconomical reactors are shut down. Rather than extending the operation of nuclear reactors, the NRC should develop objective criteria on which to base a decision to retire a nuclear reactor. Unfortunately, the Commission has never done so.

Introduction

The Nuclear Regulatory Commission is attempting to allow utilities to operate nuclear reactors beyond the 40 year term of the current license. License renewal has proven to be a high stakes gamble. Nuclear utilities can gain 20 more years of operation, and the commensurate economic benefit, while shifting the risk of future operation from the stockholder to the ratepayer. The downside, however, is that the review needed to renew a nuclear reactor license may cost the utility the remaining life on the current license,

The odds depend upon which nuclear reactor is rolling the dice. Experience has shown that even the best run nuclear reactors may have trouble proving they can operate safely for an additional 20 years. The nuclear industry's first attempt to renew a nuclear power plant license resulted in the shutdown of Yankee Atomic's Rowe reactor, once a perennial industry leader.

No commercial nuclear reactor has yet operated for 40 years. The oldest reactor, Big Rock Point in Michigan, is 32 years old and is already economically non-competitive with other sources of electricity.

Table 1

Shutdown	Reactor	State	Operation
11/30 92	San Onofre 1	CA	< 26 years
11/09/92	Trojan	OR	< 17 years
10/01/91	Yankee Rowe	MA	< 28 years
8/18/89	Fort St. Vrain	CO	< 16 years
6/28/89	Shoreham	NY	< 3 months
6/07/89	Rancho Seco	CA	< 15 years

Six nuclear reactors have been retired in the last 6 years (see Table 1 below).

On average, these reactors operated for less than half of the operating license. Even when excluding anomalies like the meltdown at Three Mile Island near Harrisburg, PA and the political meltdown that shut Shoreham in New York, retired reactors averaged only 20 years of operation. With increased competition in the electricity industry, nuclear reactors are facing a mid-life crisis and the NRC is attempting to give them a new lease on life.

The decision either to retire a nuclear reactor or renew its license will be based on a combination of economic, safety and political considerations. This report will examine a number of issues that have led or may soon lead to the early retirement of U.S. nuclear power plants. These issues include:

Steam Generator Tube Degradation
Reactor Pressure Vessel Embrittlement
Reactor Core Shroud Cracking
Economic Competitiveness
And
High Level Waste/Spent Fuel Storage

These factors, along with political considerations regarding the public perception of nuclear power, have led to the early demise of several reactors and threaten the viability of several more nuclear reactors across the country.

1. A Brief History of NRC's Attempts to Relicense Reactors

The First Rule: Two Principles of License Renewal

On December 13,1991, the U.S. Nuclear Regulatory Commission published the "final" rule regarding renewal of nuclear power plant licenses.' At that time, the Commission premised its assumption that nuclear power plants could operate safely for an additional 20 years on two principles.

> "The first principle is that, with the exception of age-related degradation unique to license renewal and possibly some few other issues related to safety only during extended operation of nuclear power plants, the regulatory process is adequate to ensure that the licensing bases of all currently operating plants provide and maintain an acceptable level of safety so that operation will not be inimical to public health and safety or common defense and security. Continuing this regulatory process in the future will ensure that this principle remains valid during any renewal term if the process is modified to include age related degradation unique to license renewal.
>
> . * *
>
> The second and equally important principle is that each plant's current licensing basis must be maintained during the renewal term, in part, through a program of age-related degradation management for systems, structures and components that are important to license renewal as defined in the final rule."[2]

The Commission's original rule was premised on the assumption that the current licensing basis—those regulations, requirements and commitments which constitute the nuclear reactor's operating license—would be sufficient to protect the public health and safety so long as it was modified to account for age related degradation. Under the original renewal rule, members of the public could not challenge the sufficiency of or question the compliance with a reactor's current licensing basis. According to the Commission, the current licensing basis (CLB) for all reactors is sufficient and all reactors are in compliance with the CLB.

Under the license renewal rule the licensee need only compile a list of the documents that constitute the reactor's current licensing basis. The NRC is neither going to review these documents nor confirm that the reactor is in compliance with the regulations imposed under the current license. Yet, the NRC acknowledges that the current licensing basis for the nations nuclear power plants is "outdated and oftentimes poorly rec~rded."~

Advisorv Committee Concerns

The myth that the current licensing basis is sufficient and that all plants are in compliance with the licensing basis fails the tests of both logic and reality. The NRC's assumption is based upon the specious argument that operating without a meltdown for a finite period of time means that safety is adequate. Hal Lewis, Subcommittee Chair of the Advisory Committee on Reactor Safeguards, recognized this fallacy when the ACRS took up the original license renewal rule. Mr. Lewis stated that:

> "the general argument that the fact that one has operated safely for a finite period of time proves that the safety level is adequate is just not statistically right, because there isn't that much history in the industry. And it's a trap. Because other agencies, for example, people have used the argument that they had **24** successful Shuttle flights, to show the level of safety was adequate. And in retrospect, after one disaster, it turned out not to be. The

Soviets, after Chemobyl, suddenly discovered that the level of safety they had before Chernobyl was not adequate. But the day before Chernobyl they would have said it was adequate on the basis of operating history.

So it is a general trap, a psychological trap, to believe that because something has not happened, you are doing just fine."[4]

Although the ACRS Commissioner's comments were directed at the original rule they apply to the current NRC proposal as well. Mr. Lewis continued his critique of the renewal rule noting that:

> "the Commission certainly doesn't know that its current regulatory process provides adequate protection to the public. It has declared that it does, and it's the operating definition, but the Commission has also promulgated safety goals and the commission doesn't know that the current licensing basis will meet the safety goals, although it believes it to be the case."5

ACRS Commissioner Lewis recognized the arbitrary nature of the Commission's key assumption in license renewal. Unfortunately, the NRC continues to labor under this false assumption.

The General Design Criteria: Older Reactors Need Not Comply

The NRC will not verify licensee compliance with the current licensing basis, nor will the Commission require that **63** nuclear reactors conform to the minimum design standards necessary to protect the public health and safety. These standards, known as the General Design Criteria or GDC, established base-line requirements for nuclear reactor design and cover a range of topics including fire protection; inspection and testing of electrical power systems; containment design and testing; inspection and testing of the emergency core cooling system as well as fuel handling and storage requirements. According to the NRC, the General Design Criteria was:

> necessary to provide reasonable assurance that the facility can be operated without undue risk to the public health and safety. The phrase 'without undue **risk'** represents the statutory requirements of Section 182 of the Atomic Energy Act for 'adequate protection of the public health and safety' The use of the statutory standard implies that the GDC represents the minimum standard for all licensees.[6]

However, the Commission decided that the General Design Criteria would not apply to nuclear reactors that received a construction permit prior to May 21,1971.7 The reactors listed in Table 2 (see page **4)** have been exempted from the General Design Criteria.

The NRC has determined that for these **63** nuclear reactors the GDC will not apply. The Commission concluded that "current regulatory processes are sufficient to ensure that plants continue to be safe and comply with the intent of the GDC."[8] The NRC's reliance on "current regulatory processes" to ensure the safety of nuclear reactors in the absence of any criteria, inspection or licensee submittal of a reactor's current licensing basis constitutes an abrogation of the Commission's statutory responsibility. Merely declaring that all reactors meet their current licensing basis does not make it so.

NRC's Lead Plant Program: Yankee Rowe & Monticello

Yankee Atomic's Rowe reactor in Western Massachusetts and Northern States Power's Monticello reactor in Minnesota were to be the first reactors to submit license renewal requests to the NRC. Originally, the licensees were to submit applications in 1991 as part of the DOE-sponsored lead plant program.~ By the end of 1992, however, Yankee Rowe had been permanently shut down and Monticello had postponed its license renewal application indefinitely.

While the NRC could merely declare that all reactors met their current licensing basis, Yankee Rowe had difficulty proving this point to the NRC staff. The issue concerning the staff revolved around the reactor pressure vessel (RPV). The vessel is the steel crucible that holds the nuclear fuel rods. The NRC staff was concerned that after years of being bombarded by neutrons from the fission reaction Yankee Rowe's vessel had become embrittled to the point where an accident could threaten the integrity of the vessel.

On September 5,1990, NRC's senior metallurgist Dr. Pryor N. Randall told the Advisory Committee on Reactor Safeguards (ACRS) that he could not justify Yankee Rowe's continued operation.

You know there are three ways the NRC handles this. If we've had a failure, you know, it's pretty simple. The industry knows how to deal with failures. About all we do is find out, well, is it generic? Is this an epidemic starting or not? If it is, we pass the word around to the utilities and so forth.

The second approach that we have that there be some staff concern, raise it with the utility. They submit a report, we review it, we have questions, we ask more, they submit more reports, we want measurements. Sometimes we want long range things. They go along pretty cheerfully because they know that in most cases when it's all done, the questioner is exhausted and we'll say, it's alright.

I'm afraid that we're into that here and I don't think we should, for safety reasons, on this plant. The third approach, which we don't use very often, is to declare a situation unacceptable. That's where I'm coming from.

I can not agree that restart is safe **or** justified.

I know it's a minority report but I have to show you what I have in mind.10

"Setting aside all of the PRA stuff," Randall continued, **"if** we let them start up with this level, we're simply gambling

Table 2

Reactor	State	Utility
Arkansas Nuclear 1	AR	Entergy
Beaver Valley 1	PA	Duquesne Light Company
Big Rock Point	MI	Consumers Power
Browns Ferry 1, 2 & 3	AL	Tennessee Valley Authority
Brunswick 1 & 2	NC	Carolina Power & Light
Calvert Cliffs 1 & 2	MD	Baltimore gas & Electric
Cooper	NE	Nebraska Public Power
Crystal River 3	FL	Florida Power Corp.
Davis Besse	OH	Toledo Edison
Cook 1 & 2	MI	Indiana/Michigan Power
Diablo Canyon 1 & 2	CA	Pacific Gas & Electric
Dresden 2 & 3	IL	Commonwealth Edison
Duane Arnold	IA	Iowa Electric Light & Power
Hatch 1	GA	Southern Nuclear Operating Co.
Fort Calhoun	NE	Omaha Public Power
Ginna	NY	Rochester Gas & Electric
Haddam Neck	CT	CT Yankee Atomic Power Co.
H.B. Robinson 2	SC	Carolina Power & Light
Indian Point 2 & 3	NY	Consolidated Edison
Fitzpatrick	NY	New York Power Authority
Kewaunee	WI	Wisconsin Public Service Corp.
Maine Yankee	ME	Maine Yankee Atomic Power Co.
Millstone 1 & 2	CT	Northeast Utilities
Monticello	MN	Northern States Power
Nine Mile Point 1	NY	Niagara Mohawk Power Co.
North Anna 1 & 2	VA	Virginia Electric & Power Co.
Oconee 1, 2 & 3	SC	Duke Power Co.
Oyster Creek	NJ	GPU Nuclear
Palisades	MI	Consumers Power Co.
Peach Bottom 2 & 3	PA	Philadelphia Electric Co.
Pilgrim	MA	Boston Edison Co.
Point Beach 1 & 2	WI	Wisconsin Electric Power Co.
Prairie Island 1 & 2	MN	Northern States Power
Quad Cities 1 & 2	IL	Commonwealth Edison
Salem 1 & 2	NJ	Public Service Electric & Gas
sequoyah 1 & 2	TN	Tennessee Valley Authority
St. Lucie 1	FL	Florida Power Co.
Surry 1 & 2	VA	Virginia Electric & Power Co.
Three Mile Island 1	PA	GPU Nuclear
Turkey Point 3 & 4	FL	Florida Power & Light
Vermont Yankee	VT	VT Yankee Nuclear Power Corp.
Zion 1 & 2	IL	Commonwealth Edison

that this transient or worse will not occur in the next fuel cycle."11 Unfortunately, two weeks earlier, while Randall was out of town, the NRC staff approved the restart of the Yankee Rowe reactor. Randall's ACRS testimony proved prescient as the NRC failed, time and time again, to declare the situation at Rowe unacceptable.

On June 4,1991, the Union of Concerned Scientists and the New England Coalition on Nuclear Pollution filed a petition with the NRC asserting that Rowe's reactor vessel violated NRC requirements and requesting Rowe's immediate shutdown. Although UCS asked that the Commissioners exercise jurisdiction over the petition the Commission refused and the NRC staff denied the petition on June 25.

On July 11,1991, UCS renewed and supplemented their petition. The Commission responded on July 31,1991 by allowing Yankee Atomic to again restart the Rowe reactor while "uncertainties" regarding Rowe's vessel were resolved. This time, however, the Commissioners exercised their jurisdiction over the petition and gave Yankee a deadline, concluding that "[i]n no event will plant operation beyond April 15,1992 be permitted, until these uncertainties have been resolved. . . ."12

On October 1,1991, over a year after NRC's senior metallurgist had called for its closure, Yankee Atomic "voluntarily" shut down the Yankee Rowe reactor. After months of dispute and with the extent of vessel embrittlement still unresolved, the Yankee Atomic board voted to retire the reactor. On February 27,1992, Yankee announced the permanent shutdown of the Rowe reactor citing "economic" reasons for its decision. The actual state of the reactor vessel has never been determined.13

Monticello & Northern States Power

In light of the events at Yankee Rowe, Northern States Power, owner of Monticello the industry's lead boiling water reactor, decided to delay the reactor's renewal application. The utility then submitted an analysis to NRC citing four reasons for its decision:

1) the uncertain resolution of the high level waste issue; 2) the uncertain resolution of the low level waste issue and rising cost associated with that uncertainty; 3) A need to demonstrate the ability to continue excellent operations while reducing costs; and **4)** the regulatory uncertainties of the NRC license renewal process.14

The utility went on to note that the recent shutdowns all had three factors in common: the availability of inexpensive replacement power, high operations and maintenance costs and large capital expenditures. Since the cost of replacement power is beyond the control of the nuclear industry, NSP recognized that "[i]t is incumbent upon nuclear power plant owners, then, to control their operations and maintenance costs and capital expenditures such that nuclear power remains competitive with alternative energy supplies."'15 To accomplish this task at Monticello, **NSP** concluded that it must keep **O & M** costs and capital additions significantly below historical trends.

The Second License Renewal Rule: Has NRC Lost Its Principles?

In the wake of the Yankee Rowe debacle, the NRC reexamined the license renewal rule. In two papers presented to the Commission, the NRC staff attempted to finesse some of the issues that were the cause of the "regulatory uncertainties of the NRC license renewal process." The Staff determined that a new approach to license renewal could be implemented without changing the existing rule.16

However, in testimony before the NRC's Advisory Committee on Reactor Safeguards, industry representative William Rasin argued that the staff's new approach was in conflict with the original rule and could lead to a court challenge. Rasin stated that "[i]t was felt it would be very easy to show that the way we applied the rule was not the way the Commission stated, by reading the statement of considerations. Therefore we feel and we continue to express to the Commission, the fact that formal Commission action is necessary.''17

The NRC eventually came around to the industry's point of view and decided to rewrite the license renewal rule. In promulgating the new license renewal provisions the NRC determined that "[p]ortions of the statements of consideration (SOC) accompanying the existing rule have been viewed to be inconsistent with the NRC staff guidance discussed in SECY-93-**049** and SECY-93-113. In addition, the industry does not believe that the existing rule provides a stable and predictable regulatory process for license renewal.''18

The Commission's changes to license renewal alter the rule's original premise by deleting the concept of age-related degradation unique to license renewal (ARDUTLR). However, the ARDUTLR concept was the linchpin to the original NRC's rule. In fact, it was the only real issue!

> Moreover, consideration of the range of issues relevant only to extended operation has led the Commission to conclude that there is likely only one real issue generally applicable to all plants—age-related degradation. The renewal rule focuses the Commission's review on this one safety issue but provides leeway for the Commission to consider, on a case-by-case basis, other issues unique to extended operation.19

Absent the ARDUTLR concept, the license renewal rule has no foundation. The recognition that there is "Age Related Degradation Unique To License Renewal" and that it could be managed allowed the NRC to determine that the CLB could be carried into the renewal term without a reduction in safety. Furthermore, the inclusion of ARDUTLR concept limited the scope of the license renewal review. NRC Chairman Ivan Selin stated that:

> if the concept of age related degradation unique to license renewal were thrown out, even though its role there is fairly limited, but the theory, if that were thrown out, then we couldn't rely on the maintenance rule. We would basically have to take all parts of the CLB and at least **look** at that to say, is there any reason to believe that these will change in the next 20 years compared to the first 40? In other words, a much wider range of issues might have to dealt with at license renewal than is currently conceived.[20]

Without the ARDUTLR concept as a means of narrowing the scope of license renewal review, many utilities may find that the new license renewal process will still require extensive justification for the continued operation of aging reactor beyond 40 years.

The Commission's change of heart and resulting rule change has not been precipitated by any realization about nuclear reactor aging and safety. But, according to James Taylor, NRC Executive Director for Operations:

> because of the language of the rule, in particular the definition of age-related degradation unique to license renewal, the staff's proposed path would have unavoidably entailed a large amount of documentation on effective programs that would be drawn into NRC's regulatory system of formal documentation and change control. It was largely for this reason that the potential renewal applicants and the industry in general thought the price of going down the staff's path was just too high.21

The NRC's rewrite of the license renewal rule rationalizes the Commission's regulatory retreat by stating that:

> the Commission still believes that mitigation of the deleterious effects of aging resulting from operation beyond the initial license term should be the focus for license renewal. After further consideration and experience in implementing the current rule, the Commission has, however, determined that the requirements for carrying out the license renewal review can and should be simplified and clarified. The Commission has concluded that, for certain plant systems, structures, and components, the existing regulatory process will continue to mitigate the effects **of** aging **to** provide an acceptable level of safety in the period of extended operation.22

Unfortunately, the experience from Rowe does not bear out the Commission's conclusions. Rather, what the Rowe experience demonstrated is that the existing regulatory process may not mitigate the effects of aging and that even the best run nuclear plant may have difficulty proving it can operate safely in the renewal term. Furthermore, the Rowe experience demonstrated that examination of the licensing basis for extended operation could jeopardize the remaining years on the current license.

NRC Gambles On The Maintenance Rule

The Nuclear Regulatory Commission's rewrite of the license renewal rule relies heavily upon the maintenance rule. The Commission's first performance-based rule, the maintenance rule will not go into effect until 1996. The Commission's basis for the license renewal rests upon the as yet unproven record of licensee compliance with the maintenance rule that requires utilities to monitor and adequately maintain the operability of aging reactor systems, structures and components. The importance of this point has not been lost on the Commissioners. During a briefing on changes to the license renewal rule, the Commissioners discussed the relationship between the two rules.

> CHAIRMAN SELIN **I** mean basically we're doubling our bet. When we passed the maintenance rule we said we believe that this rule can be implemented through reg. guidance, inspection guidance to carry out its objectives. And now we're saying, assuming that can be done, one can make a second rule depend on that. But in the case of an individual program, we're going to have experience under the maintenance rule before they renew those.[23]

The Chairman's comments were seized upon by the NRC's Director of Nuclear Reactor Regulation, Thomas Murley. Murley recognized that in doubling their bet on the maintenance rule the Commission had created a double-edged sword.

> DOCTOR MURLEY: I think you're right Mr. Chairman. To turn it around, though, let me just mention that, because this is such a cornerstone of our proposed approach, namely prospective reliance on the maintenance rule, we have to ask the question, suppose during a proceeding or during an application review we find problems in our inspection program where maintenance is not being done well? Then the whole foundation of the rule comes under challenge **for** that particular application.2~

Dr. Murley's comments were not lost on the Chairman. Chairman Selin recognized that reliance on the maintenance rule could open a licensee up to a court challenge.

> CHAIRMAN SELIN: I think what would come under challenge would be his application relying on his execution of the maintenance rule, in which his application wouldn't ***go*** through until he could satisfy us and, if necessary the courts, that we had been thorough in doing that and that's why it's so desirable that there be a timely renewal process in the rule.=

The Commission's concern regarding reliance on the maintenance rule to justify license renewal led Commissioner Remick, a major proponent of performance-based regulation, to address the issue.

> COMMISSIONER REMICK: I agree with Tom that there are indications out there that from time to time there's poor maintenance and some equipment loses its functionality and I hope, however, we're maintaining the current licensing basis today which I think we are. With a maintenance rule, the maintenance rule won't be perfect. Hopefully it might improve some of the maintenance problems, but it won't be perfect and with the maintenance rule some equipment will lose functionality even in good programs.
>
> So, I think we have to be careful we aren't thinking of something magical about a maintenance rule that's going to assure these things in the future. It's going to help but it's—and so, I still say that before there was ever something called the maintenance rule, there was maintenance, some good, some bad. I think that has

maintained the current licensing basis. It better have or we'd better take action.[26]

Unfortunately, the industry's performance in the area of maintenance mirrors the Commissioner's remarks, "some good, some bad." However, Commissioner Remick is overly optimistic in assessing the impact of poor maintenance on the current licensing basis.

In December **1993,** internal nuclear industry documents obtained by Public Citizen revealed marked disparities between what the nuclear industry was telling the Nuclear Regulatory Commission and what the Nuclear Regulatory Commission was then telling the public.

The secret documents were prepared by the Institute of Nuclear Power Operations (INPO), an Atlanta-based industry group established in the wake of the meltdown at Three Mile Island in order to avoid heightened government regulation. Public Citizen's analysis compared the INPO reports with the NRC's Systematic Assessment of License Performance or SALP report, the NRC's report card on nuclear power plant operations. The NRC uses the assessments to determine whether to increase, decrease or provide the same levels of inspection at each of the nuclear reactors.

The Public Citizen report revealed that the NRC consistently failed to address issues raised in all eight areas evaluated by the INPO reports, including maintenance.

INPO assessed each nuclear utility's maintenance program to ensure that maintenance was effectively and efficiently conducted. Furthermore, the INPO evaluations assess whether maintenance activities result in safe and reliable nuclear power plant operation. Of the 56 nuclear power plants covered in the INPO reports leaked to Public Citizen, 40 plants were cited for maintenance problems.

The INPO findings were not all of equal significance, but represented a range of problems. However, at five reactors, deficiencies in the area of maintenance were so severe that they contributed to plant events (see Table **3** below).27

The NRC's **SALP** reports only addressed this problem at **two** of the five reactors identified by the INPO reports. The NRC, responding to Senate inquiries, has claimed that many of the omissions were actually addressed in the underlying inspection reports.28 Since the **SALP** reports are supposed to incorporate the significant information contained in the inspection reports, the public is left to wonder why the negative information in the inspection reports was not included in the SALP.

Although not all maintenance problems rise to this level of significance, they are nonetheless important to reactor safety. In a regulatory analysis accompanying the Commission's maintenance rule, the NRC claimed that safety system failure rates for the best maintained plants were roughly a factor of two to three lower than for those plants that were more poorly maintained.[29]

Table 3

Reactor	Utility	State
Braidwood	Commonwealth Edison	IL
Browns Ferry	Tennessee Valley Authority	AL
Dresden	Commonwealth Edison	IL
Perry	Cleveland Electric	OH
South Texas	Houston Light & Power	TX

II. Can Nuclear Power Plants Operate for 20 More Years When Safety & Economics Threaten Current Operating Licenses

Embrittlement of Reactor Pressure Vessels

As evidenced by the shutdown of Yankee Rowe, the issue of the toughness of the reactor pressure vessel may well determine the operating life of a nuclear reactor.

Reactor Pressure Vessels (RPV) are the steel crucibles that hold the reactor's radioactive core. After years of exposure to the harsh environment, the vessel steel becomes embrittled. Embrittlement is the loss of ductility, i.e., the ability of the pressure vessel metals to withstand stress without cracking. Embrittlement is caused by neutron bombardment and is contingent upon the extent of exposure and the amount of copper and nickel in the metal. The extent of reactor pressure vessel embrittlement is thus dependent upon the unique operating history of each reactor.

The significance of reactor pressure vessel embrittlement is the increased susceptibility to pressurized thermal shock (PTS). Pressurized thermal shock is caused by the rapid cooling and repressurization of the RPV. In establishing requirements for reactor vessels the NRC found that:

> [t]he operating records for pressurized water reactors (PWRs) in the 1970's and early 1980's contained several pressurized thermal shock (PTS) events in which rapid cooldown from operating temperature was followed immediately by repressurization. The combined thermal and pressure stresses were high enough to induce fracture in a reactor vessel if it contained a flaw in the beltline and if the event had occurred later in life when the vessel was significantly embrittled by neutron radiatiion.~'

If a reactor vessel were to crack, a meltdown of the radioactive fuel rods would be virtually inevitable.

The NRC regulations governing embrittlement of reactor vessels establish two methods for measuring the state of radiation damage to the reactor vessel. One, Charpy upper shelf energy, measures the strength of the vessel welds in foot/lbs. NRC regulations require that strength of the vessel be above 75 foot/lbs prior to licensing and remain above 50 foot/lbs for the life of the reactor.31 The second, RT-NDT (reference temperature for nil ductility transition), measures the change in the mechanical properties of the metal from ductile to brittle.[32] In other words, it measures the shift in vessel strength as it is bombarded by neutrons. Since embrittlement is time-dependent, it is possible to chart when a reactor will reach its screening criteria for pressurized thermal shock (see Appendix A, page 31).

The original pressurized thermal shock rule, adopted in July 1985, established a point beyond which reactors could not operate without further safety analysis. This point, known as the screening criteria, was established for every PWR. However, the method for calculating the toughness of the reactor pressure vessel failed to account for the copper and nickel in the

The NRC later amended the rule to bring it into accord with the current state of knowledge regarding vessel embrittlement as reflected in the NRC's regulatory guide 1.99 revision **2.** However, the rule change failed to make a concomitant change in the screening criteria for pressurized thermal shock.

On March 23,1989, Dr. Pryor N. Randall, who later challenged the NRC's restart of the Yankee Rowe reactor due to embrittlement concerns, presented the NRC's case to the Advisory Committee on Reactor Safeguards (ACRS). Discussions between **Dr.** Chester Seiss of the ACRS and Dr. Randall are most revealing. During the course of his presentation to the ACRS, Dr. Randall raised questions concerning the screening criteria stating, "shouldn't we also change the screening criterion because the formula used to derive the probabilities in the original rule was the old PTS formula. And now we're going to change the formula."[34]

The discussion between Dr. Seiss and Dr. Randall continued:

> DR. **RANDALL:** The first reason I don't want to change the screening criterion is that if we do so, we will have to reopen the whole issue of PTS.
>
> DR. SEISS: This is a non-technic& reason.
>
> DR. RANDALL: I can't —
>
> DR. SEISS I mean —
>
> DR. RANDALL: Characterize it any way you like. I can't believe I can sell the idea, YSU know, that this was a neat mathematical process where we've picked an acceptable probability and we've read off a screening criterion, and how if we calculated a different probability, we're just making a delta change in the screening criteria, and are happy.[35]

While the revised PTS rule recognizes that reactors are becoming embrittled at an accelerated rate, it fails to adjust the screening criteria to ensure that reactors are tested at an earlier date. The resulting incongruity will mean that many reactors will operate longer, with more severely embrittled reactor vessels, prior to testing the strength & ductility of the WV. When utilities finally do test the reactor vessels they may be in for the same rude awakening that resulted in the shutdown of Yankee Rowe.

The attempt to re-license Yankee Rowe failed due to the inability of the licensee to prove that the reactor pressure vessel was sound. According to the NRC's pressurized thermal shock rule governing RPV embrittlement, Yankee Rowe's vessel should not have reached its screening criterion until **2025.** However, as early as **1987,** NRC knew that the strength of the Yankee Rowe vessel was cause for concern.

In response to a request from then-Director of Nuclear Reactor Regulation Thomas E. Murley, NRC staff developed a list of reactors where the Charpy upper shelf energy could fall below 50 ft-lbs and thus be in violation of fracture toughness requirements. The NRC staff found that **17** reactors were at risk of violating requirements and, as of January **1,1986,** four reactors actually were below the 50 ft-lb threshold. The information in Table **4** (below) accompanied the NRC memo.

Table 4 Reactor Vessels atlor below 50 FT/LBS

PWR Plant	End of License	Charpy USE at End of License (ft-lb)	Charpy USE on January 1, 1986 (ft-lb)
Point Beach 2	2013	34	39
Point Beach 1	2010	38	43
Turkey Point 3	2007	40	44*
Turkey Point 4	2007	40	44*
Ginna	2006	42	47
Arkansas 1	2008	44	>50**
Rancho Seco	2008	44	>50**
crystal River	2008	44	>50**
TMI1	2008	44	>50**
Oconee 1	2013	44	>50**
Oconee 3	2014	44	>50**
surry 2	2008	46	51
Zion 1	2008	47	>50***
Zion 2	2008	49	>50***
Oconee 2	2013	49	>50**
Surry 1	2008	53	57
Davis Besse	2011	56	>50**
Yankee Rowe	1997	Low Copper Welds	
Bvron 1	2024	Low Copper Welds	

*Florida Power & Light Company has provided analyses to demonstrate that the weld metal in these reactor vessels have adequate margin.

**B&W Owners Group has provided analysis to demonstrate that the Charpy USE for these reactor vessel welds will reach 50 ft-lb no earlier than 1997.

***Commonwealth Edison Co. has provided analyses to demonstrate that the Charpy USE for these reactor vessel welds will reach 50 ft-lb no earlier then 1994.[36]

The NRC staff theorized that Yankee Rowe and Byron 1 were not at risk of falling below the 50 ft-lb threshold because they used low copper metals in their welds. According to the NRC, "they are less susceptible to having their Charpy USE reduced by neutron irradiation than the other PWR reactor vessels."[37]

Less than five yeARs later Yankee Rowe would shut down because the utility could not prove to the NRC that the Charpy upper shelf energy was above 50 ft-lbs or that lower values of upper shelf energy would provide **margins** of safety equivalent to those required by Appendix G.

On the heels of the Rowe shutdown, the NRC realized that it had to get ahead of the curve on the embrittlement issue. The NRC issued a generic letter requiring reactors to address the state of RPV embrittlement. From the information submitted, the NRC developed with a list of reactors at risk of embrittlement. "We're trying to avoid any more surprises like we had with Yankee," said NRC's Director of Nuclear Reactor Regulation.38

The NRC's 1993 list identified many of those reactors first mentioned in the 1987 memo. There were, however, several notable additions and omissions from the earlier list. Virginia Power's Surry Units 1 & 2 near Williamsburg, VA, Toledo Edison Company's Davis Besse reactor in Ohio and Commonwealth Edison's Byron nuclear plant in Illinois were not included in the 1993 analysis. The NRC required or would later require analysis of the Tennessee Valley Authority's Watts Bar 1 in Tennessee, Northeast Utilities' Millstone 2 in Connecticut and Carolina Power & Light's H.B. Robinson in South Carolina. In addition to identifying these pressurized water reactors, the NRC acknowledged for the first time that embrittlement of the reactor vessel may also be a problem for boiling water reactors by singling out Niagara Mohawk's Nine Mile Point 1 in New York and Public Service Electric & Gas' Oyster Creek in New Jersey for further analysis.

The NRC's list of reactors susceptible to embrittlement has fluctuated over time as the regulator has allowed the licensees to recalculate the extent of embrittlement or justify how more severely embrittled reactors would provide the same level of safety. In October 1994, the NRC issued a proposed rule altering the fracture toughness requirements for reactor pressure vessel embrittlement. The proposed amendments would clarify the pressurized thermal shock (PTS) requirements, make changes to the Fracture Toughness Requirements and the Reactor Vessel Material Surveillance Program Requirements, and provide new requirements for thermal annealing of a reactor pressure vessel. The proposed rule change basically allows the licensees more "flexibility" in proving that the RPV can meet fracture toughness requirements.

Regardless of how the NRC allows utilities to "pencil whip" their analyses, the vessels of these reactors are not getting any stronger. Each time a utility finds additional operating margin in their embrittlement calculations it is likely to come at the expense of the safety margin. The NRC's proposed revision of fracture toughness requirements states that:

> The modification would permit a licensee to develop plant-specific data. Generally, plant-specific data would result in a reduction in the margin applied to the fracture toughness data, to reflect the reduction in uncertainties due to the availability of plant-specific data. However, this must be evaluated on a case-by-case basis.[40]

The NRC's most recent "final" rule on fracture toughness requirements is not due until September 1995.[41] However, even if the NRC can provide utilities with more "wiggle room" in regard to their embrittlement calculations, operation for the additional 20 years contemplated under a renewed license is unlikely (see table **5,** page **12).**[42]

The NRC has stated that at this point only Palisades is at risk of violating embrittlement standards during its current operating license. The utility is now confronted with the choice of annealing the vessel, replacing it or shutting down the reactor entirely. No nuclear power plant has ever replaced its pressure vessel. Replacement cost estimates approach $100,000,000 and thus appear prohibitive.

Shutdown or Anneal

On January 5, 1995, Consumers Power Company informed its employees that the Palisades reactor would reach its PTS screening criteria limit by as early as 1996. Consumers Power says it plans to anneal the Palisades vessel by the year 2000,[43] Annealing is the process of heating the vessel to approximately 850 degrees F for a week, which will allow the crystalline structure of the metal to regain its ductility. Cost estimates for vessel annealing are around $10 million. However, the outcome of annealing is uncertain. According to NRC, if the embrittled area is a weld, annealing will be less effective and the rate of re-embrittlement will be increased.[44]

If the vessel can actually last until 2000 and Consumers Power goes ahead with the annealing, Palisades will be the first commercial reactor to go through the process. As was the case with Yankee Rowe, Consumers may find that retirement is a better option than the annealing alternative. The duration of the outage required for annealing the vessel combined with the need to justify continued operation may result in the shutdown of the Palisades reactor prior to the expiration of its license in 2007. If Rowe is any indication, the decision to retire the reactor will be left in the hands of the utility while the regulators vacillate.

Steam Generator Tube Degradation

Pressurized Water Reactors (PWRs) incorporate a two-loop design in which pressurized water in one loop carries heat from the reactor's radioactive core into the steam generator. Steam generators contain thousands of tubes which carry the pressurized super-heated water. The heat from the radioactive loop causes the non-radioactive water on the opposite side of the tubing to flash to steam. This steam then drives the turbine to generate electricity[5] (see Diagram A, page 13).

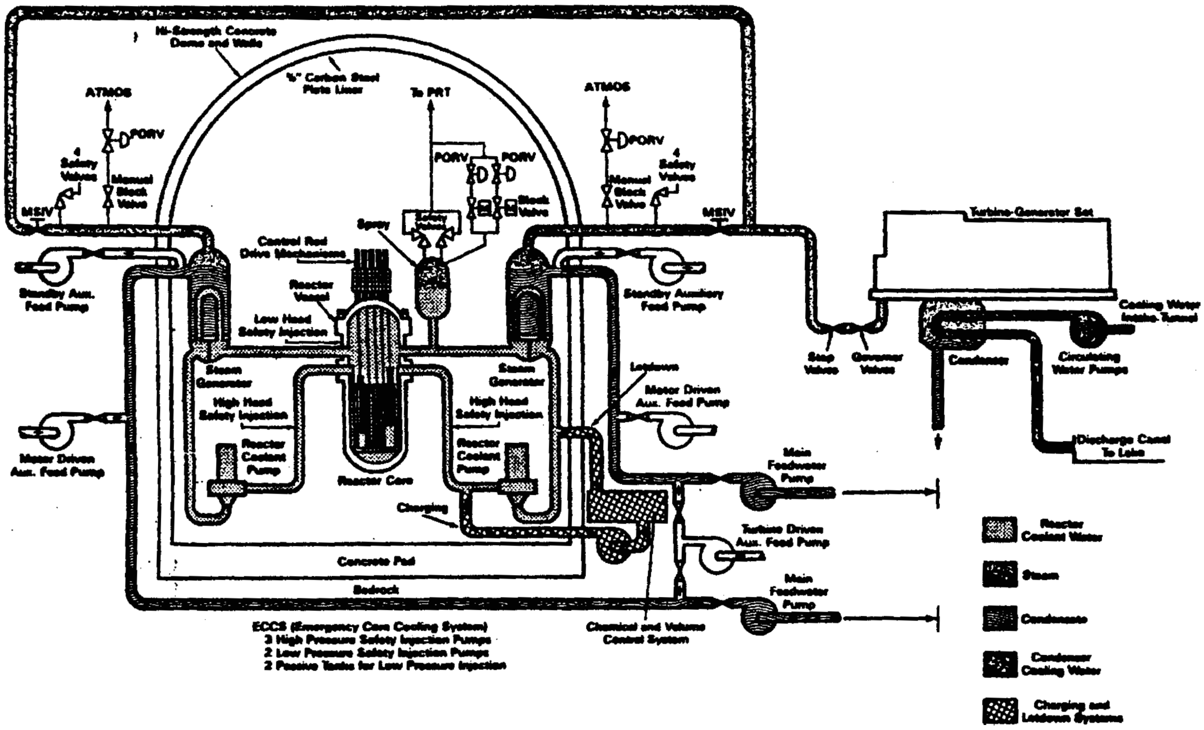
Pressurized water reactors have two or more steam generators depending on the plant design. Westinghouse and Combustion Engineering designed reactors incorporate recirculating steam generators. Operating experience has shown that recirculating steam generators are susceptible to a wide variety of age related degradation.[46] This is primarily due to the fragility of the steam generator tubes made of Inconel or Alloy-600. These tubes, which are typically .03-.05 of an inch thick, are the boundary between the radioactive and non-radioactive loops of the pressurized water reactor (see Diagram B, page 14).

Steam generator tubes are susceptible to a host of aging problems. The NRC, Westinghouse and the utilities that own Westinghouse and Combustion Engineering nuclear reactors have spent innumerable hours identifying and analyzing the many causes of steam generator tube degradation. Yet it appears that the root cause of the problem is the steam generator tube itself. The Inconel-600 is not a stable alloy when used as tubing for

Table 5: Reactors at Risk of RPV Embrittlement

PTS Date As of 1994/Rule	End of Reactor	State	Utility	License
–1996/ 1992	Palisades	MI	Consumers Power	2007
2006/ 2004	Kewaunee	WI	Wisconsin Public Service	2013
>2005/ 1997	Calvert Cliffs 1	MD	Baltimore Gas & Electric	2014
>2010/2011	PointBeach1	WI	Wisconsin Electric Power	2010
2011/2011	Zion 1	IL	Commonwealth Edison	2008
>2012/2019	Surry 1	VA	Virginia Power Company	2012
2013/1993	FortCalhoun	NE	Omaha Public Power	2008
>2013/ 2008	PointBeach2	WI	Wisconsin Electric Power	2013
2014/2048	Beaver Valley 1	PA	Duquesne Light Company	2016
2019/ 2019	Oconee 2	SC	Duke Power Company	2013
2020/2020	Salem 1	NJ	Public Service	2008
2023/2023	Zion 2	IL	Commonwealth Edison	2008
2026/2026	Ginna	NY	Rochester Gas & electric	2006
2034/2008	Dablo Canyon 1	CA	Pacific Gas & Electric	2008
203712037	Cook 1	MI	Indiana/Michigan Power	2009
>2050/ 2050	Farley 1	AL	Southern Nuclear	2007
>2050/2050	St. Lucie 1	FL	Florida Power & Light	2016

Diagram A



Source: U.S. **Nuclear** *Regulatory Commission,* **U.S.**NRC **Report on the January25,1982 Steam Generator Tube Rupture at R.E. Ginna Nuclear Power Plant,** *NUREG-0909,* ***April 1982.***

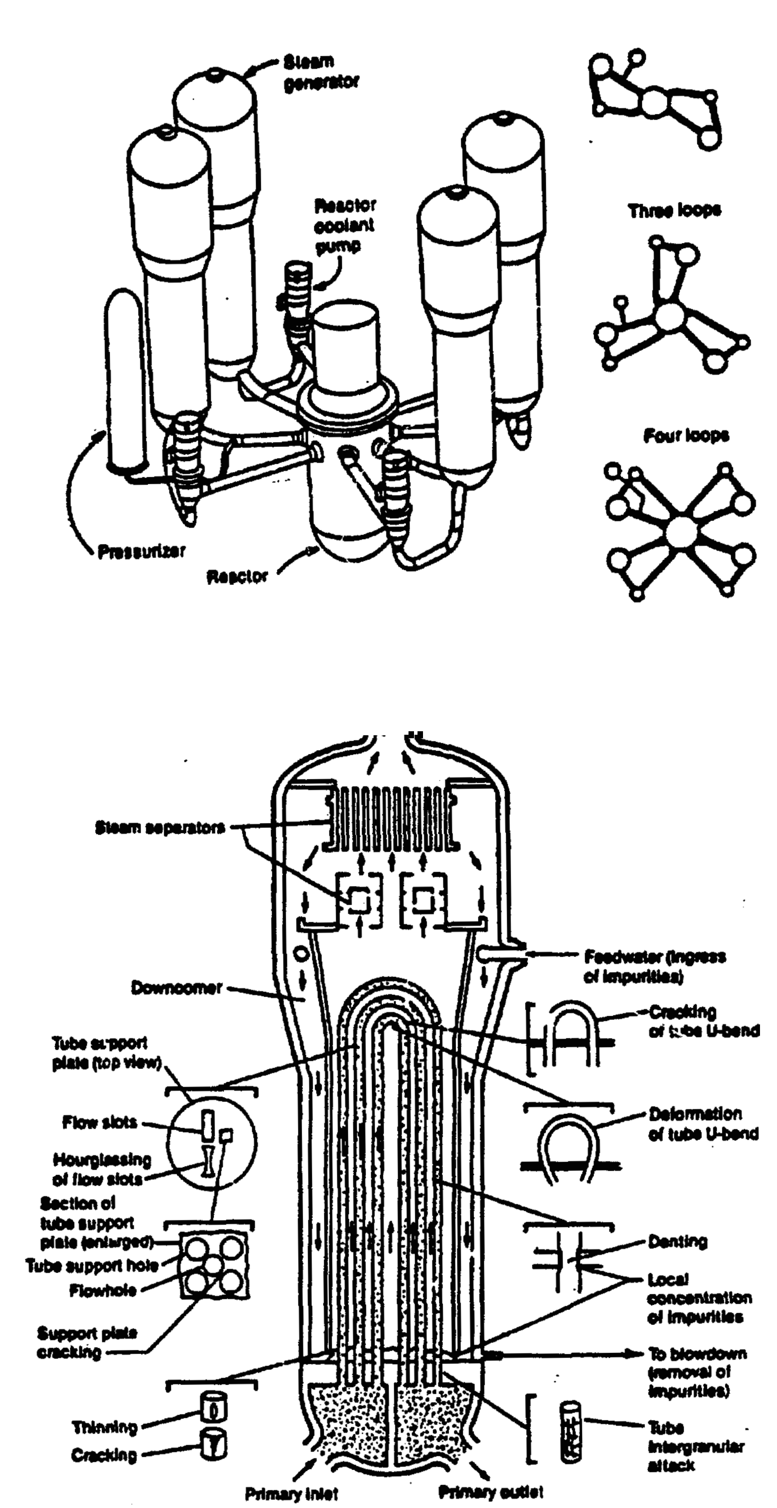
steam generator^.^^ Although originally designed to last the life of the plant, steam generators have been replaced at more than ten nuclear power plants since 1981.[48]

When degraded steam generator tubes go undetected, they may break, initiating a potentially disastrous sequence of events. The rupture of a steam generator tube is especially significant because it breaches the barrier between the radioactive and non-radioactive loops of the reactor. Such a breach can allow radioactive coolant to flow into the secondary system at a rate of several hundred gallons per minute. Unless plant operators respond correctly, pressure can increase in the secondary system forcing relief valves to open and releasing radioactive gas into the environment. Such a situation occurred at the Ginna reactor operated by Rochester Gas & Electric near Rochester, NY in 1982. The release of 90 curies of radioactive gas could have been far worse. Had there been any damage to the core of the reactor, the bypass of the containment would have provided highly radioactive fission materials a direct pathway into the environment.4~

Additionally, as the tubes continue to degrade there is the potential for a multiple tube rupture. Reactors are designed to withstand the disruption caused by the rupture **of** only a single tube. **A** multiple tube rupture is said to constitute a "beyond design basis" accident. The rupture of as few as ten steam generator tubes could result in the meltdown of the reactor fuel rods, releasing catastrophic amounts of radiation into the environment. As noted by NRC Commissioner Kenneth Rogers:

> The concern is with sudden multiple tube failures common mode failures. For example, such failures could come about by having essentially uniform degradation of the tubes. Degradation would decrease the safety margins so that, **in essence, we have a 'loaded gun,' an accident waiting to happen.** Under those conditions, a pres-

Diagram **B**



Source: **US.** Nuclear Regulatory Commision, Residual **Life** Assessment of Major Light Water Reactor Components, *NUREG/CR-4731,ml.* I, ***lune** 1987*

sure transient or a seismic event could rupture many tubes simultaneously. That could allow primary coolant to enter the secondary system and the resulting high pressure to lift the relief valves that are outside containment on the steam line, thus permitting primary water to by-pass containment and communicate with atmosphere directly, resulting in a LOCA (loss of coolant accident)[50]

Unfortunately, the commissioner's words proved prophetic. Precipitating Portland General Electric's (PGE) decision to close the Trojan reactor in Oregon, a member of the NRC staff filed a differing professional opinion (DPO) regarding an NRC decision to allow the nuclear reactor to operate with seriously degraded steam generator tubes. The problem according to the NRC staffer was that "a main steam line break (MSLB) outside containment could trigger **a multiple steam generator tube failure which could then result in a core melt because of depletion of coolant inventory.**"~'

NRC documents leaked to the Union **of** Concerned Scientists (UCS) revealed that the **risk** of a meltdown at the Trojan reactor was 300 times greater than the NRC's Safety Goal standard. As the UCS' letter to NRC Chairman Ivan Selin details:

> [t]he analysis conducted by the Office of Nuclear Reactor Research shows that operation with known flaws in the steam generator tubes can result in an accident in which several steam generator tubes rupture, leading to

the melting of the reactor core and the release of radioactive material directly to the environment out side the reactor containment building. The staff has concluded that the probability of such an accident is over 300 times more likely than your (NRC) safety goal policy permits.[52]

Whether steam generator tubes are sleeved, plugged or replaced altogether, the solution is an expensive one for the utility and ultimately the consumer. While the cost of steam generator tube repair is substantial—repairing microscopic cracks in Trojan's steam generators cost $37 million and kept the reactor shut down for a year—the cost of replacement can prove so prohibitive as to result in the shutdown of the reactor. After fending off numerous voter referenda calling for the shutdown of Trojan, PGE decided to close the nuclear reactor and sue Westinghouse rather than replace the steam generators at a cost of at least $200 million.[53]

However, the NRC allowed at least five other nuclear reactors to operate with similarly degraded steam generators.
These reactors include:

Table 6

Utility Reactor	State
Southern Nuclear Joseph M. Farley Units 1 & 2	**AL**
Michigan/Indiana Power Donald C. Cook Unit 1	MI
Duke Power Company Catawaba Unit 1	**SC**
Commonwealth Ediso.ı Braidwood Unit 1	IL[54]

In a November 1992 memo, which had until recently been withheld from public disclosure, the NRC's Director of Nuclear Reactor Regulation reported that "steam generator tube rupture (SGTR) events appear to be unavoidable."[55] The memo also points out that NRC regulation is less stringent than other countries. "Regarding steam generator tube inspection programs, it is clear that the U.S. lags behind the major European countries in terms of scope of inspection. . . . Further, the leak rates allowed were reported to be consistently much lower than that allowed by U.S. Technical specification^."^^

While the NRC knowingly provides less protection than its European counterparts, the Commission continues to ignore the advice of its own engineers here at home. On July 13, 1994, the same NRC staffer who filed the DPO in the Trojan case again challenged the NRC's lax enforcement of steam generator requirements. In a memorandum to NRC Executive Director for Operations James M. Taylor, the engineer explained that the newly proposed generic letter allowing Westinghouse reactors to operate with degraded stream generator tubes would increase the probability of a core melt accident and the likelihood of a serious release radiation to the environment. The engineer concluded that:

> The lack of prompt disposition of safety concerns that I have brought to **RES** management attention has been systematic and pervasive. For example in 1987 I predicted certain complex SG degradations (11). When RES failed to act I raised the issue with the Commission which promptly issued an inquiry. Several years later the degradation occurred almost exactly as predicted at San Onofre and Maine Yankee. I believe that if prompt action had been taken in 1987 unnecessary risk to plant and costly outages could have been avoided.
>
> In summary public health and safety can be best protected by replacing the affected steam generator units and not by the institution of easily tunable plugging criteria.[57]

The NRC engineer went on to conclude that NRC's generic letter would result in reactors violating regulatory limits for potential radiation dose rates and that Commonwealth Edison's Braidwood unit 1 in Illinois already exceeded the requirements. Unfortunately, the NRC has thus far ignored the warnings of its own engineers.

Serious questions were raised again this year as to whether NRC's inspection criteria were sufficient to detect cracking in the steam generator tubes. Maine Yankee was shut down in July **1994** due to steam generator tube cracks that had been present since **1990** but had gone undetected. The Maine Yankee Atomic Power Company claims that, even with the circumferential cracks, the steam generator tubes could have withstood a worst-case-accident. Whether Maine Yankee violated NRC's requirements for steam generator tube integrity remains unclear.[58] What is becoming increasingly clear, however, is that Maine Yankee may soon have to replace its steam generators or retire the reactor.

While many reactors have replaced degraded steam generators, others have decided that replacement is not economically justified. Given NRC's lax enforcement, nuclear reactors will continue to operate with seriously degraded steam generator tubes until the reactor is forced to shut down.

The nuclear reactors in Wisconsin are a good case in point. WEPCO replaced the steam generators at Point Beach Unit 1 during the **1980s** and has already ordered replacements for the generators in unit 2. However, WEPCO's proposal to replace the unit **2** steam generators next year at a cost of **$120,000,000** has been put on hold **by** state regulator^.^^

Wisconsin Public Service has decided not to replace the steam generators at Kewaunee. "When we did our steam generator analysis, I think we had a rude awakening," said Clark Steinhardt, senior vice president for nuclear operations. The analysis showed that it would be cheaper to retire Kewaunee in **1998** and replace it with a combined cycle gas facility than it would to replace the steam generators and continue operating the reactor.[60]

Since the life of the steam generator will determine the remaining life of the reactor, the utility is attempting to extend the service life of the steam generator tubes. Kewaunee is even attempting to unplug tubes that have previously been taken out **of service.**[61] Since Kewaunee's license doesn't expire until 2013, the reactor appears to be another candidate for early retirement. Even if the steam generator problems do not shut down the reactor, Kewaunee will face embrittlement concerns prior to license expiration. The only real question remaining is whether the reactor will be shut down by the NRC, by the utility or by an accident.

While steam generator replacement costs have already led to the shutdown of PGE's Trojan reactor, the quick fixes undertaken by utilities to avoid replacement costs are proving problematic. The plugs used to remove cracking steam generator tubes from service are themselves cracking. The risk is that a cracked tube plug could act like a bullet and shoot through the tube bundle resulting in a multiple tube rupture. Westinghouse has recommended that, during the next refueling outage, utilities repair or replace **2,400** plugs in as many as **26** nuclear reactors.[62] Westinghouse acknowledged that there may not be any plugs that have life estimates later than **1994.** Westinghouse and NRC have refused to identify those reactors that are at risk, yet only half of the *26* reactors have outages scheduled prior to June 1995.[63] The Commission has abdicated its responsibility on this issue to Westinghouse and in the process obfuscated the truth from public disclosure. The NRC knows which nuclear reactors have the defective tube plugs; they recognize that "in essence, we have a 'loaded gun,' **an** accident waiting to happen." However, the nuclear bureaucrats refuse to require a timely response to the threat (see Table **7,** page **17).**

Considering the steep cost of steam generator replacement and the uncertainty of recouping the investment, some utilities may decide not to replace their steam generators and forgo the opportunity to renew their operating licenses. However, the prospect of reactors limping along with degraded steam generators is neither in the interest of the nuclear utilities nor in the interest of public health and safety.

Cracking In Boiling Water Reactors

As nuclear power plants split atoms, the intense radiation and the harsh environs of the reactor core weaken and begin to crack the metal components of the nuclear reactor. The Nuclear Regulatory Commission has long recognized that the reactor vessels—the crucibles that hold the radioactive fuel—can crack precipitating a Chernobyl-like catastrophe. However, the regulators have been slow to acknowledge that radiation-induced damage to other parts of the nuclear reactor could be just as catastrophic. (See Diagram C, page 18.)

More than a dozen General Electric designed nuclear reactors in the U.S. and abroad have evidence of cracking in the reactor core shroud—a metal cylinder surrounding the reactor fuel rods. The owners of these boiling water reactors have contended that the core shroud is of little safety significance. However, the NRC has acknowledged that cracking of the core shroud could damage the radioactive fuel rods, prohibit the insertion of control rods and lead to a meltdown of the reactor.[65]

If this scenario were not frightening enough, another design flaw in the General Electric reactors virtually ensures that the radiation from a meltdown would be released directly into the environment and surrounding communities. As early as 1971, government regulators knew that the public's last line of defense against radiation, the containment, was worthless yet licensed the GE reactors anyway. When staff members suggested that this type of containment be banned, the Commission's deputy director for technical review responded that it "could well be the end of nuclear power. It would throw into question the continued operation of licensed plants, could make unlicensable the GE and Westinghouse ice condenser plants now in review and would generally create more turmoil than I can think about."[66] Only years later when documents were released to Public Citizen via the Freedom Of Information Act did the public learn that GE designed reactor containments have a 90% probability of failure in the event of a meltdown.[67] The NRC's *Reactor Risk Reference Document,* a report that studied both GE Mark I and Mark III containments, found that "[i]n general, these data indicate that early containment failure (during a severe accident) can not be ruled out with high confidence for any of the plants."[68] In the event of a meltdown, GE-designed reactors leave the public virtually defenseless.

On July 25,1994 the NRC issued a generic letter regarding the cracking of core shrouds in boiling water reactors.~~

The NRC acknowledged that cracking had been observed in nine U.S. reactors. The NRC letter required all BWR owners, with the exception of Big Rock Point, which does not have a core shroud, to inspect their reactors for cracking no later than the next refueling outage and to perform a safety analysis supporting continued operation until the inspections were completed.'~

Since the issuance of the generic letter several

Table 7: Anticipated Steam Generator Replacements

1993	Indian Point 2	NY	Consolidated Edison **(DELAYED)**
1995	North Anna 2	VA	Virginia Power
1996	Ginna	NY	Rochester Gas & Electric
	Point Beach 2	WI	Wisconsin Electric Power
	Zion 1	IL	Commonwealth Edison
	McGuire 1	NC	Duke Power Company
1997	Kewaunee	WI	Wisconsin Public Service Co.
1998	Catawba 1*	SC	Duke Power Company
	Farley 2	AL	Alabama Power Company
	Braidwood 1	IL	Commonwealth Edison
	Byron 1	a	Commonwealth Edison
1999	Maine Yankee*	ME	Maine Yankee Atomic Power
	Fort Calhoun*	NE	Omaha Public Power District
2000	Cook 1*	MI	American Electric Power
	St. Lucie 2*	FL	Florida Power & Light
	San Onofre 2 & 3*	CA	Southern California Edison
	Calvert Cliffs 1 & 2*	MD	Baltimore Gas & Electric
	McGuire 2*	NC	Duke Power Company
	- Shearon Harris	NC	Carolina Power & Light
	> Farley 2	AL	Alabama Power Company
2001	St. Lucie 1*	FL	Florida Power & light
	Beaver Valley 1 & 2*	PA	Duquesne Light Company
	Zion 2*	IL	Commonwealth Edison
2002	Salem 1	NJ	Public Service Electric & Gas
2006	Salem 2	NJ	Public Service Electric & Gas
	Prairie Island 1 & 2	MN	Northern States Power

* denotes approximate date provided by vendor

Diagram C

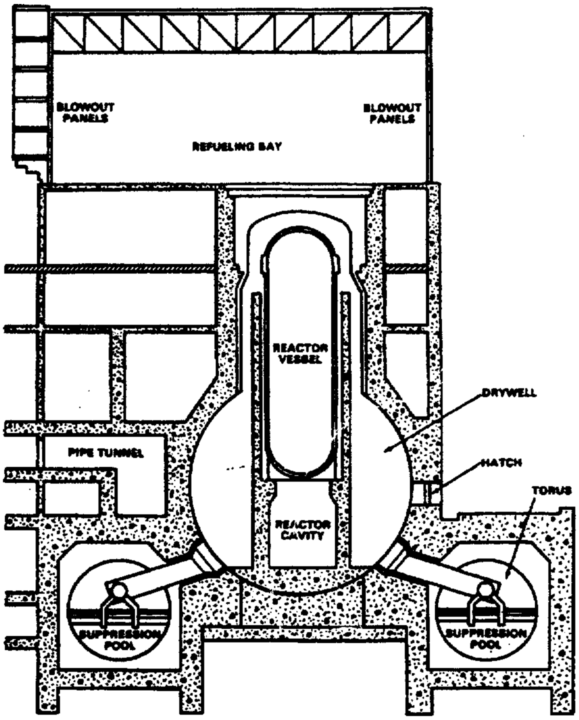
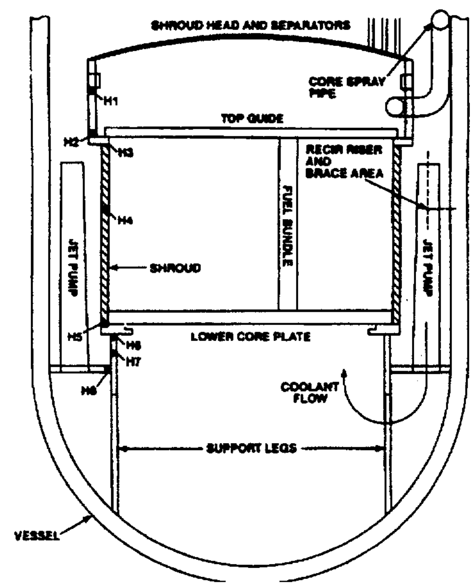


FIGURE 1

CORE SHORUD STRUCTURAL CONFIGURATION



other reactors have turned up cracks in their core shrouds. The following chart lists U.S. BWRs and the year they were licensed. Those reactors which appear in bold have experienced cracking while other reactors are planning preemptive fixes on the core shroud (see Table **8,** page 19).[71]

The problem of core shroud cracking is now believed to affect most, if not all, older General Electric reactors. However, "older" is a relative term. Cracking has been found in reactors that have operated for less than 10 years, only one quarter of reactor's operating license. Replacement of the core shroud will cost millions of dollars and calls into question the economic viability of many of these nuclear reactors.[72]

While U.S. utilities are scrambling to repair the reactor core shrouds, German and Swiss owners of boiling water reactors are looking at replacement. PreussenElektra, owner of Germany's oldest BWR, Wurgassen, said that replacement of the core shroud would take 18 months and could cost as much as $120 million.'' The utility is only prepared to pay **$64** million for the replacements, placing the future of the German BWR in doubt.

Faced with an 18-month shutdown and replacement costs potentially running into the hundreds of millions of dollars, U.S. nuclear utilities are attempting to come up with quick fixes for the core shrouds. General Electric has recommended, and Hatch **1** and Oyster Creek have already installed, modifications designed to prevent the shroud from shifting in the event of an accident. The quick fix is slated to cost between $2 and **$3** million and take six to ten weeks to install.7~

Although the concern so far has been that a lateral shift of the core shroud could damage the fuel rods and prevent insertion of control rods in the event of an accident, it appears that the core shroud is not the only cracking reactor component. In fact, cracking in the core shroud appears to be an indicator that other reactor internals are experiencing similar degradation.~~ The NRC has identified at least 25 BWR internals that are susceptible to degradation. The NRC concluded that "[f]ailures of internals could create conditions that may challenge the integrity of the reactor primary containment system, but they do not affect the effectiveness of primary containment systems. However, aging related failures may require extensive shutdown time for repair work."[76]

While the issue of core shroud cracking has not yet resulted in the permanent shutdown of a U.S. reactor, extended operation of boiling water reactors is anything but certain. It is doubtful whether any reactor could economically justify the two-year down time estimated for core shroud replacement. Even if reactors can operate with hastily repaired core shrouds, the degradation of other reactor internals will pose both safety and economic problems which make license renewal improbable.

Table 8: Boiling Water Reactors

Year Licensed	Nuclear Reactor	State
1969	Dresden 2	IL
	Nine Mile Point 1	NY
	Oyster Creek	**NJ**
1970	**Millstone 1**	**CT**
1971	**Dresden 3**	**IL**
	Monticello	MN
1972	Pilgrim	MA
	Quad Cities 1	**IL**
	Quad Cities 2	IL
1973	Browns Ferry 1	AL
	Peach Bottom 2	PA
	Vermont Yankee	VT
1974	Browns Ferry 2	AL
	Brunswick 2	**NC**
	Cooper	NE
	Duane Arnold	IA
	Hatch 1	GA
	Fitzpatrick	**NY**
	Peach Bottom 3	**PA**
1976	**Browns Ferry 3**	**AL**
	Brunswick 1	**NC**
1978	**Hatch 2**	**GA**
1982	LaSalle .	IL
	Susquehanna 1	PA
1984	Grand Gulf	MS
	LaSalle 2	IL
	Susquehanna 2	PA
	Washington Nuclear 2	WA
1985	**Fermi 2**	**MI**
	Limerick 1	PA
	River Bend	LA
1986	Hope Creek	NJ
	Perry	OH
1987	Clinton	IL
	Nine Mile Point 2	NY
1989	Limerick 2	PA

The Economics Of Current Operation Threaten License Renewal

The economics of license renewal are problematic at best. Increased competition in the wholesale electricity market is already placing serious economic pressure on nuclear utilities. When Northern States Power (NSP) removed Monticello from NRC's lead plant program, the utility recognized that the recent shutdowns of Yankee Rowe, San Onofre Unit 1 and Trojan "demonstrate the changing economic climate which nuclear operations must adjust to if they are going to remain viable options."[77] NSP concluded that there were three factors that were common to each of the shutdown reactors: 1) Alternative energy costs, **2)** Operations and maintenance costs and ***3)*** capital expenditure^.'^

In March **1992,** the Shearson Lehman Brothers investment firm brought together three former NRC Commissioners as well as the president of Yankee Atomic Electric Company to discuss the economic viability of the nuclear industry.[79] The conference, spurred on by the shutdowns of Yankee Rowe and San Onofre Unit 1, recognized that the nuclear industry is facing a mid-life crisis. The panel acknowledged that "there are increasing prospects that **a number of additional plants will be permanently shutdown while large unamortized investment remains on their owners' books**."[80]

Peter Bradford, former NRC Commissioner d then Chairman of the New York State Public Service Commission, highlighted the problem posed by early retirement of reactors.

> As to the unamortized portion of the power plant itself, that which is left in the rate base—that's assuming its prudent—and there's no reason to think that if its been around as long as Yankee Rowe unchallenged that it wouldn't be—that has to be recoverable. Because otherwise the utility doesn't have the right incentive to make the sensible going forward decision. That is if it does the right thing by the

ratepayers in not pursuing relicensing, and thereby risks taking an $80 million disallowance from its rate base because it's not using the plant anymore, then you create a discrepancy between the customer's interests and the shareholder's interests which—its that type of discrepancy—its in a lot of different forms—that did so much to get this industry in trouble in the 70's and 80's. So I have no difficulty in it.[81]

The problem of stranded investment, detailed by Mr. Bradford, clearly illustrates the dilemma faced by many nuclear utilities. While many reactors are non-competitive sources of electricity, the utilities fear that they will be unable to recover their sunk costs if they retire these reactors. The situation is further exacerbated when the reactor in question is a poor performer. Although **Mr.** Bradford contends that Yankee Rowe was a prudent investment, few if any nuclear reactors can match Rowe's performance history. Thus for many reactors, the prudence of the nuclear investment will likely come into question when state regulators determine the amount of stranded investment, if any, the utility will be allowed to recoup after closing the plant.

While some analysts contend that the government has an obligation to the investor, a number of states will disallow recovery of costs from plants that are not "used and useful." Whether the government has an obligation to the shareholders or to the ratepayer is a matter of debate. However, if utilities can not recoup their investments after a nuclear reactor is retired, they may continue to operate unsafe and uneconomical reactors. Last September, NRC Chairman Ivan Selin acknowledged that economic pressure was providing utilities with an "incentive to cut corners."[82] If nuclear reactors are too expensive to operate but utilities are reluctant to close them down due to stranded investments, we could have an economic recipe for disaster.

In March **1994,** *Nucleonics* Week reported on Edison Electric Institute (EEI) studies which concluded that "(o)nly a quarter of U.S. nuclear plants produced power more cheaply than the average replacement power available in their power pools as of January 1993. . . ."[83] Remarkably, the EEI study found that half of U.S. nuclear plants would not be competitive even if utilities were able to reduce Operations and Maintenance (O&M) costs by 20%.~

While the EEI study has not been publicly released, the methodology which produced these shocking results can be repeated by comparing each nuclear plants O&M costs Per kilowatt hour (KWH) with the average cost of replacement power. The following chart shows those reactors which are under the most competitive pressure by comparing O&M and replacement power costs. Results for each nuclear power plant are included in the appendices.

As Table 9 on the following page illustrates, more than half of the nuclear reactors in the U.S. are more expensive to operate than the cost of replacement power. While the analysis is not dispositive, it illustrates the dire state of nuclear economics. If nuclear reactors can not compete in the current market, the prospects for license renewal would appear dim and fading. Even if nuclear utilities can bring **O&M** costs under control and reverse historic trends, the combination of cheap replacement power, large capital additions and a growing high-level waste problem will likely doom many renewal efforts.

High-Level Radioactive Waste/ Spent Fuel Storage

Of commercial nuclear energy's many dangers, few promise to vex humanity for as long as high-level nuclear waste. Extending the licenses of operating reactors will only increase the amount of waste with which future generations will have to contend. Neither the nuclear industry nor the government has developed the means to isolate high-level radioactive waste for the duration of its hazardous life. Coping with the wastes that result from any proposed license extension looms as an unknown cost and possible taxpayer liability of the NRC's license renewal rule.

High-level waste is defined as irradiated (or spent) nuclear fuel or the wastes that result from reprocessing such materials. U.S. commercial nuclear power plants have generated and

Table 9: Reactors with Operating and Maintenance Costs Above Reulacement Power.8~

	Utility	Reactor	O+M costs (Mills/KWH) /KWH)	Replacement Cost" (Mills	Margin
1	Houston Lighting and Power Company	South Texas-1	79.76	20.7	59.06
1	Houston Lighting and Power Company	South Texas-2	79.76	20.7	59.06
3	Consumers Power Company	Big Rock Point-1	65.99	22.9	43.09
4	Tennessee Valley Authority	Browns Ferry-2	48.64	8.5	40.14
4	Tennessee Valley Authority	Browns Ferry-3	48.64	8.5	40.14
6	Gulf States Utilities Company	River Bend-1	48.38	12	36.38
7	Carolina Power and Light Company	Brunswick-1	52.81	19.6	33.21
7	Carolina Power and Light Company	Brunswick-2	52.81	19.6	33.21
9	Florida Power and Light Company	Turkey Point-3	52.63	25.4	27.23
9	Florida Power and Light Company	Turkey Point-4	52.63	25.4	27.23
11	Cleveland Electric Illuminating Company	Perry-1	36.08	10.2	25.88
12	Omaha Public Power District	Fort Calhoun-1	33.38	10.9	22.48
13	Illinois Power Company	Clinton-1	27.59	9.1	18.49
14	New York Power Authority	Indian Point-3	48.03	33.2	14.83
15	Duquesne Light Company	Beaver Valley-1	26.95	12.4	14.55
15	Duquesne Light Company	Beaver Valley-2	26.95	12.4	14.55
17	GPU Nuclear Corporation	Oyster Creek-1	36.59	22.2	14.39
18	Toledo Edison Company	Davis-Besse-1	24.99	11.7	13.29
19	Tennessee Valley Authority	Sequoyah-1	21.87	8.7	13.17
19	Tennessee Valley Authority	Sequoyah-2	21.87	8.7	13.17
21	Northeast Utilities Service Company	Millstone-1	36.02	22.9	13.12
22	Northeast Utilities Service Company	Millstone-2	36.02	23.3	12.72
23	Indiana Michigan Power Company	Cook-1	23.33	11.8	11.53
23	Indiana Michigan Power Company	Cook-2	23.33	11.8	11.53
25	Iowa Electric Light and Power Company	Duane Arnold	22.67	12.1	10.57
26	Northeast Utilities Service Company	Haddam Neck	30.88	21.8	9.08
27	Detroit Edison Company	Fermi-2	26.91	18	8.91
28	System Energy Resources, Inc.	Grand Gulf-1	20.58	12.7	7.88
29	Nebraska Public Power District	Cooper Station	20.08	12.8	7.28
30	Northern States Power Company	Monticello	20.06	13.8	6.26
31	Washington Public Power Supply System	Wash. Nuclear-2	25.01	18.8	6.21
32	Northeast Utilities Service Company	Millstone-3	28.99	22.8	6.19
33	Philadelphia Electric Company	Peach Bottom3	27.47	21.3	6.17
34	Philadelphia Electric Company	Peach Bottom-2	27.47	21.4	6.07
35	Arkansas Power and Light Company	Arkansas-1	20.46	15.7	4.76
35	Arkansas Power and Light Company	Arkansas-2	20.46	15.7	4.76

continued on next page

*Table 9, **continued***

	Utility	Reactor	O+M costs (Mills/KWH)	Replacement Cost* (Mills /KWH)	Margin
37	Carolina Power and Light Company	Robinson-2	23.35	19.7	3.65
38	Boston Edison Company	Pilgrim-1	28.93	25.4	3.53
39	Union Electric Company	Callaway-1	16.31	13	3.31
40	TU Electric	Comanche Peak-1	22.91	19.8	3.11
40	TLJ Electric	Comanche Peak-2	22.91	19.8	3.11
42	Louisiana Power and Light Company	Waterford-3	18.27	15.8	2.47
43	New York Power Authority	Fitzpatrick	*34*	31.7	2.3
44	Public Service Electric and Gas Company	Salem-1	25.47	23.7	**1.77**
44	Public Service Electric and Gas Company	Salem-2	25.47	23.7	**1.77**
46	Commonwealth Edison Company	Dresden-2	29.48	28	1.48
47	Arizona Public Service Company	Palo Verde-1	22.14	20.8	1.34
47	Arizona Public Service Company	Palo Verde-2	22.14	20.8	1.34
47	Arizona Public Service Company	Palo Verde-3	22.14	20.8	1.34
50	Commonwealth Edison Company	Quad Cities-1	25.64	24.4	1.24
51	Northern States Power Company	Prairie Island-2	14.92	13.8	1.12
52	Northern States Power Company	Prairie Island-1	14.92	13.9	1.02
53	Commonwealth Edison Company	Dresden-3	29.48	28.5	*0.98*
54	Georgia Power Company	Hatch-2	21.79	21	0.79
55	Georgia Power Company	Hatch-1	21.79	21.1	0.69
56	Commonwealth Edison Company	Quad Cities-2	***25.64***	**25**	0.64
57	Consumers Power Company	Palisades	23.42	22.9	0.52

+Replacementcosts are for the winter of 1993-4

Sources: U.S. Nuclear Regulatory Commission, Replacement Energy costs **for** Nuclear Electricity — Generating Units in the United States: 1992-1996, NUREG/CR-4012, October 1992, p. 79-190; Inside NRC, June 13,1994, p. 1-4

discharged over 25,000 metric tons high-level waste in the form of irradiated fuel. The Department of Energy projects that this figure will rise to **84,300** by the year 2030.[86]

The toxicity and longevity of high-level nuclear waste present unique challenges. Irradiated fuel rods contain some of the deadliest substances known to humanity. **An** individual standing three feet away from unshielded irradiated fuel would receive a lethal dose in 10 seconds.[87] One large nuclear power plant generates annually as much long-lasting radioactivity as a thousand Hiroshima-type atomic bombs.[88] While irradiated fuel constitutes, by volume, a small portion of the over **5** million cubic meters of nuclear waste in the nation, reactor discharges to date contain over **95** percent of the radioactivity.[89]

The government's track record for dealing with the high-level waste problem does not engender confidence. Speaking before the Institute of Nuclear Materials Management, NRC Chairman Ivan Selin acknowledged that:

> The history of spent fuel management in this country has taken several turns, with a final solution still out of reach. Several repository programs have started, stalled and stopped. The latest effort at Yucca

> Mountain is proceeding but, at best is years away from the early phases of licensing, much less the actual underground disposal of spent fuel. A monitored retrievable storage *(MRS)* facility was expected to start accepting commercial spent fuel beginning in 1998, but no such facility is clearly on the horizon. All of these recent developments have changed the circumstances that we face with spent fuel management.90

The Chairman noted that both operating and retired nuclear reactors would have to provide additional on-site spent fuel storage for a longer period than originally planned. "But, the dry storage option has triggered an unprecedented amount of local opposition at many sites, further taxing NRC and industry resource^."^^

For obvious reasons, license extensions will exacerbate the challenges of high-level nuclear waste disposal. Current DOE projections, which, as noted above, predict the metric tonnage of irradiated fuel to approach 85,000 by 2030, assume that current reactors will operate to the end of their licenses and that no licenses will be extended or new reactors ordered. When these calculations are amended to assume that half of the nation's operating reactors receive 20-year license extensions, the projection rises to 103,000 metric tons. The amount of anticipated accumulated radioactivity would double, rising from 25,000,000,000 to 53,400,000,000 curies.[92]

Disposal of High-Level Radioactive Waste

Compounding the dangers of high-level radioactive waste is humanity's current inability to guarantee either safe disposal or long-term isolation of highly radioactive materials. The current plan for coping with high-level waste calls for burial in a geologic repository. In 1987, Congress, in a move dictated by political expedience rather than scientific consensus, designated Yucca Mountain in Nevada as the sole candidate for a permanent repository. Site characterization studies have proceeded in the face of vigorous state opposition, Native American claims to the land in question, cost overruns, and significant scientific uncertainty about the Yucca Mountain site in particular, and the notion of geologic disposal in general. As a result, serious doubt exists as to whether a geologic repository, once expected in 1998 but now envisioned by optimistic timetables in 2010, will ever be available.

Many of Yucca Mountain's geologic features cast the site's feasibility as a repository in doubt. For example, one important requirement to ensure waste isolation is keeping water away from containers. One of Yucca Mountain's supposed advantages is slow travel time of the water through the ground. Studies suggest, however, that water may move through the mountain at rates faster than once thought.9~ Conditions of the water table beneath the site may also pose a risk. Over 30 seismic faults cross Yucca Mountain's area. Critics of the repository program fear that an earthquake could raise the water table and flood the repository.[94] Uncertainties about volcanic activity are another problem. A volcano 20 kilometers away from the site appears to have erupted within the last 20,000 years, rather than 270,000 as once thought.[95] When one remembers that the wastes to be deposited will be highly toxic for over 250,000 years, Yucca Mountain's long-term stability becomes a serious concern. Indeed, considering nuclear toxins' longevity, permanent isolation may never be a certainty.

In fact, the feasibility of "disposing" of high-level nuclear waste in an underground storage facility has never been more in doubt. Scientists at Los Alamos National Laboratory in New Mexico fear that high-level radioactive wastes stored in the proposed repository at Yucca Mountain could eventually explode. The scientists fear that plutonium could escape from disposal canisters into the surrounding rock, which possesses physical properties that might aid a spontaneous chain reaction and explosion.~~

The possibility that radioactive wastes buried below Yucca mountain could detonate in a nuclear blast was first raised last year by Dr. Charles D. Bowman and Dr. Fancesco Venneri. "We think there is a generic problem with putting fissile materials underground," said Dr. Bowman. Since Plutonium-239 has a half life of 24,360 years, significant amounts would still be present long after the metal of the radioactive waste container had disintegrated. Even if the postulated precursors to the explosion do not occur for thousands of years, Plutonium-239 decays into Uranium-235, which contains the same explosive potential as Plutonium but takes millions of years to decay.[97] Scientists at the DOE facility at Savannah River have endorsed Bowman's thesis.[98]

Site feasibility studies at Yucca Mountain have already cost over $1.7 billion. Even if scientists eventually disprove Dr. Bowman's thesis, the seriousness of the current dispute so late in the process threaten plans for a repository at Yucca mountain. The Department of Energy projects that a repository, which would still cost at least **$15** billion to construct, could open in 2010 if the site is deemed suitable and a license is granted.

The nuclear industry argues that the government has a responsibility to take the high-level radioactive waste it generated at the 109 licensed nuclear reactors in 1998 and that the study of the Yucca mountain site should continue. "We're concerned that this not be used as an excuse by the opponents of waste solutions to stop the scientific analysis of the mountain,'' said Cathy Roche, vice president of communications for Nuclear Energy Institute (NEI), lobbyists and propagandists for the nuclear industry.[99]

Burying high-level radioactive waste and hoping that Yucca Mountain will not erupt in a nuclear blast hardly seems an appropriate solution to the high-level waste problem. Even nuclear scientists are beginning to understand what environmentalists and public interest advocates have been arguing for decades, that one can not merely "dispose" of radioactive wastes that have a hazardous life of over 240,000 years.

Even if Yucca Mountain eventually opens as a repository, radioactive waste disposition costs will remain high. For one thing, the Nuclear Waste Policy Act calls for a permanent repository to hold no more than 70,000 metric tons of irradiated fuel. **As** noted above, over 80,000 tons are expected by the year 2030. Demands upon space will also be made by 7,000 tons of defense wastes that are currently earmarked for Yucca Mountain.[100] If the nation intends to continue to pursue geologic storage, more sites will clearly be needed, with all the risks, costs, and citizen opposition that implies.

Finally, serious doubts exist as to whether sufficient funds exist to finance the disposal program without imposing high costs to taxpayers. **As** part of the Nuclear Waste Policy Act of 1982, Congress created the Nuclear Waste Fund to finance a permanent solution to the high-level waste problem. The Waste Fund's money comes from a tenth of a cent per kilowatt hour fee assessed on commercial nuclear power plants. The fee has not changed since the fund's establishment in 1983. In the intervening 12 years, inflation eroded the fee's buying power by 40 percent.[101] Although the fund has collected over **$8** billion, over $4 billion has already been spent.[102] Demands upon the fund, however, are extensive. Characterization of Yucca Mountain alone, once estimated in the hundreds of millions, could cost over $6 billion.[103] In addition to site characterization, the Waste Fund is the intended source of money for construction **of** the repository and interim storage facility, as well as technical assistance and training funds for communities affected by radioactive waste transport.

The potential for a budget shortfall is compounded by the Department of Energy's management of the Yucca Mountain Program. Critics have faulted the DOE for running overbudget, neglecting important scientific studies, and failing to conduct an honest evaluation of Yucca Mountain's shortcomings. Independent bodies like the General Accounting Office and the Nuclear Waste Technical Review Board have consistently called for an independent review of the Yucca Mountain project and, in the case of the GAO, of the nation's entire nuclear waste policy. "Without a comprehensive independent review of the disposal program and its policies," warns the GAO, "millions—if not billions —f dollars could be wasted."[104]

Interim Storage of High-Level Radioactive waste

In the meantime, waste continues to accumulate at reactors around the nation. Without a so-called permanent solution for the high-level waste dilemma, interim measures are necessary. One option strongly favored by the nuclear utilities is the establishment of a centralized interim storage facility.

In addition to being expensive, an interim facility would raise risks and costs to the public. If a centralized away-from-reactor storage facility opens, transportation of high-level nuclear waste would proceed on an unprecedented scale. A dump at Yucca Mountain, for example, would require **43** states to bear the risks associated with **transport.**[105]

Transporting nuclear materials poses significant risks to populations along the route. With an increasing number of shipments, the likelihood of a serious accident involving a cask of irradiated fuel waste increases. Adequate steps have not been taken to ensure cask integrity in the event of such a mishap. Cask safety standards fail to incorporate the full range of trauma to which a container may be exposed in an accident. For example, temperature tolerance standards are lower than the temperatures that a cask might experience in a fire that results from **an** accident. Furthermore, regulations do not even require that testing be performed on full-scale models to ensure that the containers meet regulatory standards. Even accident-free transport causes radiation exposures along routes, as casks are unable to fully contain radiation.[106]

The political difficulties attendant on transporting radioactive waste mean that any interim facility will likely become a defacto repository. Unlike a repository, however, an interim dump will not have been selected with long-term isolation of high-level nuclear wastes in mind.

On-Site Storage of High-Level Radioactive Waste

When Northern States Power dropped out of the license renewal process it concluded that one of the major impediments to renewal was the high level radioactive waste problem. The utility realized that:

> Waste is *the* issue in the political and public arena and must be resolved before the nuclear industry can expect to advance to extended operation of nuclear power plants. Until a satisfactory long term solution to the high and low level waste issues is realized, as perceived by the public, the contention that nuclear power is environmentally benign power source will never be accepted by the public, or state and local governmental and policy leaders. The basic issue for extended operation is how can a nuclear power plant owner be allowed to continue to generate waste for an additional twenty years if no solution for dealing with the waste generated under its current **40** year license **is** at hand or at least is moving **forward.**[107]

Northern States Power's comments were not mere speculation or rhetoric. Within a year, NSP was facing a challenge to the continued operation of its Prairie Island reactors due to the inability *to* store additional high level radioactive waste in the reactor's spent fuel pool. While the situation in Minnesota, where a state law prohibited the siting of a high-level waste dump without legislative approval, was unique, the predicament faced by Prairie Island is not. The chart on the opposite page shows those reactors that will lose their ability to operate absent some form of additional storage of high level radioactive waste (see Table 10, page **26).**

In the absence of either a repository or interim facility, many utilities are running out of space in their spent fuel pools for discharged assemblies. **As** many as 14 reactors anticipate this condition by the year **2000.**[108]

Another option for interim storage of irradiated fuel is using dry casks at the reactor site. Dry casks offer several advantages to continued reliance upon fuel pools. Casks do not require water and therefore present less of a criticality risk than fuel pools. Furthermore, casks do not rely upon systems that may break down and do not generate wastes by their operation. Finally, use of dry cask on-site storage does not present the transportation risks attendant upon shipping waste to a repository or interim facility.

Dry casks do, however, present risks. Past decisions to resort to usage of the containers

Table 10: Reactor Operability Due to Loss of Irradiated Fuel Storage Capacity			
Utility	Reactor	Projected Loss of Ability to Operate	License Expiration Date
Baltimore Gas and Electric Company	Calvert Cliffs-1	1994'	2014
Northern States Power Company	Prairie Island-1	1995'	2013
Northern States Power Company	Prairie Island-2	1995'	2014
Arkansas Power and Light Company	Arkansas-1	1996'	2014
Arkansas Power and Light Company	Arkansas-2	1997*	2018
Wisconsin Electric Power Company	Point Beach-2	1998'	2013
PECO Energy Company	Limerick-2	1998	2029
IES Utilities, Inc.	Duane Arnold	1998	2014
Wisconsin Electric Power Company	Point Beach-1	1998*	2010
PECO Energy Company	Peach Bottom-2	1998	2008
Washington Public Power Supply System	Wash. Nuclear-2	1999	2023
PECO Energy Company	Peach Bottom-3	1999	2008
Maine Yankee Atomic Power Company	Maine Yankee	1999	2008
Consumers Power Company	Big Rock Point-1	1999	2000
Commonwealth Edison Company	Dresden-2	2000	2006
Virginia Power	North Anna-1	2000	2018
PECO Energy Company	Limerick-1	2000	2024
GPU Nuclear Corporation	Oyster Creek-1	2000'	2009
Louisiana Power and Light Company	Waterford-3	2000	2024
Virginia Power	North Anna-2	2001	2020
Carolina Power and Light Company	Brunswick-1	2001	2016
Florida Power and Light Company	St. Lucie-2	2001	2023
Pennsylvania Power and Light Company	Susquehanna-2	2001'	2024
Pennsylvania Power and Light Company	Susquehanna-1	2001*	2022
Commonwealth Edison Company	Dresden-3	2001	2011
Northeast Utilities Service Company	Haddam Neck	2002	2007
Wisconsin Public Service Corporation	Kewaunee	2002	2013
Baltimore Gas and Electric Company	Calvert Cliffs-2	2002*	2016
Nebraska Public Power District	Cooper Station	2002	2014
Public Service Electric and Gas Company	Salem-1	2002	2016
Consolidated Edison Company of New Yor	Indian Point-2	2003	2013
Georgia Power Company	Hatch-2	2003	2018
Georgia Power Company	Hatch-1	2003	2014
Boston Edison Company	Pilgrim-1	2003	2012
Northeast Utilities Service Company	Millstone-3	2003	2025
Gulf States Utilities Company	River Bend-1	2003	2025
Tennessee Valley Authority	Sequoyah-2	2003	2021
Rochester Gas and Electric Corporation	Ginna	2003	2009

*continued on **next** page*

Table 10, continued

Utility	Reactor	Projected Loss of Ability to Operate	License Expiration Date
New York Power Authority	Fitzpatrick	2003	2014
Carolina Power and Light Company	Brunswick-2	2003	2014
Northeast Utilities Service Company	Millstone-1	2004	2010
Northeast Utilities Service Company	Millstone-2	2004	2015
Northern States Power Company	Monticello	2004	2010
Tennessee Valley Authority	Sequoyah-1	2004	2020
Carolina Power and Light Company	Robinson-2	2004*	2010
Vermont Yankee Nuclear Power Corporation	Vermont Yankee	2004	2012
Pacific Gas and Electric Company	Diablo Canyon-1	2004	2008
Southern California Edison Company	San Onofre-3	2005	2013
Southern California Edison Company	San Onofre-2	2005	2013
Arizona Public Service Company	Palo Verde-2	2005	2025
Niagara Mohawk Power Corporation	Nine Mile Point-1	2005	2009
Arizona Public Service Company	Palo Verde-1	2005	2024
System Energy Resources, Inc.	Grand Gulf-1	2005	2022
Commonwealth Edison Company	Zion-1	2006	2013
Kansas Gas and Electric Company	Wolf Creek-1	2006	2025
Tennessee Valley Authority	Browns Ferry-3	2006	2016
Arizona Public Service Company	Palo Verde-3	2006	2027
Commonwealth Edison Company	Quad Cities-2	2006	2012
Detroit Edison Company	Fermi-2	2006	2025
Commonwealth Edison Company	Zion-2	2006	2013
New York Power Authority	Indian Point-3	2006	2015
Pacific Gas and Electric Company	Diablo Canyon-2	2006	2010
Duke Power Company	McGuire-2	2006	2023
Union Electric Company	Callaway-1	2007	2024
Consumers Power Company	Palisades	2007*	2007
Duke Power Company	McGuire-1	2007	2021
Florida Power and Light Company	St. Lucie-1	2007	2016
Commonwealth Edison Company	Quad Cities-1	2007	2012
Omaha Public Power District	Fort Calhoun-1	2007	2013
Illinois Power Company	Clinton-1	2008	2026
South Carolina Electric and Gas Company	Summer-1	2008	2022
Public Service Electric and Gas Company	Salem-2	2008	2020
Cleveland Electric Illuminating Company	Perry-1	2009	2026
Georgia Power Company	Vogtle-1	2010	2027
Duke Power Company	Oconee-1	2010*	2013
Duke Power Company	Oconee-2	2010*	2013
Florida Power Corporation	Crystal River-3	2010	2016

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Table 10, continued

Utility	Reactor	Projected **Loss of Ability** to Operate	**License** Expiration Date
Tennessee Valley Authority	Browns Ferry-2	2010	2014
Alabama Power Company	Farley-1	2010	2017
Georgia Power Company	Vogtle-2	2010	2029
Public Service Electric and Gas Company	Hope Creek-1	2010	2026
Tennessee Valley Authority	Browns Ferry-1	2010	2013
Duquesne Light Company	Beaver Valley-2	2011	2027
Commonwealth Edison Company	Byron-1	2011	2024
Indiana Michigan Power Company	Cook-2	2011	2017
Duke Power Company	Catawba-2	2011	2026
Duke Power Company	Oconee-3	2011*	2014
Indiana Michigan Power Company	Cook-1	2011	2014
Duke Power Company	Catawba-1	2011	2024
Commonwealth Edison Company	Byron-2	2011	2026
Duquesne Light Company	Beaver Valley-1	2012	2016
Commonwealth Edison Company	Braidwood-1	2012	2026
Florida Power and Light Company	Turkey Point-3	2012	2007
Virginia Power	Surry-1	2012*	2012
North Atlantic Energy Service Corporation	Seabrook-1	2012	2026
Commonwealth Edison Company	Braidwood-2	2013	2027
Virginia Power	Surry-2	2013*	2013
Alabama Power Company	Farley-2	2013	2021
Commonwealth Edison Company	LaSalle-1	2013	2022
Florida Power and Light Company	Turkey Point-4	2013	2007
GPU Nuclear Corporation	Three Mile Island-1	2014	2014
Commonwealth Edison Company	LaSalle-2	2015	2023
Toledo Edison Company	Davis-Besse-1	2017*	2017
Niagara Mohawk Power Corporation	Nine Mile Point-2	2017	2026
Carolina Power and Light Company	Shearon Harris-1	2018	2026
TU Electric	Comanche Peak-1	2019	2030
TU Electric	Comanche Peak-2	2021	2033
Houston Lighting and Power Company	South Texas-1	2027	2027
Houston Lighting and Power Company	South Texas-2	2028	2028

* indicates that on-site cask storage is either available or planned

Source: EIA Service Report, Spent Nuclear Fuel Discharges from US. Reactors 1993 (Energy Information Administration, February 1995) raised concerns about lack of public participation and failure to extensively test the casks to ensure maximum containment of radiation. At the Palisades reactor in Michigan, for example, the Nuclear Regulatory Commission refused to hold public hearings on a proposed dry cask, having approved the container under a generic licensing procedure. Michigan citizens have found several instances of site-specific issues that can not be addressed generically, along with several examples of the NRC's violating its own rules.[109] The citizens' concerns have already been borne out—flaws have been found in one of the loaded casks at Palisades, and the utility will have to unload and repair the container.[110] The NRC has also cited Northern States Power for contractor violations in the making of casks for the Prairie Island reactors' irradiated fuel."'

The daunting challenges presented by high-level radioactive waste will influence utility decisions to renew a reactor's license. Faced with the politically unsavory task of attempting to site additional dry cask storage at the reactor site, utilities with reactors nearing the end their licenses may opt to avoid the political and economic costs and decide instead to retire the nuclear reactor.

Conclusions and Recommendations

No nuclear reactor has yet operated for the 40-year term of its operating license. It appears increasingly unlikely that older reactors will remain competitive with alternative sources of electricity. Given the myriad safety problems facing aging reactors, many nuclear power plants will have difficulty even lasting to the end of their current licenses. When one also considers the utilities' ever growing high-level radioactive waste problem and dismal economics, operation of nuclear reactors beyond 40 years seems like a pipe dream. In fact, the nuclear industry acknowledges that Wall Street will not take license renewal seriously until a licensee actually receives a renewed license.

So why is the NRC, the agency charged with protecting the public health and safety, pursuing license renewal? The answer lies in the woeful economics of the nuclear industry. Absent the ability to amortize large capital additions over an additional 20 year period, nuclear utilities will be forced by economics and safety to retire nuclear reactors prior to license expiration. Early shutdown of nuclear reactors may result in stranding large utility investments and under-funding utility commitments such as decommissioning and waste disposal. Utilities do not want to make their investors swallow these costs. Through license renewal, they can shift the risk of the bad investment in nuclear power from the investor to the ratepayer. While some states have regulatory requirements that plants be "used and useful," many industry analysts believe that utilities will nonetheless be allowed to recoup some or all of their uneconomic investment in nuclear power.

Public Citizen believes that the state utility regulators have a responsibility to ensure that ratepayers are not gouged by the nuclear utilities. The ratepayers already bear both the high costs and the radiological risks of nuclear power. They should not bear the cost of nuclear reactors that are not producing electricity. If utilities continue to operate uneconomical nuclear reactors, they, not the ratepayer, should bear the financial consequences. However, if nuclear reactors are too expensive to operate but utilities refuse to close them down due to stranded investment, we have an economic recipe for a nuclear disaster.

The NRC's attempt to extend the operating licenses of nuclear reactors is little more than a regulatory "slight of hand" which would allow utilities to shift the financial risk of nuclear power from the investor to the ratepayer.

The new license renewal rule has no foundation in safety. Merely relying upon the current regulatory process to protect the public while failing to require that reactors document compliance with the current licensing basis is an abdication of the Commission's responsibility. Absent any enforceable standard for renewal, the *NRC's* new license renewal rule appears to be little more than a rubber stamp. If the Commission were truly concerned with safety, it would ensure that aging, unsafe and uneconomical reactors are shut down. Rather than extending the operation of nuclear reactors, the NRC should develop objective criteria on which to base a decision to retire a nuclear reactor. Unfortunately, the NRC has never done so.

Table 1 Changes in RT at EOL for all PWRs if revision used

Plant name	Applicable screening criterion, deg. F	RT at end life, deg. F PTS Rule	Rev. 2	End of licensed life (CP + 40) unless noted)	Estimated year screening criterion will be reached PTS Rule	Rev, 2
Arkansas Nuclear One, Unit 1	300	264	268	2008	2049	2049
Arkansas Nuclear One, Unit 2	270	180	172	2012	>2050	>2050
Beaver Valley Power Station, Unit 1	270	258	257	2010	2032	2048
Byron Station Unit 1	270	123	113	2024 (OL + 40)	>2050	>2050
Callaway Plant	270	161	152	2024 (OL + 40)	>2050	>2050
Calvert Cliffs Nuclear Power Plant Unit No. 1	270	238	301	2014 (OL + 40)	2039	1997
Calvert Cliffs Nuclear Power Plant Unit No. 2	270	199	197	2016 (OL + 40)	>2050	>2050
Catawba Nuclear Station, Unit 1	270	104	87	2024 (OL + 40)	>2050	>2050
Catawba Nuclear Station, Unit 2	270	127	120	2024 (OL + 40)	>2050	>2050
Donald C. Cook Nuclear Plant Unit No. 1	300	251	260	2009	2033	2037
Donald C. Cook Nuclear Plant Unit No. 2	270	205	210	2009	>2050	>2050
Crystal River Unit 3	300	267	257	2008	2029	2039
Davis Besse Unit No. 1	300	217	249	2011	>2050	>2050

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Table 1 (Continued)

Plant name	Applicable screening criterion, deg. F	RT at end life, deg. F PTS Rule	Rev. 2	End of licensed life (CP + 40) unless noted)	Estimated year SCREENIng criterion will be reached PTS Rule	Rev. 2
Diablo Canyon Unit No. 1	270	202	270	2008	>2050	2008
Oiablo Canyon Unit No. 2	270	209	211	2010	>2050	>2050
Joseph M. Farley Nuclear Plant Unit No. 1	270	191	186	2012	>2050	>2050
Joseph M. Farley Nuclear Plant Unit No. 2	270	233	233	2012	>2050	>2050
Fort Calhoun	270	235	302	2008	2030	1993
R. E. Ginna Nuclear Power Plant	300	266	283	2006	2032	2026
Haddam Neck Plant	270	165	159	2004	>2050	>2050
Indian Point Unit 2	270	214	226	2006	>2050	>2040
Indian Point Unit 3	270	269	269	2009	2010	2010
Kewaunee Nuclear Power Plant	300	329	313	2013 (OL + 40)	2004	2006
Maine Yankee Atomic Power Plant	300	243	252	2008	>2050	>2050
Millstone 2	300	197	187	2010	>2050	>2050
McGuire Unit 1	270	247	256	2013	2038	2038

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Table 1 (Continued)

Plant name	Applicable screening criterion, deg. F	RT at end of licensed life, deg. F PTS Rule	Rev. 2	End of licensed life (CP + 40) unless noted)	Estimated year screening criterion will be reached PTS Rule	Rev. 2
McGuire Unit No. 2	270	194	188	2013	>2050	>2050
North Anna Power Station Unit 1	270	225	221	2011	>2050	>2050
North Anna Power Station Unit 2	270	228	217	2011	>2050	>2050
Oconee Nuclear Station Unit 1	270	239	249	2007	2046	2034
Oconee Nuclear Station Unit 2	300	299	292	2013 (OL + 40)	2014	2019
Oconee Nuclear Station Unit 3	300	233	261	2007	>2050	>2050
Palisades Plant	270	270	322*	2007	2007	1992*
Palo Verde Unit 1	270	142	128	2024 (OL + 40)	>2050	>2050
Point Beach Nuclear Plant Unit 1	270	249	269	2010 (OL + 40)	2029	2011
Point Beach Nuclear Plant Unit 2	300	293	305	2013 (OL + 40)	2018	2008
Prairie Island Unit 1	300	178	181	2008	>2050	>2050

*Depending on the efficacy of the proposed flux reduction program, RT_{PTS} at end of life will be reduced and the Screening Criterion will not be reached before 1992.

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Table 1 (Continued)

Plant name	Applicable screening criterion, deg. F	RT at end life, deg. F PTS Rule	Rev. 2	End of licensed life (CP + 40) unless noted)	Estimated year screening criterion will be reached PTS Rule	Rev. 2
Prairie Island Unit 2	300	222	208	2008	>2050	>2050
Rancho Seco	270	264	255	2008	2012	2018
H. B. Robinson Steam Electric Plant, Unit No. 2	300	269	262	2007	2032	>2050
Salem Generating Station Unit 1	270	255	256	2008	2021	2020
Salem Generating Station Unit 2	270	160	202	2006	>2050	>2050
San Onofre Nuclear Generating Station, Unit 1	270	265	228	2004	2010	>2050
San Onofre Nuclear Generating Station, Unit 2	270	145	137	2013	>2050	>2050
San Onofre Nuclear Generating Station, Unit 3	270	131	124	2013	>2050	>2050
Sequoyah Nuclear Plant Unit 1	270	240	225	2010	>2050	>2050
Sequoyah Nuclear Plant Unit 2	270	172	166	2010	>2050	>2050
St. Lucie Unit 1	270	231	239	2010	2050	>2050
St. Lucie Unit 2	270	179	172	2023 (OL + 40)	>2050	>2050

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Table 1 (Continued)

Plant name	Applicable screening criterion, deg. F	RT_{PTS} at end of licensed life, deg. F PTS Rule	Rev. 2	End of licensed life (CP + 40) unless noted)	Estimated year screening criterion will be reached PTS Rule	Rev. 2
Virgil Summer	270	162	155	2013	>2050	>2050
Surry Power Station Unit 1	270	169	260	2012	2013	2019
Surry Power Station Unit 2	270	225	233	2013	>2050	>2050
Three Mile Island Nuclear Station Unit 1	270	270	262	2008	2008	2011
Trojan Nuclear Plant	270	191	196	2011	>2050	>2050
Turkey Point Unit 3	300	263	283	2007	2035	2020
Turkey Point Unit 4	300	263	283	2007	2035	2020
Waterford 3	270	84	83	2024 (OL + 40)	>2050	>2050
Wolf Creek Generating Station Unit No. 1	270	140	131	2025 (OL+40)	>2050	>2050
Yankee Rowe	270	239	249	1997	2029	2025
Zion Station Unit 1	300	311	299	2008	2005	2011
Zion Station Unit 2	270	259	249	2008	2017	2023

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Table 2 Select list of PWR's, arranged in order of the increase in RT if the formula in revision 2, R.G. 1.99, were put in rule

	Applicable screening criterion, deg. F	RT at end life, deg. F PTS Rule	Rev. 2	Difference: Rev. 2 minus PTS Rule
Diablo Canyon Unit No. 1	270	202	270	68
Fort Calhoun	270	235	302	67
Calvert Cliffs Nuclear.. Power Plant Unit No. 1	270	238	301	63
Palisades Plant	270	270	322	52
Salem Generating Station Unit 2	270	160	202	42
Davis Besse Unit No. 1	300	217	249	32
Oconee Nuclear Station Unit 3	300	233	261	28
Point Beach Nuclear Plant Unit 1	270	249	269	20
Turkey Point Unit 3	300	263	283	20
Turkey Point Unit 4	300	263	283	20
R. E. Ginna .Nuclear Power Plant	300	266	283	17
Indian Point Unit 2	270	214	226	12
Point Beach Nuclear Plant Unit 2	300	293	305	12
Oconee Nuclear Station Unit 1	270	239	249	10
Yankee Rowe	270	239	249	10

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Table 3 PWR's that equal or exceed, or come within one degree of the screening criterion at EOL if revision 2 were used

Plant name	Applicable screening criterion, deg. F	RT at end of life, deg. F, per Rev. 2	Difference	End of licensed life (CP + 40) unless noted)	Estimated year screening criterion will be reached
Palisades Plant	270	322	52	2007	1992"
Fort Calhoun	270	302	32	2008	1998
Calvert Cliffs Nuclear Power Plant Unit No. 1	270	301	31	2014 (OL' + 40)	1997
Kewaunee Nuclear Power Plant	300	313	13	2013 (OL + 40)	2006
Point Beach Nuclear Plant Unit 2	300	305	5	2013 (OL + 40)	2008
Diablo Canyon Unit No. 1	270	270	0	2008	2008
Indian Point Unit 3	270	269	-1	2009	2010
Point Beach Nuclear Plant Unit 1	270	269	-1	2010 (OL + 40)	2011
Zion Station Unit 1	300	299.	-1	2008	2011

Depending on the efficacy of the proposed flux reduction program, at end of life will be reduced and the Screening Criterion will not be reached

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Table 4 PWR'S that equal, or exceed, or come within one degree of the screening criterion at EOL if the PTS rule is not changed

Plant name	Applicable screening criterion, deg. F	RT at end of life deg. F, per the PTS rule	Difference	End of [redacted]nsed life (CP + 40) unless noted)	Estimated year screening criterion will be reached
Kewaunee Nuclear Power Plant	300	329	29	2013 (OL+40)	2004
Zion Station Unit 1	300	311	11	2008	2005
Palisades Plant	270	270	0	2007	2007
Three Mile Island Nuclear Station Unit 1	270	270	0	2008	2008
Indian Point Unit 3	270	269	-1	2009	2010
Oconee Nuclear Station Unit 2	300	299	-1	2013 (OL+40)	2014
Surry Power Station Unit 1	270	269	-1	2012	2013

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Appendix B: Reactor Operating and Replacement Power Costs

Utility	Reactor	O+M Costs (Mills/ KWH)	Replace-ment cost*	Margin (Mills/ KWH)
Arkansas Power and Light Company	Arkansas-1	20.46	15.7	4.76
Arkansas Power and Light Company	Arkansas-2	20.46	15.7	4.76
Duquesne Light Company	Beaver Valley-1	26.95	12.4	14.55
Duquesne Light Company	Beaver Valley-2	26.95	12.4	14.55
Consumers Power Company	Big Rock Point-1	65.99	22.9	43.09
Commonwealth Edison Company	Braidwood-1	15.24	28.2	-12.96
Commonwealth Edison Company	Braidwood-2	15.24	28.2	-12.96
Tennessee Valley Authority	Browns Ferry-1	48.64	NA	
Tennessee Valley Authority	Browns Ferry-2	48.64	8.5	40.14
Tennessee Valley-Authority	Browns Ferry-3	48.64	8.5	40.14
Carolina Power and Light Company	Brunswick-1	52.81	19.6	33.21
Carolina Power and Light Company	Brunswick-2	52.81	19.6	33.21
Commonwealth Edison Company	Byron-1	14.2	28.4	-14.2
Commonwealth Edison Company	Byron-2	14.2	28.4	-14.2
Union Electric Company	Callaway-1	16.31	13	3.31
Baltimore Gas and Electric Company	Calvert Cliffs-1	21.42	23.7	-2.28
Baltimore Gas and Electric Company	Calvert Cliffs-2	21.42	23.7	-2.28
Duke Power Company	Catawba-1	16.66	19.7	-3.04
Duke Power Company	Catawba-2	16.66	19.7	-3.04
Illinois Power Company	Clinton-1	27.59	9.1	18.49
TU Electric	Comanche Peak-1	22.91	19.8	3.11
TU Electric	Comanche Peak-2	22.91	19.8	3.11
Indiana Michigan Power Company	Cook-1	23.33	11.8	11.53
Indiana Michigan Power Company	Cook-2	23.33	11.8	11.53
Nebraska Public Power District	Cooper Station	20.08	12.8	7.28
Florida Power Corporation	Crystal River-3	24.74	25.3	-0.56
Toledo Edison Company	Davis-Besse-1	24.99	11.7	13.29
Pacific Gas and Electric Company	Diablo Canyon-1	18.69	30.7	-12.01
Pacific Gas and Elect IC Company	Diablo Canyon-2	18.69	30.7	-12.01
Commonwealth Edison Company	Dresden-2	29.48	28	1.48
Commonwealth Edison Company	Dresden-3	29.48	28.5	0.98
Iowa Electric Light and Power Company	Duane Arnold	22.67	12.1	10.57
Alabama Power Company	Farley-1	18.8	23	-4.2
Alabama Power Company	Farley-2	18.8	23	-4.2
Detroit Edison Company	Fermi-2	26.91	18	8.91
New York Power Authority	Fitzpatrick	34	31.7	2.3
Omaha Public Power District	Fort Calhoun-1	33.38	10.9	22.48
Rochester Gas and Electric Corporation	Ginna	23.32	33	-9.68

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Utility	Reactor	**O+M** Costs (Mills/ **KWH)**	Replace-ment ***Cost****	**Margin** (MIllsi **KWH)**
System Energy Resources, Inc.	Grand Gulf-1	20.58	12.7	7.88
Northeast Utilities Service Company	Haddam Neck	30.88	21.8	9.08
Georgia Power Company	Hatch-1	21.79	21.1	0.69
Georgia Power Company	Hatch-2	21.79	21	0.79
Public Service Electric and Gas Company	Hope Creek-1	19.07	23.9	-4.83
Consolidated Edison Company of New York	Indian Point-2	28.96	31.9	-2.94
New York Power Authority	Indian Point3	48.03	33.2	14.83
Wisconsin Public Service Corporation	Kewaunee	20.52	22.3	-1.78
Commonwealth Edison Company	LaSalle-1	16.63	27.9	-11.27
Commonwealth Edison Company	LaSalle-2	16.63	27.9	-11.27
Philadelphia Electric Company	Limerick-1	17.93	23	-5.07
Philadelphia Electric Company	Limerick-2	17.93	23	-5.07
Maine Yankee Atomic Power Company	Maine Yankee	15.74	26.7	-10.96
Duke Power Company	McGuire-1	17.25	19.2	-1.95
Duke Power Company	McGuire-2	17.25	19.2	-1.95
Northeast Utilities Service Company	Millstone-1	36.02	22.9	13.12
Northeast Utilities Service Company	Millstone-2	36.02	23.3	12.72
Northeast Utilities Service Company	Millstone-3	28.99	22.8	6.19
Northern States Power Company	Monticello	20.06	13.8	6.26
Niagara Mohawk Power Corporation	Nine Mile Point-1	27.77	29.7	-1.93
Niagara Mohawk Power Corporation	Nine Mile Point-2	27.01	30	-2.99
Virginia Power	North Anna-1	13.77	20.7	-6.93
Virginia Power	North Anna-2	13.77	20.7	-6.93
Duke Power Company	Oconee-1	14.22	19.8	-5.58
Duke Power Company	Oconee-2	14.22	19.8	-5.58
Duke Power Company	Oconee-3	14.22	19.8	-5.58
GPU Nuclear Corporation	Oyster Creek-1	36.59	22.2	14.39
Consumers Power Company	Palisades	23.42	22.9	0.52
Arizona Public Service Company	Palo Verde-1	22.14	20.8	1.34
Arizona Public Service Company	Palo Verde-2	22.14	20.8	1.34
Arizona Public Service Company	Palo Verde-3	22.14	20.8	1.34
Philadelphia Electric Company	Peach Bottom-2	27.47	21.4	6.07
Philadelphia Electric Company	Peach Bottom-3	27.47	21.3	6.17
Cleveland Electric Illuminating Company	Perry-1	36.08	10.2	25.88
Boston Edison Company	Pilgrim-1	28.93	25.4	3.53
Wisconsin Electric Power Company	Point Beach-1	14.28	22.9	-8.62
Wisconsin Electric Power Company	Point Beach-2	14.28	22.9	-8.62
Northern States Power Company	Prairie Island-1	14.92	13.9	1.02
Northern States Power Company	Prairie Island-2	14.92	13.8	1.12

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Appendix B, *continued*

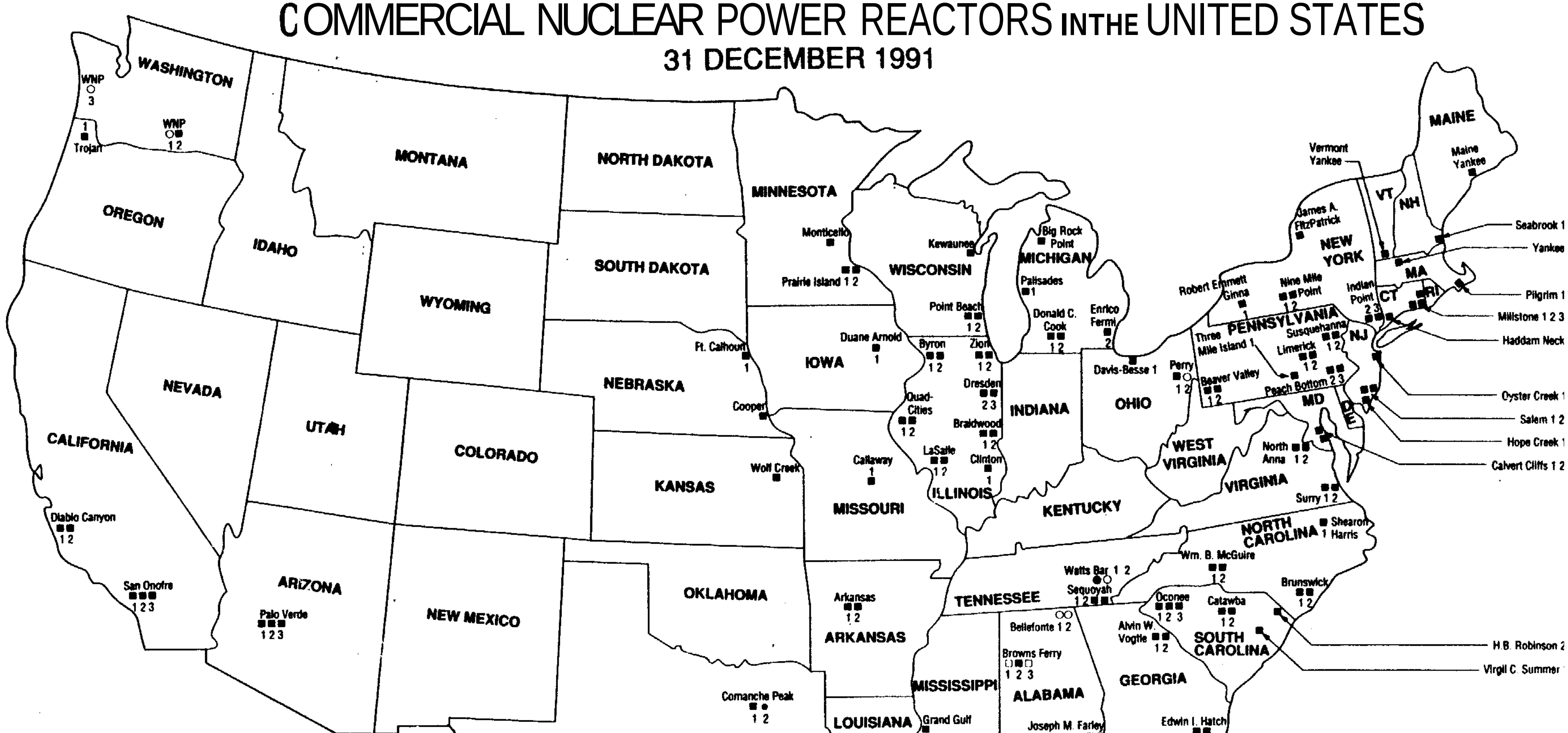
Utility	Reactor	O+M Costs (Mills/ **KWH)**	Replace-ment **Cost***	Margin (Mills/ **KWH)**
Commonwealth Edison Company	Quad Cities-1	25.64	24.4	1.24
Commonwealth Edison Company	Quad Cities-2	25.64	25	0.64
Gulf States Utilities Company	River Bend-1	48.38	12	36.38
Carolina Power and Light Company	Robinson-2	23.35	19.7	3.65
Public Service Electric and Gas Company	Salem-1	25.47	23.7	1.77
Public Service Electric and Gas Company	Salem-2	25.47	23.7	**1.77**
Southern California Edison Company	San Onofre-2	23.35	26.4	-3.05
Southern California Edison Company	San Onofre-3	23.35	26.4	-3.05
North Atlantic Energy Service Corporation	Seabrook-1	21.9	24.2	-2.3
Tennessee Valley Authority	Sequoyah-1	21.87	8.7	13.17
Tennessee Valley Authority	Sequoy ah-2	21.87	8.7	13.17
Carolina Power and Light Company	Shearon Harris-	16.24	20	-3.76
Houston Lighting and Power Company	South Texas-1	79.76	20.7	59.06
Houston Lighting and Power Company	South Texas-2	79.76	20.7	59.06
Florida Power and Light Company	St. Lucie-1	19.65	25.6	-5.95
Florida Power and Light Company	St. Lucie-2	19.65	25.6	-5.95
South Carolina Electric and Gas Company	Summer-1	18.61	18.8	-0.19
Virginia Power	Surry-1	15.76	19.3	-3.54
Virginia Power	Surry-2	15.76	19.3	-3.54
Pennsylvania Power and Light Company	Susquehanna-1	19.64	22.6	-2.96
Pennsylvania Power and Light Company	Susquehanna-2	19.64	22.6	-2.96
GPU Nuclear Corporation	Three Mile Island-1	19.9	23.4	-3.5
Florida Power and Light Company	Turkey Point-3	52.63	25.4	27.23
Florida Power and Light Company	Turkey Point-4	52.63	25.4	27.23
Vermont Yankee Nuclear Power Corporation	Vermont Yankee	24.18	25.8	-1.62
Georgia Power Company	Vogtle-1	14.87	19.7	-4.83
Georgia Power Company	Vogtle-2	14.87	19.7	-4.83
Washington Public Power Supply System	Wash. Nuclear-2	25.01	18.8	6.21
Louisiana Power and Light Company	Waterford-3	18.27	15.8	2.47
Kansas Gas and Electric Company	Wolf Creek-1	15.67	18.2	-2.53
Commonwealth Edison Company	Zion-1	21.43	28	-6.57
Commonwealth Edison Company	Zion-2	21.43	28.1	-6.67

*Replacementcosts are for the winter of 1993-4

Sources: U.S. Nuclear Regulatory Commission, Replacement Energy costs for Nuclear Electricity— Generating Units in the United States: 1992-1996, NUREG/CR-4012, October 1992, p. 79-190; Inside NRC, June 13,1994, p. 1-4

COMMERCIAL NUCLEAR POWER REACTORS IN THE UNITED STATES

31 DECEMBER 1991



NUCLEAR GENERATING UNIT PROFILE

31 DECEMBER 1991

Status	No.	MD Capacity* net MW(e)	Design, electrical power net MW(e)
W Full-power license	109	97.6800	99,2570
	2	2,130.0	2,1300
Under active construction	2	0 0	2,3150
O Construction deferred/halted	6	0 0	7,3480
Total	119	99,810.0	111,050.0

*Maximum Dependable Capacity or Design Electrical Rating

Office of Scientific and Technical Information
U.S. Department of Energy

December 31,1991

From *Nuclear Reactors Built, Being Built, or Planned* (DOE/OSTI-8200-R55)

R55 (SUM)

DE92012402

Notes

1. 56 Fed.Reg. 64943

2. 56 Fed.Reg. 64946

3. U.S. Nuclear Regulatory Commission, "Regulatory Options for Nuclear Power Plant License Renewal, Draft for Comment," NUREG-1317, August 1988, p. x.

4. Advisory Committee on Reactor Safeguards, Subcommittee on Regulatory Policies and Practices: License Renewal, ACRS-T-1789, March 26,1990, pp. 153,154.

5. Id. at 165,166. emphasis added.

6. U.S. Nuclear Regulatory Commission, "Resolution of Deviations Identified During The Systematic Evaluation Program," SECY-92-223, June 19,1992, p. 7.

7. U.S. Nuclear Regulatory Commission, Memorandum for: James M. Taylor, Executive Director for Operations, From: Samuel J. Chilk, Secretary, Subject: SECY-92-223—Resolution of Deviations Identified During The Systematic Evaluation Program, September 18,1992, p. 1.

8. Id. at 1.

9. U.S. Congress, Office of Technology Assessment, Aging Nuclear Power Plants: Managing Plant Life and Decommissioning, OTA-E-575, September 1993, p. 14.

10. U.S. Nuclear Regulatory Commission, Advisory Committee on Reactor Safeguards, Transcript of ACRS Subcommittee Meeting on Materials and Metallurgy, September 5,1990, pp. 202—203. emphasis added.

11. Id. at 206. emphasis added.

12. US. Nuclear Regula ory Commission, *In the Matter of Yankee Atomic Electric Company, Yankee Rowe Nuclear Power Station,* CLI-91-11, July 31,1991, p. 27.

13. Airozo, David, "Is NRC's Process Killing Chances for Nuclear Power Plant License Renewal," *Inside NRC,* March 9,1992, p. 1.

14. Northern States Power Company, "Perspectives on the License Renewal Process," November 20, 1992, p. i.

15. Id. at pp. 7-8.

16. U.S. Nuclear Regulatory Commission, "Implementation of 10 CFR Part 54, 'Requirements for Renewal of Operating Licenses for Nuclear Power Plants", SECY-93-049, March 1,1993; "Additional Implementation Information for 10 CFR Part 54, 'Requirements for Renewal of Operating Licenses for Nuclear power Plants", SECY-93-113, April 30, 1993.

17. U.S. Nuclear Regulatory Commission, Advisory Committee On Reactor Safeguards, 396th General Meeting, April 15,1993, p. 18.

18. U.S. Nuclear Regulatory Commission, Regulatory Analysis: For the Proposed Rule on Nuclear Power Plant License Renewal, 10 CFR Part 54, August 1994, pp. ***3-4.*** emphasis added.

19. 56 Fed.Reg. 64946. emphasis added.

20. U.S. Nuclear Regulatory Commission, Briefing On Results of License Extension Workshop & Proposed Changes to License Renewal Rule, Wednesday December 22,1993, p. 23.

21. U.S. Nuclear Regulatory Commission, Briefing On Results of License Extension Workshop & Proposed Changes to License Renewal Rule, Wednesday December 22,1993, p. 7. emphasis added.

22. 59 Fed.Reg. 46577. emphasis added.

23. U.S. Nuclear Regulatory Commission, Briefing On Results of License Extension Workshop & Proposed Changes to License Renewal Rule, Wednesday December 22,1993, pp. 39-40. emphasis added.

24. Id. at 40. emphasis added.

25. Id. at 41

26. Id. at pp. 62-63

27. Riccio and Freedman, "Hear No Evil, See No Evil, Speak No Evil: What the NRC Won't Tell You About America's Nuclear Reactors," Public Citizen, December 15,1993, Volume 1, p. 16.

28. U.S. Nuclear Regulatory Commission, Letter from Chairman Ivan Selin to Senators Joseph Lieberman and Howard Metzenbaum, January 25, 1994, p. 1.

29. U.S. Nuclear Regulatory Commission, Draft Regulatory Analysis for Proposed Rulemaking on Maintenance of Nuclear Power Plants, November 1988, p. 43.

30. U.S. Nuclear Regulatory Commission, Regula-

tory Analysis For Proposed Amendment of the PTS Rule, 10 CFR 50.61, "Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events," May 2, 1989, p.1. emphasis added.

31. 10 CFR 50, Appendix G, Fracture Toughness Requirements

32. 10 CFR 50.61 Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock

33. U.S. Nuclear Regulatory Commission, Regulatory Analysis For Proposed Amendment of the PTS Rule, 10 CFR 50.61, "Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events," May 2,1989, p. 2.

34. U.S. Nuclear Regulatory Commission, Advisory Committee on Reactor Safeguards, Transcript of Joint ACRS Subcommittee on Materials and Metallurgy/Structural Engineering on Revised PTS Rule and Embrittlement of RPV Supports; p.37,, (March 23,1989).

35. Id. at 39.

36. U.S. Nuclear Regulatory Commission, Memorandum For: Thomas E. Murley, Director, Office of Nuclear Reactor Regulation; From Lawrence C. Shao, Director, Division of Engineering and Systems Technology, "Reactor Vessels Most Susceptible to Having Their Charpy Upper Shelf Energy Reduced Below 50 ET-LB," September 24,1987

37. Id. at p. 2.

38. Wald, Matthew L., "NRC Says 15 Reactors Need Testing," ***New York** Times,* April 2,1993.

39. Id.

40. U.S. Nuclear Regulatory Commission, Proposed Rule on Fracture Toughness Requirements For Light Water Reactor Pressure Vessels, 10 CFR Part 50,59 *Fed. Reg.* 50513, October 4,1994.

41. Conversation with Alfred Taboada, Division of Engineering, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatorv Commission, March 14, 1995.

42. "Outlook On Life Extension,'' *Nucleonics Week,* 1994, p. 10; U.S. Nuclear Regulatory Commission, Regulatory Analysis For Proposed Amendment of the **PTS** Rule, 10 CFR 50.61, "Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events," May 2,1989.

43. Dizard 111, Wilson, "Consumers May Anneal Palisades' Vessel-A U.S. First," *Nucleonics Week,* January 12,1995, p. 1.

44. "Outlook ***On*** Life Extension," *Nucleonics Week,* 1994, p. 10.

45. US Nuclear Regulatory Commission, Information Digest, NUREG-1350, Vol. 6,1994, p.33.

46. **U.S.** Nuclear Regulatory Commission, Steam Generator Operating Experience, Update for 1989-1990, NUREG/CR-5796, December 1991. note: After this report the NRC stopped compiling steam generator data. This information is still submitted to NRC annually by each licensee.

47. Memorandum for E. Beckjord, Director Office of Nuclear Reactor Research, From J. Hopenfeld, Reactor & Plant Safety Issues Branch, Division of Safety issue Resolution, RES, Subject: A New Generic Issue: Multiple Steam Generator Leakage, March 27,1992, p. 17.

48. U.S. Congress Office of Technology Assessment, Aging Nuclear Power Plants: Managing Plant Life and Decommissioning, OTA-E-575, September 1993, **p.** 42.

49. U.S. Nuclear Regulatory Commission, NRC Report on the January 25,1982 Steam Generator Tube Rupture at R.E. Ginna Nuclear Power Plant, NUREG-0909, April 1982.

50. Commissioner Kenneth C. Rogers, U.S. Nuclear Regulatory Commission, Nuclear Power Plant Aging: The U.S. Regulatory Perspective, International Symposium on Nuclear Power Plant Aging, August 30,1988, p. 2. emphasis added.

51. Memorandum for E. Beckjord, Director Office of Nuclear Reactor Research, From **J.** Hopenfeld, Reactor & Plant Safety Issues Branch, Division of Safety issue Resolution, RES, Subject: **A** New Generic Issue: Multiple Steam Generator Leakage, March 27,1992. emphasis added.

52. Letter from Robert Pollard, Nuclear Safety Engineer, Union of Concerned Scientists To: Chairman **Ivan Selin,** James R. Curtiss, E. Gail de Planque, Forrest J. Remick, Kenneth C. Rogers, U.S. Nuclear Regulatory Commission, Subject: Multiple Steam Generator Tube Rupture Accidents, November 23, 1992, p. 1.

53. "PGE Sues Westinghouse for 'Faulty Equipment' at Closed Trojan Reactor," Electric Utility Week, February 23,1993, pp.7-8.

54. Hebert, Josef H. "Cracking Reactor Pipes" Associated Press, November 24,1992; "NRC Staff Dispute Raises Questions About New Steam Generator Tube Criteria," *Nucleonics Week,* Nov. 26,1992, p. 1.

55. Memorandum for James M. Taylor, Executive Director For Operations, From Thomas E. Murley, Director, Office of Nuclear Reactor Regulation, Subject: Report on trip to Sweden, France, NEA

(Committee for Nuclear Regulatory Activities [CNRA]), and the U.K. —June 18-30,1992, p. 2. emphasis added.

56. Id. at p. 2. emphasis added.

57. US. Nuclear Regulatory Commission, Memorandum for: James M. Taylor, Executive Director for Operations, From: Joram Hopenfeld, Engineering Issues Branch, Division of Safety Issues Resolution, Office of Nuclear Reactor Regulation, RE: Differing Professional Opinion Regarding Voltage Based Interim Repair Criteria for Steam Generators, July 13,1994, p. 5. emphasis added.

58. Airozo, Dave, "Maine Yankee Moves Up Outage; Steam Generator Questions Persist," *Nucleonics Week,* February 2,1995, p. 6.

59. Hiruo, Elaine, "PSC Deferral Keeps Point Beach-2 At **Risk** Of Premature Shutdown," *Nucleonics Week,* January 12,1995, p. 5.

60. Stellfox, David, "Risk **of** Premature Shutdown Grows; Kewaunee, Ft Calhoun On Guard," *Nucleonics Week,* September 3,1992, pp.l, 11.

61. Stellfox, David, "Plan to Accept Sleeved Tubes With Cracks in Upper Joints Shot Down," *Inside NRC,* February 6., 1995. emphasis added.

62. Stellfox, David, "Twenty-Six Licensees Could Face Plug Replacement At Next Outages," *Inside NRC,* December 26,1994

63. Id.

64. Stellfox, David, "Reactor Vendors Shift Focus To U.S. Steam Generator Market," *Nucleonics Week,* May 14,1992, p. 7 & 8; Zuercher, Richard R., "North Anna Steam Generator Trade Out Moved Up One Year," *Nucleonics Week,* October 6,1994, p. **1;** U.S. Nuclear Regulatory Commission, Weekly Information Report—Week Ending December 23,1994, enclosure **A;** Weekly Information Report—Week Ending, January 25,1995.

65. Hart, Kathleen, "NRC Pushing BWR Owners Group To Address Core Shroud Cracking Issue," *Inside NRC,* May 30,1994, P. 1.

66. US. Atomic Energy Commission, Memorandum to John F. O'Leary from Joseph M. Hendrie, September 25,1972. emphasis added.

67. Jordan, Brian, "Denton Urges Industry to Settle Doubts About Mark I Containment," *Inside NRC,* June 9,1986, pp. **1,3.**

68..U.S. Nuclear Regulatory Commission, *Reactor Risk Reference Document,* NUREG 1150, February 1987, pp. ES-14.

69. U.S. Nuclear Regulatory Commission, "Intergranular Stress Corrosion cracking of Core Shrouds in Boding Water Reactors," GL-94-03, July 25,1994.

70. Id. at p. 1.

71. U.S. Nuclear Regulatory Commission, "Intergranular Stress Corrosion cracking of Core Shrouds in Boiling Water Reactors," GL-9403, July 25,1994

72. Hart, Kathleen, "NRC Pushing BWR Owners Group To Address Core Shroud Cracking Issue," *Inside NRC,* May 30,1994, P. 1.

73. "Cracks in German Plant", World Information Service on Energy, December 19,1994, p. 4.

74. Hart, Kathleen, "NRC Pushing BWR Owners Group To Address Core Shroud Cracking Issue," ***hide*** *NRC,* May 30,1994, P. 15.

75. **U.S.** Nuclear Regulatory Commission, Boiling Water Reactor Intemals Aging Degradation Study, NUREG/CR 5754, September 1993.

76. Id., at 42.

77. Northern States Power Company, "Perspectives on the License Renewal Process," November 20, 1992, p. 7.

78. Id.

79. Shearson Lehman Brothers, "Are Older Nuclear Plants Still Economic?" Electric Utility Commentary, Vol2. No.21, May 27,1992, p.1.

80. Id. at 1.emphasis added.

81. Shearson Lehman Brothers, "Are Older Nuclear Plants Still Economic?" Electric Utility Commentary, Vol2. No.21, May 27,1992, p. ***25.***

82. Wald, Matthew L., "Regulator Says Economics Could Lead Nuclear Plants to Scrimp," ***New*** *York Times,* September 9,1994, p. A-19.

83. "EEI Studies Warn Many U.S. Units Not Producing Competitively," *Nucleonics Week,* March 17,1994, P. 1

84. Id at 12.

85. U.S. Nuclear Regulatory Commission, Replacement Energy Costs for Nuclear Electricity-Generating Units in the United States: 1992-1996, NUREG/CR-4012, October 1992 pp. 79-190; "More Plants Combine Cost Efficiency, Production and Safety in 1991-93, *Inside NRC,* June 13,1994, **pp.** 1-4.

86. U.S. Department of Energy, Office of Civilian Radioactive Waste Management, "Integrated Data Base for 1993: US. Spent Fuel and Radioactive Waste Inventories, Projections and Characteristics", March 1994, p. 26.

87. Fact sheet prepared by Radioactive Waste Management Associates, New York City.

88. John W. Gofman and Arthur R. Tamplin. *Poisoned Power: The Case Against Nuclear Power Plants Before and After Three Mile IsZand,* Rodale Press, Emmaus, PA. 1979, p. 4

89. U.S. Department of Energy, Office of Civilian Radioactive Waste Management, "Integrated Data Base for 1993: U.S. Spent Fuel and Radioactive Waste Inventories, Projections and Characteristics", March 1994, p. 10.

90. **Selin,** Ivan, Chairman, U.S. Nuclear Regulatory Commission, "Timely Topics ***On*** Spent Fuel Storage," Annual Meeting of the Institute of Nuclear Materials Management, July 18,1994, p. 1.

91. Id. at 2.

92. U.S. Department of Energy, Office of Civilian Radioactive Waste Management, "Integrated Data Base for 1993: U.S. Spent-Fuel and Radioactive Waste Inventories, Projections and Characteristics", March 1994, p. 26,29.

93. Rogers, Keith, "Policy holds no alternative to Yucca Mountain," *Las Vegas Review-Journal.* October 13,1994, p. 4A

94. Nicholas Lenssen, "Nuclear Waste: The Problem That Won't Go Away." Worldwatch Paper 106, December 1991, p. 27.

95. Id.

96. William J. Broad, "Scientists Fear Atomic Explosion Of Buried Waste," *New York Times,* March 5, 1995, p. 1.

97. Id. emphasis added.

98. William J. Broad, "Theory on Threat of Blast at Nuclear Waste Site Gains Support." The New York Times, March 23,1995, p. A18.

99. William J. Broad, "Scientists Fear Atomic Explosion Of Buried Waste," *New York Times,* March 5, 1995, p. 1.

100. U.S. Department of Energy, *Civilian Radioactive Waste Management Program Plan: Volume* I, *Program Overuiew* (Washington, December 19,1994), p. 44.

101. Friends of the Earth and National Taxpayers Union, "The Green Scissors Report: Cutting Wasteful and Environmentally Harmful Spending and Subsidies," 1995, p. 26.

102. U.S. Department of Energy, Office of Civilian Radioactive Waste Management Fact Sheet, February 24,1995.

103. U.S. Department of Energy, "Civilian Radioactive Waste Management Program Plan: Volume I, Program Overview," December 19,1994, p. **6.**

104. General Accounting Office, *"Nuclear Waste: Comprehensive **Review** of the Disposal Program is*

2.

105. Nevada Agency for Nuclear Projects, "High Level Waste Shipping Route Maps to Yucca Mountain and Shipment Number Estimates: Multi-Purpose Canister Base Case," January 1995.

106. **Scott** Saleska, "Nuclear Legacy: **An** Overview of the Places, Problems, and Politics of Radioactive Waste in the United States" (Public Citizen, September 1989), p. VIII—4—VIII-6.

107. Northern States Power Company, "Perspectives on the License Renewal Process," November 20, 1992, p. 8.

108. EIA Service Report, "Spent Nuclear Fuel Bscharges from U.S. Reactors 1993," February 1995.

109. Sinclair, Mary, "Statement presented to the Nuclear Waste Technical Review Board," November 1,1993

110. Schneider, Keith, "By Default and Without Debate, Utilities Ready Long-Term Storage of Nuclear Waste," *New York Times,* February 15, 1995, p. A19.

111. U.S. Nuclear Regulatory Commission, "Notice of Violation," Docket No. 72-0010, January 24,1994