United States General Accounting Office

GAO

Report to the Honorable
Sid Morrison, House of Representatives

September 1988

NUCLEAR SCIENCE

Questions Associated With Completing WNP-1 as a Defense Materials Production Reactor

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GAO

United States
General Accounting Office
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Resources, Community, and
Economic Development Division

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September 21, 1988

The Honorable Sid Morrison
House of Representatives

Dear Mr. Morrison:

On December 11, 1987, you asked us to answer several questions regarding a partially completed commercial nuclear power plant which the Department of Energy (DOE) is considering acquiring and completing as a nuclear weapons materials production facility. The plant is located on DOE's Hanford Reservation near Richland, Washington, and is presently owned by the Washington Public Power Supply System (Supply System).

The questions you asked stemmed from a DOE report[1] that assessed the feasibility of acquiring and completing the plant, referred to as Washington Nuclear Plant #1 (WNP-1), as a tritium[2] production facility. Your questions dealt with issues related to the safety, licensability, and cost of WNP-1, and the schedule for completing it. In addition, you asked if completing the reactor would (1) be a violation of the 1968 Nuclear Non-Proliferation Treaty or law and (2) result in an act of default, making the WNP-1 bonds[3] due and payable.

Results in Brief

Our review disclosed no major safety, technical, or other barriers which would preclude WNP-1 from being considered as an option for the next new materials production reactor. In addition, we found no basis to question the process used by DOE contractors for estimating the WNP-1 completion cost and schedule. However, we did identify several unresolved issues that could have an impact on the cost and schedule for completing the WNP-1. These include:

- Potential design changes identified by NRC and common to all pressurized light water reactors. For example, WNP-1's decay heat removal system and the station blackout prevention system may need to be modified.

[1] Technical Feasibility Task Force WNP-1 Conversion Preinvestment Analysis Report, Mar. 1987.

[2] Tritium is a gaseous isotope used in nuclear weapons. It is produced in a nuclear reactor when uranium neutrons react with another element, lithium.

[3] WNP-1 was financed by the Supply System with long-term revenue bonds.

- Technical issues associated with (1) ensuring the integrity of the tritium fuel pins, (2) preventing recriticality,[4] and (3) achieving the required production of tritium.
- Establishment of safety requirements or standards that may be needed for completing the WNP-1 as a tritium production reactor, instead of its intended commercial purpose. These may require review of the existing systems and also review of any modifications necessary in order to produce tritium.
- Remaining legal questions surrounding the acquisition cost for the WNP-1. The cost could range from $30 million (salvage value) to $2.1 billion (total of outstanding bonds).
- Policy questions arising from completing a commercial reactor as a weapons materials production reactor. Traditionally, the peaceful and military uses of atomic energy have been separated.

Regarding the legal implications, we found that completion of the WNP-1 as a production reactor would not violate federal law or the Non-Proliferation Treaty. We also found that condemnation of the WNP-1 by DOE would not be an event of default and would not make the bonds immediately due and payable.

The remainder of this letter provides you with a summary of our findings, including a discussion of the unresolved issues. More detailed answers to your specific questions on WNP-1's design, technology, licensability, cost, schedule for completion, and legal and policy questions are provided in appendixes I through VI.

Background

DOE is responsible for producing nuclear weapons materials for national defense purposes. The primary materials used are tritium and plutonium, which are produced in nuclear reactors. The only defense production reactors presently operating are located in South Carolina. These reactors are over 30 years old and have had power reductions due to environmental and safety concerns.

The N-Reactor, located on DOE's Hanford Reservation, has been used mainly for plutonium production since it started operating in the early 1960s. The N-Reactor could be modified to produce tritium; however, it has been shut down since January 1987 for safety work and is not

[4]Recriticality is an event that may occur during an accident in which the nuclear fuel melts and reshapes itself in a configuration that sustains an uncontrolled nuclear reaction.

expected to be restarted. Thus, DOE is presently planning to construct and operate a new reactor especially for the production of tritium.

One option available to DOE is completing the WNP-1 as a materials production reactor. WNP-1 is a pressurized light water[5] reactor designed by Babcock & Wilcox for commercial power production. Construction on the plant was halted by the Supply System in 1982 because of financial problems and uncertainties concerning future electric power demand. The plant is 63-percent complete and has been maintained in accordance with Nuclear Regulatory Commission (NRC) licensability requirements.

In August 1986, DOE established a task force to examine the feasibility of completing WNP-1 as a materials production reactor. The task force assessed only the WNP-1 and did not compare it with other options. The task force's March 1987 report concluded that WNP-1 could be modified and associated support facilities made available at a cost and schedule appropriate to the requirements of DOE.

In January 1988, DOE initiated a two-prong study to aid in the selection of a site and technology for the new materials production reactor. DOE established a site evaluation team of internal officials to evaluate and advise on the suitability of several sites for the new production reactor. DOE also requested the Energy Research Advisory Board (Advisory Board), an independent peer review board appointed by the Secretary of Energy to provide input to DOE, to evaluate four different reactor types as candidate technologies for a new production reactor. In July 1988, the Advisory Board provided the Secretary of Energy with its report specifying the strengths and weaknesses of alternate technologies.[6]

On August 3, 1988, the Secretary of Energy recommended that two reactors be constructed at separate locations. He recommended a heavy water[7] reactor at DOE's Savannah River Plant in South Carolina and a high-temperature, gas-cooled reactor at Idaho National Engineering Laboratory in Idaho. In addition, as a contingency, the Secretary stated that research and development should continue on the light water reactor

[5]"Light water" refers to water whose molecules contain normal rather than "heavy" hydrogen.

[6]These technologies are the heavy water reactor; light water reactor; high-temperature, gas-cooled reactor; and liquid metal reactor. WNP-1 is a pressurized light water reactor, a type of reactor explained in more detail in appendix II.

[7]Any of several isotopic varieties of water, especially deuterium oxide, consisting chiefly of molecules containing hydrogen with a mass number greater than 1, and used as a moderator in certain nuclear reactors.

option (WNP-1), and that work should continue on solving any institutional problems associated with its completion. (See app. I.)

Overcoming Design Problems

The Babcock & Wilcox Owners Group, an organization of owners of Babcock & Wilcox reactors, has proposed 215 recommendations for improving the operation and safety of its reactors. A number of the recommendations concern design issues which may apply to the WNP-1 reactor. However, the Supply System has deferred action on the recommendations until after reactor construction resumes.

In February 1987, the Union of Concerned Scientists[8] petitioned the NRC to shut down Babcock & Wilcox-designed plants because it believed the plants had serious design problems that made them unsafe to operate. The problems cited in the petition were associated with the (1) once-through steam generators, (2) reactor pressurizer, (3) auxiliary feedwater system, (4) integrated control system, and (5) non-nuclear instrumentation system. (App. II explains these features and describes the systems.)

NRC denied the petition in October 1987, although it agreed that Babcock & Wilcox reactors have experienced problems. In denying the petition, NRC stated that:

- Substantive improvements have been made to Babcock & Wilcox reactors.
- The petition contained no substantial health and safety issues that would warrant suspension of any licenses or permits for Babcock & Wilcox reactors, or that would be resolved by granting the relief requested.

We examined the applicability of the five design issues to the WNP-1 reactor and found that Babcock & Wilcox and the Supply System either have taken steps to ensure that the issues will not affect safe operation of the WNP-1 reactor or have plans to take such steps. Four of the five design features have been resolved on the WNP-1 reactor through design changes, and the fifth—the integrated control system—is planned for modification during completion of the reactor.

In addition to the problems pointed out by the Union of Concerned Scientists, NRC has identified two problems common to all pressurized

[8]An independent group of scientists concerned with U.S. energy and arms policies, especially nuclear policy.

light water reactors. The major problems are decay heat removal and station blackout. (See app. II.)

- The decay heat removal system is used to remove heat from the core once the reactor is shut down. NRC has ruled that the decay heat issue be addressed in the risk analysis submitted to NRC for each reactor. WNP-1's independent heat removal system is not dedicated solely to the removal of decay heat, a condition NRC may require.
- A station blackout occurs when all alternating current power to the reactor is lost. NRC has recently issued a ruling that plants be capable of enduring a blackout for up to 8 hours. The main concern is that the seals around the pumps, which circulate coolant through the reactor, may leak. For WNP-1, a backup system powered by a dedicated diesel motor is planned to prevent the failure of the pump seals.

Resolving Technical Issues

WNP-1 was designed as a commercial nuclear power plant with a steam supply system to generate electricity. While most of the systems are adaptable to a tritium-producing reactor, certain modifications will be necessary because the design was not engineered to produce tritium. The major change will require redesigning the core to include fuel assemblies containing enriched uranium fuel rods and tritium target pins.

In commercial light water reactors, the core is made up of thousands of rods, each containing pellets of uranium fuel. These rods are fixed in fuel assemblies containing several hundred rods each. In WNP-1, 205 fuel assemblies form the core. In a defense production reactor producing tritium, target pins filled with lithium are added to the core. The lithium in the target pins reacts with the neutrons released during the nuclear process to form tritium.

The key issue with respect to tritium production in the WNP-1 reactor is whether tritium target pins can be designed and manufactured that will retain their structural integrity and hold the tritium during the production process. The core will contain approximately 13,000 tritium target pins that must be manufactured to extremely high quality to ensure their integrity and avoid the loss of tritium. Whether the target pins will work satisfactorily cannot be fully resolved until full-scale manufacturing and irradiation testing of the target pins have been completed.

As part of the irradiation testing, the DOE contractor plans to test a relatively small number of target pins in a DOE test reactor to determine whether leaks occur. However, testing even a few hundred target pins will only confirm that there are no gross deficiencies in the final design. It will not demonstrate that several thousand pins can be produced virtually defect-free. According to DOE's contractor, component tests and a quality assurance program are planned as a part of the manufacturing process to increase confidence that the pins can be successfully manufactured on a large scale. In addition, an alternative target pin design may be developed and tested, but questions remain regarding the quantity of tritium it can produce.

Another technical issue is that the uranium fuel in the WNP-1 assemblies will require uranium with a higher enrichment level[9] than a commercial power reactor needs. DOE initially planned to run the reactor with 20-percent enriched uranium fuel. However, with 20-percent enriched fuel, there is a chance of a safety concern called "recriticality." Recriticality is a condition that, on a rare occurrence, can result in an extremely severe accident. If the nuclear fuel inside a reactor becomes too hot—for example, if it overheats because the flow of coolant in the cooling system is interrupted—it may melt or slump into a shape in which the nuclear reaction restarts but is no longer controlled by the reactor control system. While DOE contends that such an accident would not breach containment, it has not done calculations which provide full support for this conclusion.

The fuel enrichment has since been lowered to 10 percent, and DOE's contractor concluded that at this level of enrichment, the possibility of recriticality in WNP-1 is precluded. A consulting nuclear physicist we used to help us review technical issues examined the redesigned core and concluded, on the basis of the data and models available, that the possibility of recriticality would be virtually nil at the 10-percent enriched uranium level.

A third technical issue is whether the WNP-1 reactor will be able to produce goal-established amounts of tritium. This issue has not been fully resolved. DOE's contractor believes that tritium production goals can be achieved using 10-percent enriched uranium fuel. However, this confidence assumes that a tritium target pin for WNP-1 can be successfully designed and manufactured. (See app. III.)

[9]The level of enrichment of the uranium is the percentage of U^{235} present. Natural uranium is only about 0.7-percent U^{235}, the other 99.3 percent being another uranium isotope. The uranium fuel in commercial power reactors is "enriched" to 2- to 4-percent U^{235}.

Ensuring Licensability

There is considerable interest within the Congress and scientific community that DOE receive external and independent review of its reactor safety decisions of the type regularly obtained in the commercial reactor industry for all of its nuclear facilities. Currently, however, DOE production reactors are not licensed by NRC.

The NRC has found that the Supply System is maintaining the WNP-1 reactor in a way that meets the NRC's licensing standards. However, completing the plant for defense production instead of for commercial purposes would require safety analyses of the existing systems and modifications needed to complete the reactor for tritium production. In this respect, the WNP-1's pressurized light water reactor design is well known and understood, thus it would seem that techniques needed to analyze the modified reactor against safety standards could be developed and used.

It is not clear how DOE plans to provide assurance that its facilities will meet NRC standards. In this regard, we and the National Academy of Sciences have pointed out the need for independent oversight of DOE facilities to ensure and certify that safe standards are maintained. We have pointed to the need for a review process to include (1) independence, (2) technical expertise, (3) the ability to perform review of DOE facilities as needed, (4) clear authority to require DOE to address the oversight organization's findings and recommendations, and (5) a system to provide public access to the organization's findings and recommendations.[10]

Legislation is in progress to establish a safety board, made up of outside experts, to review the safety of DOE facilities. However, as of August 1988, the provision to establish such a board had not been signed into law. (See app. IV.)

Reasonableness of Cost and Schedule Estimates

A DOE subcontractor estimated in March 1988 that the cost to complete WNP-1 for tritium production is $2.6 billion, excluding the cost of acquiring the plant from the Supply System. We found no basis to question the process used by DOE contractors and subcontractors for estimating the WNP-1 completion cost and schedule. Although we did not perform a detailed examination of all of the components of the estimate, we did so for the estimate related to installing electrical cable. This is one of the larger items left to be completed; approximately 6 million feet of cable

[10] Key Elements of Effective Independent Oversight of DOE's Nuclear Facilities (GAO/T-RCED-87-32, June 16, 1987).

remains to be installed. We found the estimate for cable installation in WNP-1 to be reasonable.

The DOE subcontractor estimates it will take 6 years to complete WNP-1 as a tritium production plant. An important item in meeting the 6-year estimate is the successful development and testing of tritium target pins. In addition, legal uncertainties concerning the government's acquisition of a partially completed commercial plant for defense purposes could delay the completion. Delays in either case, or in the environmental or safety reviews, could ultimately affect the final cost and schedule estimates of WNP-1. (See app. V.)

Legal and Policy Issues

Legally, condemnation of WNP-1 by DOE would not be an event of default and would not make the bonds—totalling $2.1 billion—immediately due and payable. The following are other issues associated with completing WNP-1 as a defense production plant:

- Although DOE has statutory authority to condemn the WNP-1 plant, the plant's cost through condemnation is not known. The cost could range from $30 million (salvage value) to $2.1 billion (total of the outstanding bonds).
- While DOE's condemnation and completion of a partially completed commercial power plant as a defense production plant do not violate the 1968 Non-Proliferation Treaty or existing law, it may raise policy questions. For example, such action may be criticized on the basis that it breaks away from the traditional separation between peaceful use of atomic energy and military use. (See app. VI.)

Objectives, Scope, and Methodology

The objective of our review was to assess the issues associated with DOE's acquiring and completing WNP-1 as a defense production plant. Our specific objectives were to (1) examine safety issues by reviewing the design and technical feasibility of the completion, (2) assess the cost and schedule estimates, and (3) answer specific legal questions.

Our scope was limited to assessing the WNP-1's completion only. We did not compare the WNP-1's completion with the other options being considered by DOE for a new materials production reactor. DOE had independent studies conducted which compare the options for the reactor technology and the site. These studies were completed after we completed our field work.

We conducted our review from November 1987 through July 1988. This review included (1) an examination of DOE's March 1987 report entitled Technical Feasibility Task Force WNP-1 Conversion Preinvestment Analysis Report, its classified appendixes, and supporting studies, (2) a limited review of the estimated cost and schedule to complete WNP-1 as a materials production plant, and (3) discussions with representatives from DOE, DOE contractors and subcontractors, state governments, the Union of Concerned Scientists, the Supply System, and the Natural Resources Defense Council.[11] A consulting nuclear physicist assisted us.

During the course of our work, we obtained the views of responsible DOE and contractor officials on the information we gathered. These officials generally agreed with the facts presented, and we incorporated their views in the report where appropriate. We did not obtain official agency comments on this report. This review was conducted in accordance with generally accepted government auditing standards.

As arranged with your office, we are sending a copy of this report today to Representatives Vic Fazio and Norm Dicks, who also requested this work. In addition, a similar but separate report is being sent to Senator Brock Adams. Unless you or the other recipients of this report or the sister report publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to the appropriate congressional committees and the Secretary of Energy. We will also make copies available to others upon request.

This work was performed under the direction of Keith O. Fultz, Senior Associate Director. Other major contributors are listed in appendix VIII.

Sincerely yours,

J. Dexter Peach
Assistant Comptroller General

[11] Environmental organization staffed by lawyers and scientists who undertake litigation and research. Provides information on environmental issues, including nuclear power and non-proliferation.

Contents

Abbreviations

DOE	Department of Energy
NRC	Nuclear Regulatory Commission
WNP	Washington Nuclear Plant

Background and History Surrounding WNP-1's Completion as a Defense Production Reactor

In 1973, the Washington Public Power Supply System (Supply System), a state of Washington municipal corporation consisting of a number of public electric utilities, started construction on five commercial nuclear power reactors. Three of the reactors, Washington Nuclear Plant (WNP) 1, 2, and 4, are located on the Department of Energy's (DOE) Hanford Reservation near Richland, Washington. WNP-2 was completed in 1984 and is in operation. However, WNP-1 and 4 have not been completed because of a decrease in the need for electrical power and financial difficulty. WNP-4 was terminated in January 1982, when it was 24-percent complete, and is being salvaged. In April 1982, WNP-1 was placed in an extended delay when construction was 63-percent complete. The Supply System, expecting to complete the plant in the future, has maintained the plant and kept its construction permit current with the Nuclear Regulatory Commission (NRC).

In 1982, the Secretary of Energy created a panel of experts to provide recommendations on a new reactor for producing tritium, a material used in nuclear weapons. This panel was named the "Glennan panel," after its chairman, T. Keith Glennan. The panel was asked to provide recommendations on what type of reactor might be used, and where it might be located. The panel examined the conversion of WNP-4, but not WNP-1. The final report recommended a heavy water reactor sited at DOE's Savannah River Plant in South Carolina. The panel believed that this type of reactor provided the greatest assurance of meeting production goals.

In August 1986, DOE created a technical task force to examine the feasibility of acquiring and completing WNP-1 or 4 for defense production purposes. The task force issued its report in March 1987, entitled Technical Feasibility Task Force WNP-1 Conversion Preinvestment Analysis Report (Technical Feasibility Report). It found that material was already being salvaged from WNP-4 and concluded that because the general condition was poor and key equipment had been sold, WNP-4 should not be studied further. With respect to WNP-1, the study concluded that the reactor could be modified and that associated support facilities could be made available at a cost and schedule appropriate to DOE's requirements. Completion of the electrical generating facilities is also planned so that electricity could be coproduced.

In January 1988, the Secretary of Energy established a site evaluation team made up of DOE officials to evaluate several DOE sites for suitability for a new production reactor. At that time, he also requested the Energy Research Advisory Board (Advisory Board), an independent peer review board, to evaluate four candidate technologies for a new reactor. The Advisory Board's study also included examining the option of completing WNP-1 as a defense production reactor. The site evaluation team found all three sites that it studied—Hanford, Washington; Idaho Falls, Idaho; and Savannah River, South Carolina—acceptable for a new production reactor. The final report by the Advisory Board concluded that the heavy water reactor has the most mature technology for tritium production and presents the least schedule risk because of the existing facilities, personnel, and experience at Savannah River. The report also pointed out that WNP-1 is a unique option that offers the possibility of a shorter schedule and lower initial cost.

On August 3, 1988, the Secretary of Energy recommended that two reactors be constructed at separate locations. He recommended a heavy water reactor at DOE's Savannah River Plant in South Carolina and a high-temperature, gas-cooled reactor at Idaho National Engineering Laboratory in Idaho. In addition, as a contingency, the Secretary stated that research and development should continue on the light water reactor option (WNP-1) and that work should continue on solving any institutional problems associated with its completion.

Overcoming Design Problems

The WNP-1 reactor is a pressurized light water reactor designed by the Babcock & Wilcox Company. The Babcock & Wilcox Owners Group, an organization of owners of Babcock & Wilcox-designed reactors, has proposed 215 recommendations for increasing the level of plant safety in Babcock & Wilcox-designed reactors. Representative Sid Morrison asked us to determine if the proposed completion of the WNP-1 reactor will adequately address the Babcock & Wilcox Owners Group recommendations.

Concerns about the safety of Babcock & Wilcox-designed reactors have also been raised by the Union of Concerned Scientists and NRC. While conducting our work on the Babcock & Wilcox Owners Group recommendations, we also determined (1) if the unique Babcock & Wilcox design features identified by the Union of Concerned Scientists will cause potential safety problems for the WNP-1 reactor and (2) if the pressurized light water reactor safety issues identified by NRC will cause potential safety problems for the WNP-1 reactor.

In brief, we found that the Supply System has conducted a preliminary review of the Babcock & Wilcox Owners Group recommendations and a number of these concerned design issues which may apply to WNP-1. However, the Supply System has deferred action until after reactor construction resumes. In addition, we found that two areas of concern associated with the WNP-1 reactor have yet to be resolved, specifically,

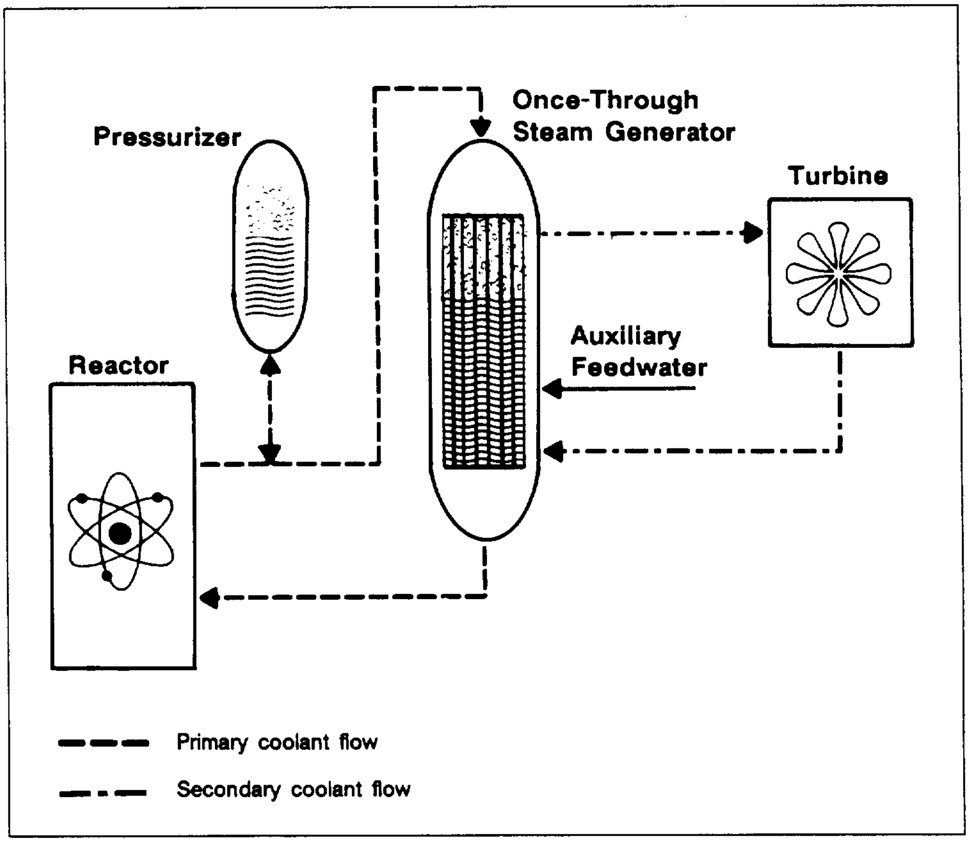
- of five Babcock & Wilcox design features questioned by the Union of Concerned Scientists, four have been resolved for WNP-1 through design changes and the fifth is planned for modification during completion of the reactor and
- two safety issues raised by NRC, which are applicable to all pressurized light water reactors, have not been resolved completely for WNP-1.

Babcock & Wilcox Pressurized Light Water Reactors

Counting the WNP-1 reactor, there are 11 pressurized light water reactors designed by Babcock & Wilcox in the United States. Eight of them are currently in operation for electric power production. Two others are being built for the Tennessee Valley Authority for electric power production also. The two reactors under construction, along with the WNP-1 reactor, are the newer (205) design, while the other eight are of the earlier (177) design.

Like the other Babcock & Wilcox reactors, the WNP-1 reactor was originally designed to produce steam for generating electricity. Figure 2.1 shows the basic components of the reactor.

Figure 2.1: Basic Design of the Babcock & Wilcox Pressurized Light Water Reactor



Source: Westinghouse Hanford Corporation.

Steam is ultimately produced in Babcock & Wilcox reactors from the heat released by uranium fuel rods in the reactors' core. The heat given off from the nuclear reaction occurring in the fuel rods is first passed through the pressurized water in the primary coolant system to a steam generator. There, the heat from the primary coolant is passed to the secondary coolant water, which turns to steam. The steam turns a turbine, which in turn rotates a generator producing electric power. An auxiliary feedwater system provides an additional source of coolant if the normal secondary coolant flow is interrupted.

Babcock & Wilcox Owners Group Recommendations

In response to the accident at the Three Mile Island reactor, owners of nuclear power plants in the United States made improvements in their facilities. However, NRC was concerned that despite these improvements, the number and complexity of events in plants with reactors designed by Babcock & Wilcox had not decreased as expected. Consequently, in a January 1986 letter, the NRC Executive Director for Operations informed the chairman of the Babcock & Wilcox Owners Group that the number of these events led NRC to conclude that the basic design requirements for Babcock & Wilcox reactors needed to be reexamined.

In February 1986, the Babcock & Wilcox Owners Group began evaluating ways to reduce the frequency of overcooling and overheating events in Babcock & Wilcox plants. The objectives of the evaluation were to (1) reassess the basic design requirements of Babcock & Wilcox plants, (2) reassess the operational characteristics of Babcock & Wilcox plants, and (3) compare the overall safety of Babcock & Wilcox plants with the safety of other pressurized light water reactors. Based on the results of its evaluation, the Babcock & Wilcox Owners Group identified 215 recommendations for improving the operation and safety of Babcock & Wilcox-designed reactors.

The Supply System conducted a preliminary review of the 215 Babcock & Wilcox Owners Group recommendations to determine which ones are applicable to the WNP-1 reactor. On the basis of its review, the Supply System determined that

- 2 of the recommendations have been superceded and do not apply to WNP-1;
- 41 of the recommendations apply to specific reactors other than WNP-1;
- 65 of the recommendations concern reactor operation and administration issues which do apply to WNP-1 and which will be incorporated into the operating, training, and safety manuals;
- 107 of the recommendations concern technical issues, such as the integrated control system, which may apply to WNP-1.

In a June 1988 letter to the NRC, the Supply System stated that because of the mothballed status of the WNP-1 reactor, implementation of the Babcock & Wilcox Owners Group recommendations will be deferred until after reactor construction resumes. According to the Supply System, after construction resumes, it will develop a schedule, compatible with the NRC licensing process, for resolving the applicable Babcock & Wilcox Owners Group recommendations.

To alleviate DOE concern about the applicability of the Babcock & Wilcox Owners Group recommendations to WNP-1 as a new production reactor, Westinghouse Hanford Company (Westinghouse) requested that one of its subcontractors conduct a detailed evaluation of each one of the 215 recommendations to determine which apply specifically to WNP-1. The subcontractor will determine what WNP-1 modifications, including equipment requirements, may be needed in response to each specific recommendation. According to the subcontractor, the detailed evaluation is essentially complete, and no significant WNP-1 impact has been identified beyond the already planned incorporation of the advanced control system to replace the integrated control system. However, it is expected that minor instrument and control changes to the feedwater system may be necessary and a few minor changes may be required in the plant instrument air system—a system for supplying compressed air to control valves throughout the plant. The subcontractor plans to complete documenting his detailed evaluation by September 1988.

Issues Raised by Union of Concerned Scientists

On February 10, 1987, the Union of Concerned Scientists submitted a petition to NRC regarding Babcock & Wilcox-designed reactors. The petition, which was also signed by a number of citizens groups, environmental organizations, and private citizens, asked NRC to take immediate action to relieve what it called "undue risks" to public health and safety posed by the operation of the reactors. According to the petition, five design features intended to make Babcock & Wilcox reactors more efficient than other pressurized light water reactors also make them more dangerous. These five features, discussed in detail below, were intended to make the reactors better able to respond to changes in electrical demand and to be more efficient in converting heat to electricity. The petition alleged that these features also made the reactors more sensitive to variations in operating conditions and equipment malfunctions. The five design features are the (1) once-through steam generators, (2) reactor pressurizer, (3) auxiliary feedwater system, (4) integrated control system, and (5) non-nuclear instrumentation system.

NRC concluded that the design concerns identified in the petition are not substantial health and safety issues. In a response on October 19, 1987, NRC declined to take action because

- substantive improvements have been made to Babcock & Wilcox-designed reactors,
- owners of Babcock & Wilcox-designed reactors are continuing to make improvements to their reactors,

- no new significant generic safety problems have been identified to date by the NRC staff in the ongoing reassessment of Babcock & Wilcox-designed reactors, and
- the petition did not present any substantial health or safety questions associated with the operation or construction of Babcock & Wilcox-designed reactors that would be resolved by granting the relief requested.

In examining the applicability of the five design issues raised by the Union of Concerned Scientists to the WNP-1 reactor, we found that actions have been taken to prevent these issues from affecting safe operation of the WNP-1 reactor. Four of the design features in question were modified by Babcock & Wilcox as part of the newer 205 design or have already been incorporated in the WNP-1 reactor as now constructed, and the Supply System has included in the reactor design a modification for the remaining feature.

Once-Through Steam Generators

All pressurized light water reactors have steam generators which use the heat from the nuclear reaction to make steam for generating electricity. In the steam generators, the primary coolant that circulates through the reactor itself passes through tubes heating other water (called feedwater) that flows over the outside of the tubes. The heat from the primary coolant changes the feedwater to steam, which then passes to the turbine. This steam, after turning the turbine, is condensed back to water and recirculated to the steam generators. This transfer of heat to the feedwater reduces the temperature of the primary coolant, which circulates again to the reactor. In this way, the feedwater in the steam generators both transfers energy to the turbine and serves to cool the primary reactor coolant and, thereby, the reactor core.

Although completion of the WNP-1 reactor as a tritium production facility will have a different primary purpose than electric power generation, it will still have a steam-driven turbine capable of turning a generator for producing electric power. Also, plans are to add another condenser so that, if desired, the reactor can be operated by condensing all the steam without passing it through the turbine to generate electric power. However, in either mode of operation, the transfer of heat from the primary coolant to the feedwater to produce steam is an essential feature of the system that cools this type of reactor. This passage of heat from the reactor to the feedwater to make steam takes place in the steam generators.

Babcock & Wilcox reactors have once-through steam generators, whereas the other manufacturers of pressurized light water reactors use recirculating-type steam generators. The once-through steam generators allow the reactor to respond more quickly to changing conditions in the turbine, generator, and feedwater systems. This is an advantage for most situations in that it allows the plant to quickly accommodate changing power load demand and various system malfunctions. However, it also makes the temperature and pressure of the primary coolant more sensitive to changes in the flow of feedwater and steam. In addition, the volume of feedwater in the secondary side of the steam generators is much less than in the steam generators used in other pressurized light water reactors.

The petition alleged that because of the small volume of feedwater in the steam generators, even a small change in flow into the once-through steam generator (referred to as "feedwater flow") can affect the height to which feedwater covers the tubes inside the generator. Changes in this water level can affect the temperature in the reactor because heat transfer is highest in the portion of the tubes covered with feedwater. Thus, according to the petition, a change in feedwater flow to the once-through steam generators may result in a large, rapid change in the temperature of the reactor-cooling system.

Early in the construction of WNP-1, the Supply System recognized the potential for the primary cooling system to heat up or cool down faster than desired in some circumstances. The Supply System made a number of changes to the reactor to eliminate this problem. For example, the Supply System

- provided increased control of both the main and auxiliary feedwater flowing to the steam generators and steam leaving the steam generators to prevent overcooling of the primary cooling system,
- changed the reactor's control system and the auxiliary feedwater system to prevent overheating of the primary cooling system as a result of disturbances in the flow of the secondary cooling system, and
- changed a number of other areas to make the plant less sensitive to equipment malfunctions that could lead to overcooling or overheating situations.

Babcock & Wilcox evaluated the changes the Supply System made to the WNP-1 reactor to determine if the changes would be effective in reducing the frequency and magnitude of overcooling and overheating events and would not affect reactor operability. According to the Supply System, the Babcock & Wilcox analysis demonstrated that the WNP-1 changes resolved all of the sensitivity issues related to interruptions in the steam and feedwater flows experienced by the once-through steam generators.

Reactor Pressurizer

The Babcock & Wilcox reactor pressurizer is connected to the primary cooling system. The main purposes of the pressurizer are to:

- Pressurize the primary cooling system to prevent boiling elsewhere in the system. The pressurizer does this by maintaining a higher internal temperature in the pressurizer than elsewhere in the primary cooling system. This produces a steam bubble in the pressurizer, which pressurizes the primary cooling system.
- Provide information on the amount of water in the primary cooling system to the reactor operator and to the primary coolant makeup system so it can make automatic flow adjustments.
- Serve as a location for mounting the primary cooling system safety and relief valves. These valves release excessive pressure from the pressurizer during abnormal operation.

According to the petition, pressurizers in Babcock & Wilcox reactors are relatively small compared with those in other pressurized light water reactors and, as such, are likely to experience larger changes in water level and pressure if the temperature changes in the primary cooling system. Small pressurizers cannot accommodate changes in primary coolant temperature as easily as large pressurizers can. The petition states that the combination of the once-through steam generator design and the small pressurizer makes reactor temperature and pressure in a Babcock & Wilcox reactor extremely sensitive to a change in feedwater flow.

According to a Westinghouse subcontractor, reports prepared for evaluating WNP-1 as a new production reactor state that the pressurizer concerns are not applicable to the WNP-1 reactor for the following three reasons:

- Babcock & Wilcox reactors of the 205 design—including WNP-1—have the largest reactor pressurizers in the United States in terms of both absolute and relative volume. The 2,250-cubic foot volume of the WNP-1 pressurizer is 25-percent greater than the volume of the largest Combustion Engineering and Westinghouse[1] pressurizers and 50-percent greater than the pressurizer volumes on the operating Babcock & Wilcox plants of the 177 design. In terms of their relative volume, the ratio of the primary cooling system-to-pressurizer volume in WNP-1 and the other plants of the 205 design is 5.24—the most favorable ratio of any pressurized light water reactor in the United States.

- In most of the overcooling events at operating Babcock & Wilcox-designed reactors, the problem was mainly that the water level dropped below the lowest point measured by the level meter, not that the pressurizer itself was empty. In the WNP-1 reactor, the lowest point measured by the level meter is near the bottom of the pressurizer. This was not the case for the operating 177 design Babcock & Wilcox reactors.
- In 1984, Babcock & Wilcox evaluated the response of WNP-1 to various postulated reactor problems. The studies showed that for all of the realistic and moderate frequency events analyzed, the pressurizer level indication for WNP-1 remained on scale. Consequently, the pressurizer would not completely drain or fill, and the operator would always have an accurate indication of the amount of water in the primary cooling system.

Auxiliary Feedwater System

The auxiliary feedwater system provides a back-up source of water for the once-through steam generators. If the flow of water in the secondary cooling system were insufficient to remove the heat from the primary coolant, the reactor would shut down and the auxiliary feedwater system would begin to provide flow to the steam generators. This situation could happen, for example, if all electrical power to the main feedwater system pumps were lost.

The petition said that NRC originally classified the Babcock & Wilcox-designed reactor auxiliary feedwater system as a "non-safety" system rather than a "safety" system. A non-safety system is not designed to comply with the higher reliability standards that NRC sets for those parts of the nuclear plant affecting its safe operation. A safety system, on the other hand, meets these higher standards. The petition said that the auxiliary feedwater system and the instrumentation used to initiate and control its operation must be highly reliable because the once-through steam generators, about which it was already concerned, are the primary means of removing heat from the reactor cooling system.

[1]There are only three designers of pressurized light water reactors in the United States: Babcock & Wilcox, Combustion Engineering, and Westinghouse Electric Corporation.

According to a Westinghouse subcontractor, documentation for the WNP-1 reactor indicates that the reactor's auxiliary feedwater system meets the higher safety-system standard without exception. The subcontractor told us that the reactor's auxiliary feedwater system and controls are safety grade and meet NRC's reliability standards. Specifically:

- Three different Supply System studies have found that the auxiliary feedwater system is reliable and that it meets all NRC requirements for safety grade and reliability.
- The WNP-1 auxiliary feedwater system includes a single 100-percent capacity, steam-driven pump and two 50-percent capacity, motor-driven pumps. These pumps are capable of moving the auxiliary feedwater through the once-through steam generators and removing heat from the primary cooling system if electrical power to the main feedwater system pumps is lost. In addition, for WNP-1 as a new production reactor, a second 100-percent capacity, steam-driven pump is to be installed, thereby having one steam-driven pump and one motor-driven pump for each of the two steam generators.
- The primary water source for the auxiliary feedwater system is a safety-grade demineralized water storage tank that has an assured capacity of 330,000 gallons. A second water source is a non-safety-grade condensate storage tank that also has 330,000 gallons. The auxiliary feedwater system can also be cross-connected to the safety-grade ultimate heat sink spray pond that contains a minimum of 13 million gallons.

Integrated Control System

The integrated control system in a Babcock & Wilcox-designed reactor uses inputs received from many sensors throughout the plant to control the amount of power the reactor produces. The system has been accepted as a non-safety system by NRC. It controls such equipment as the main feedwater system, the main turbine throttle and bypass valves, and the reactor control rods. The petition stated that failures originating in either the integrated control system or its electrical power supplies can produce severe over- or undercooling by causing the equipment it controls to malfunction.

The integrated control system will be replaced in the WNP-1 reactor. Studies conducted by the Babcock & Wilcox Owners Group, which we previously discussed in detail in this appendix, addressed the integrated control system's limited capability to detect and reject invalid input from its various sensors and its vulnerability to power supply failures. As a result of these and previous studies, the system will be replaced in the WNP-1 reactor with an advanced control system. It will be a digital system, allowing changes that are impractical with the current integrated control system.

The advanced control system is intended to have improved reliability, back-up control systems, and the ability to detect and reject invalid input signals. In a recently completed Babcock & Wilcox test of an advanced control system connected to a Babcock & Wilcox reactor simulator, the viability of this concept was demonstrated.

Non-Nuclear Instrumentation System

The non-nuclear instrumentation system in a Babcock & Wilcox-designed reactor is a non-safety system that provides information to the control room operators, the integrated control system, and the plant computer. The information it provides includes the temperature, pressure, and flow of the primary coolant, feedwater, and main steam. The petition alleged that failures in the non-nuclear instrumentation system or in its electrical power supplies could have a widespread adverse effect. Such failures could send false information to the integrated control system, which in turn would direct the reactor to respond as if the signals represented actual conditions.

The WNP-1 is provided with a fully safety-grade and redundant essential controls and instrumentation system, which operating Babcock & Wilcox-designed reactors do not have. According to a Westinghouse subcontractor, the essential controls and instrumentation system will prevent the complete loss of critical control room displays at a time when the information is needed most. It consists of duplicate assemblies having redundant indications and controls. Each assembly is associated with a separate instrument panel and power source. The two power sources for the assemblies are also separate from the power source for the non-nuclear instrumentation system. The non-nuclear instrumentation system will also be less critical to the performance of the advanced control system because of the ability of the advanced control system to recognize and reject invalid input signals.

Issues Raised by NRC

According to a Westinghouse subcontractor, NRC reported on the status of unresolved safety issues generic to all pressurized light water reactors in its 1986 annual report. The two major issues were decay heat removal and station blackout. These two issues apply to the WNP-1 reactor. At the time of our review, they had not been resolved completely. As a result, they remain potential safety problems.

Decay Heat Removal

The heat generated in the reactor core after the reactor is shut down is called "decay heat." Removing this heat is necessary to avoid damaging the reactor core. The most significant aspect of the decay heat removal issue, according to the nuclear industry, is whether independent and dedicated safety-grade decay heat removal systems must (1) be added to existing reactors and (2) be required for new reactors to provide adequate assurance that nuclear plants do not pose unacceptable risks. An independent and dedicated decay heat removal system has its own source of power, is used only for the removal of decay heat, and is physically separated. According to a Westinghouse subcontractor, NRC's Division of Research and the Advisory Committee on Reactor Safeguards recommended in January 1988 that the resolution of the decay heat removal issue be included with the risk assessments for each specific reactor.

Although the WNP-1 reactor has an independent safety-grade decay heat removal system, decay heat removal is an unresolved safety issue because the existing system is not dedicated solely for the removal of decay heat. However, given the recent NRC direction of including this concern with the individual plant risk assessments, and considering the fully safety-grade design of the existing WNP-1 decay heat removal system, a Westinghouse subcontractor believes the probability of having to add a dedicated decay heat removal system to WNP-1 is very low.

Station Blackout

In the postulated condition called "station blackout," all alternating current power to the reactor would be lost. To produce this condition, a number of systems would have to fail. These include the plant's connections to its regular sources of power, its main generator, and its emergency alternating current generators.

In June 1988, NRC issued its ruling on station blackout. The ruling required that all plants have the equipment on-site and capable of coping with station blackout for periods of up to 8 hours.

The main concern related to station blackout has been addressed for the WNP-1 reactor. For pressurized light water reactors, an NRC concern was that the pump seals for the reactors' primary coolant system will fail, resulting in a leak of primary coolant that will be hard to stop. For WNP-1, a backup seal injection pump driven by a small dedicated diesel motor is planned to be installed.

Two other station blackout concerns remained to be resolved for WNP-1. These concerns were (1) cooling the various rooms in the building with no electrical power available to run the rooms' cooling systems and (2) the capacity of the plant's batteries. The Supply System did not see these as significant risks toWNP-1. For station blackout, the temperature in the rooms would be low, and much of the equipment is already designed for high temperatures. The WNP-1 batteries probably would not last for 4 hours, but portable backup generators can be used to provide additional capacity.

A subcontractor for Westinghouse performed a preliminary review of NRC's ruling and compared it with the design of WNP-1 as a new materials production reactor. The subcontractor has concluded that no significant changes to the plant design would be required to meet this new ruling.

Resolving Technical Issues

Several concerns have been raised about technical issues related to the completion of the WNP-1 reactor as a tritium production facility. In its March 1987 Technical Feasibility Report, DOE said the WNP-1 reactor would be able to produce the requisite amount of tritium needed. However, the same report also said $75 million in research and development funds would be needed to resolve safety issues, $55 million in research and development funds would be needed to develop the technology for the tritium target pins to be used inside the reactor, and completion of the WNP-1 reactor as a tritium production plant would require modifications to the reactor's core. In addition, there is concern that modifications to the reactor may result in significantly increasing the possibility of an accident.

During our review, we addressed the technical issues associated with completing the WNP-1 reactor as a tritium production plant. Specifically, we determined if

- the technical issues related to the safety of converting the WNP-1 reactor are known;
- DOE currently possesses the technology to produce goal-established quantities of tritium in a pressurized light water reactor and, in particular, in WNP-1;
- the production of tritium in the WNP-1 reactor will result in a dramatically different core configuration and demands on the plant's control and safety system than those originally conceived by Babcock & Wilcox, when it designed the plant, and NRC, when it issued a construction permit for the reactor; and
- a Probabilistic Risk Assessment has been developed for the WNP-1 reactor as a tritium production plant.

We found two unresolved technical issues associated with completing the WNP-1 reactor. First, the issue of whether the reactor will be able to produce goal-established amounts of tritium has not been fully resolved. Second, a quantification of the probabilities of potential accidents and their consequences if tritium is produced in the WNP-1 reactor has not been prepared.

To produce tritium in the WNP-1 reactor, the reactor needs a fuel core that differs from the core used to produce electricity alone. Tritium production requires the irradiation of two materials in the reactor core—uranium and lithium. In a nuclear reaction, the radioactive uranium emits neutrons, which lithium can absorb to produce tritium. The uranium is contained in fuel rods, and the lithium is contained in target pins. The WNP-1 core will need to be redesigned to accommodate the uranium fuel rods and lithium target pins.

As part of the redesigned fuel core, a tritium-producing WNP-1 reactor will need a higher enrichment, or fissionable fraction, of uranium in the fuel rods than if it were to be a strictly electricity-producing reactor. Electricity-producing reactors can operate on uranium that is perhaps 3- to 4-percent enriched in its fissionable component, namely uranium 235. By comparison, the WNP-1 reactor will use uranium in the redesigned core that is 10-percent enriched.

Safety-Related Technical Issues

DOE officials based the safety-related technical conclusions of the March 1987 Technical Feasibility Report on studies by several DOE contractors. They concluded that any changes made to the design of the WNP-1 reactor for tritium production would be technically feasible. However, because the contractors were uncertain about the extent of the design or testing effort needed to demonstrate that the technical modifications to the reactor would be safe, DOE added an allowance of $75 million to the WNP-1 completion cost estimate in the Technical Feasibility Report to resolve any safety concerns.

Purpose of the $75 Million Request for Safety Studies

The $75 million identified in the Technical Feasibility Report was designated primarily for studies of recriticality, the only new safety issue involved with completing WNP-1 as a tritium production reactor. Recriticality is a condition that, on a rare occurrence, can result in an extremely severe accident. If the nuclear fuel inside a reactor becomes too hot—for example, if it overheats because the flow of coolant in the cooling system is interrupted—it may melt or slump into a shape in which the nuclear reaction restarts but is no longer controlled by the reactor's control system. While DOE officials contend that such an accident would not breach containment, they have not done calculations which provide full support for this conclusion.

In March 1988, in its latest cost estimate for completing the WNP-1 reactor as a tritium production plant, DOE eliminated the $75 million allowance. It did so on the grounds that the safety problems associated with recriticality were resolved by redesigning the reactor's core. In DOE's view, the uranium fuel in the redesigned core would not be subject to recriticality even under the most severe accident conditions. The redesign involved reducing the diameter of the uranium fuel rods in the reactor core, increasing the amount of water in the core, and reducing the concentration of fissionable uranium in the fuel rods. These changes worked as follows:

- Tritium is made in a nuclear reactor basically by the absorption of neutrons in lithium, a substance that turns to tritium when it absorbs the neutrons. The neutrons in the reactor are produced during the splitting of fissionable uranium atoms contained in fuel rods in the reactor core; the lithium is contained in target pins also present in the core. Water in the core acts as a coolant and also slows the speed of the neutrons, allowing the lithium to absorb them.
- By reducing the diameter of the enriched uranium fuel pins from 0.379 inches to 0.270 inches, the volume of water in the core was increased in the new design. The increased volume of water slows down a higher number of neutrons released by the enriched uranium fuel in the reactor, making the absorption of neutrons by the lithium more efficient.
- The increased efficiency allowed the reactor to operate with fuel rods that had a lower level of enrichment in the fissionable form of uranium, namely uranium 235. In the original design of the reactor, the uranium in the fuel rods had to be enriched to the point where the fissionable uranium was 20 percent of the total, compared with less than 1 percent in naturally occurring uranium. Under the redesign, the 20-percent enrichment was reduced to 10 percent.

Westinghouse concluded that fuel rods containing 10-percent enriched uranium would not subject the WNP-1 reactor to recriticality. Our consultant examined the redesigned core and concluded, on the basis of data and models available, that the possibility of recriticality would be virtually nil at the 10-percent enriched uranium fuel level.

Production-Related Technical Issues

The issue of whether the WNP-1 reactor will be able to produce goal-established amounts of tritium has not been fully resolved. Westinghouse believes that tritium production goals can be achieved using 10-percent enriched uranium fuel if a tritium target pin can be successfully designed and manufactured.

The key issue with respect to tritium production in the WNP-1 reactor is whether target pins can be designed and manufactured that will retain their structural integrity and hold the tritium during the production process. The core will contain approximately 13,000 tritium target pins. The quality of the manufacturing process used to make these pins must be extremely high to ensure the structural integrity of the target pins and avoid the loss of tritium from defective pins.

Westinghouse is currently developing two tritium target pin designs—a reference pin, which is the preferred design, and an alternate pin to be used if the reference pin design is unsuccessful. Westinghouse has completed the basic research and development on the technology for the reference target pin and has demonstrated its feasibility. The remaining engineering task is to show that defect-free pins capable of withstanding the conditions in the WNP-1 reactor core can be manufactured.

Purpose of the $55 Million Request for Development of Tritium Target Technology

The $55 million identified in the Technical Feasibility Report is to be used for the following:

- Designing a prototype of the reference target pin for the WNP-1 reactor.
- Verifying the manufacturing parameters and procedures for the reference target pin to ensure that it will function in the WNP-1 reactor.
- Conducting reactor-scale irradiation tests of the reference target pins to ensure that they will not leak in the WNP-1 reactor.
- Verifying the extraction process parameters to ensure that tritium can be extracted from the WNP-1 reference target pin successfully.

These tasks probably cannot be completed—and the issue of whether the reference target pin will work probably cannot be resolved—until full-scale manufacturing and testing of the thousands of target pins required have been under way for some time. As part of the irradiation testing, Westinghouse plans to test a relatively small number of target pins in DOE's Advanced Test Reactor at the Idaho National Engineering Laboratory to determine whether leaks occur. However, testing even a few hundred target pins will only confirm that there are no gross deficiencies in the hardware versions of the final design. It will not demonstrate that 13,000 pins can be produced virtually defect-free. Component tests and a quality assurance program, according to Westinghouse, are planned as a part of the manufacturing process to increase confidence that the pins can be successfully manufactured on a large scale.

The WNP-1 completion schedule calls for completing manufacture of the first core loading of target pins 63 months after receiving authorization to proceed with WNP-1 acquisition. However, a critical point in the qualification program is reached at 42 months after authorization when a decision is made to select either the reference target pin design or the alternate pin design. Manufacture of the first target pins—either the reference or the alternate—must begin at this time in order to maintain the schedule for reactor start-up. A demonstration radiation test program would continue after this decision has been made. However, if problems arise during this demonstration program, there will not be time to correct the problems and run new confirming radiation tests without delaying reactor start-up beyond the 6-year schedule.

If, after 42 months the target pin development program has not clearly indicated that the reference design can be used in manufacturing the first core loading of target pins, the alternate target pin design will be chosen. The alternate target pin design, which involves encapsulating the lithium target material in aluminum, was used successfully to produce tritium in DOE's N-Reactor from 1966 to 1968. Britain has also used it successfully. However, the alternative pin has several potential drawbacks:

- The aluminum cladding melts at a relatively low temperature and may form low-temperature aluminum-iron mixtures, raising safety questions about tritium releases and lithium relocation in an accident situation.
- Limitations on the ability of the aluminum cladding to withstand the high gas pressures developed inside the target pins mean that the reactor may have to shut down more frequently for target pin replacement.
- The aluminum cladding would occupy more volume inside the pin, reducing the space available for the lithium target material.
- Westinghouse estimates that use of the alternate target pin technology would somewhat reduce the tritium yield, but that production would reach more than 90 percent of the WNP-1 tritium goal.

Westinghouse is evaluating the significance of the potential drawbacks associated with using the alternate target pin design in the WNP-1 reactor to (1) determine if problems actually exist with the design, (2) identify what can be done to eliminate any problems encountered, and (3) increase the amount of tritium produced with the alternate pin. The preliminary results of this study are expected to be available by October 1988.

The cost of developing the WNP-1 target pin remains an issue. As of May 1988, Westinghouse estimated that it will cost $66 million to develop the reference target pin. However, it now estimates that additional testing of the reference target pin may raise the cost to $119 million, and developing and testing the alternate target pin may raise the total cost to as much as $159 million.

The process for extracting tritium from irradiated target pins has been demonstrated in the Savannah River and N-Reactor tritium production programs. The same basic extraction process is planned to be used with the WNP-1 reference and alternate target pin designs using the Fuels and Materials Examination Facility at Hanford.

Other Core Configuration Changes

The Technical Feasibility Report identified a number of changes that will have to be made to the WNP-1 reactor core to complete it as a tritium production facility. According to Westinghouse, the major change will be the installation of new fuel assemblies containing enriched uranium fuel rods and tritium target pins. The issues associated with the installation of enriched uranium fuel rods and tritium target pins were discussed earlier in this appendix. In addition, other modifications will be made to the core including installing (1) a new plenum assembly, (2) additional or new control rod drives, and (3) equipment for handling the fuel assemblies.

According to the Richland Operations Office, the new core design will not affect the WNP-1 reactor control and safety systems because the new core is designed to stay within the capabilities of the reactor's existing control and safety systems. The results of the November 1987 WNP-1 Core Optimization for Tritium Production Study, prepared by Hanford Contractors, states that the redesigned core will

- not introduce new safety issues,
- utilize proven technologies,
- use proven pressurized light water reactor fuel materials and fuel pin design approaches, and
- use fuel assembly technology that remains consistent with current commercial reactor practices.

Our consultant reviewed the WNP-1 core configuration changes associated with completion of the reactor as a tritium production plant. Except as discussed earlier in this appendix, he is of the opinion that the alterations will not introduce new safety issues that could not be handled by the plant's safety systems.

Probabilistic Risk Assessment Not Completed

A Probabilistic Risk Assessment—a method of quantifying the probabilities of potential accidents and their consequences—has not been prepared for completion of the WNP-1 reactor as a new production facility. However, according to Westinghouse, to satisfy NRC's reactor accident and safety concerns, a Probabilistic Risk Assessment, including sensitivity studies, will be developed for the WNP-1 reactor at an estimated cost of $5 million once all design modifications to upgrade safety and reliability have been made and other modifications to complete the WNP-1 reactor as a production facility are finalized. The Probabilistic Risk Assessment will evaluate all WNP-1 design modifications and the impacts on them from internal events such as a loss of coolant accident and from such external events as fire, flooding, and seismic activity.

Ensuring Licensability

DOE materials production reactors are not licensed by NRC. However, there is considerable interest within the Congress and the scientific community in ensuring that DOE receives external and independent reviews of its reactor safety decisions of the type regularly obtained in the commercial reactor industry for all of its nuclear facilities. In the commercial reactor industry, much of this external and independent review takes place during the licensing process.

With regard to the licensability of WNP-1, Representative Morrison asked us to

- determine if the WNP-1 reactor could be completed to licensable standards and if the licensing requirements have been documented and maintained and
- determine if the proposed completion would be consistent with the recent National Academy of Sciences (Academy) recommendations for future DOE materials production reactors.

Closely linked to Representative Morrison's questions are recommendations we made for ensuring the safe operation of DOE's nuclear facilities.

Compliance With NRC Licensing Standards

In October 1987, a Westinghouse subcontractor completed an evaluation of all the NRC technical, safety, and licensing issues associated with completing WNP-1 as a production reactor. The subcontractor concluded that completion of the reactor would meet NRC safety and licensing standards. In addition, Westinghouse believes completion of WNP-1 will comply with NRC's safety and licensing standards for the following reasons:

- At the time construction of the WNP-1 reactor was deferred in May 1982, the Supply System had submitted a final safety analysis report and an environmental report to NRC for approval as part of the reactor's operating license application process.
- Design and safety concerns raised by NRC and the Union of Concerned Scientists had been assessed, and the Babcock & Wilcox Owners Group concerns are being evaluated. (See app. II for a discussion of these concerns.)
- The Supply System had maintained a quality assurance program and a preservation program to ensure performance of those activities necessary to preserve the WNP-1 construction permit and the ability to obtain an operating license for the reactor.

NRC has found that the Supply System is maintaining the WNP-1 reactor in a way that meets NRC's licensing standards. In a May 3, 1985, letter to the Supply System, NRC stated that implementation of the quality assurance and preservation programs has maintained the licensability of the WNP-1 reactor. The letter stated further that if those programs are implemented effectively, the long-term potential licensability of the WNP-1 reactor in terms of preserving structures, equipment, and records can be maintained. NRC's most recent inspection of the quality assurance and preservation programs, completed in October 1987, disclosed no violations or deviations in the Supply System's implementation of the programs.

According to the Advisory Board, pressurized light water reactors, such as WNP-1, incorporate the most mature and widely used nuclear technology for commercial nuclear reactors. This includes extensive experience in the licensing process. According to the Advisory Board,

- the safety-related information available on light water reactors has expanded considerably;
- the safety review process for light water reactors is well established;
- the WNP-1 reactor is similar to the commercial designs being reviewed by NRC; and
- with proper design and a sound safety review process, a light water reactor production facility can provide a level of safety that is at least equivalent to that of the best commercial power reactors.

We cannot say for certain that completion of the WNP-1 reactor as a production facility will meet NRC's licensing standards. The licensing standards, for example, require that commercial reactors be able to comply with NRC's policy statements on severe accidents and safety goals. Compliance with those policy statements will not be addressed until the reactor design is completed and the Probabilistic Risk Assessment, as discussed in appendix III, is developed.

Prior Recommendations Made by the National Academy of Sciences and GAO

Shortly after the April 1986 nuclear accident at the Chernobyl Nuclear Power Station in the Soviet Union, the Secretary of Energy requested that the Academy provide an independent assessment of the implications of the accident for the safe operation of DOE's large production reactors. The assessment focused on the DOE safety framework, technical issues, and reactor management associated with the safe operation of defense production reactors. According to the Academy's assessment, to ensure safe operation of production reactors, DOE must (1) develop and use methods and analytical techniques that are at least comparable in technical sophistication to those used within the commercial nuclear industry and (2) receive external and independent review of its reactor safety decisions of the type regularly obtained in the commercial reactor industry.

The Academy concluded that DOE is not receiving external and independent review of its reactor safety decisions of the type regularly obtained in the commercial reactor industry because no organization within or associated with DOE (1) exercises reactor safety responsibilities analogous to those of the Advisory Committee on Reactor Safeguards or (2) reviews reactor operations in a manner similar to that exercised by the Institute of Nuclear Power Operators for commercial reactors. In addition, the Academy concluded that DOE has made little use of the services of independent safety review committees such as those employed routinely by individual utilities to examine safety issues at commercial reactors.

We have a long history of supporting the need for independent oversight of the various aspects, including reactor safety, of DOE nuclear facilities. In testimony before the Congress in June 1987, we reiterated our position that DOE needs independent oversight of various aspects of its nuclear activities. In that testimony, we set forth five key elements that should be incorporated into any oversight approach. These are (1) independence, (2) technical expertise, (3) the ability to perform reviews of facilities as needed, (4) clear authority to require DOE to address the organization's findings and recommendations, and (5) a system to provide public access to the organization's findings and recommendations. We believe that these elements serve as useful criteria for DOE to follow when establishing an external and independent review committee for evaluating the safety of a new production reactor.

Legislation is in the process to establish a safety board, made up of outside experts, to review the safety of DOE facilities. However, as of August 1988, the provision to establish such a board had not been signed into law.

Resolving Cost and Schedule Uncertainties

A Westinghouse subcontractor estimated in a March 1988 cost document[1] that the cost to complete WNP-1 as a DOE defense production plant, exclusive of the cost of acquiring the plant from the Supply System but inclusive of the cost of support activities, is $2.6 billion; and the estimated time needed to complete the plant to full operation is 6 years from the time that acquisition of WNP-1 is authorized. In regard to the estimated cost and schedule, Representative Morrison asked us to

- analyze and comment on the methodology and reasonableness of DOE's cost and schedule estimates for completing WNP-1 as a production plant and
- compare the WNP-1 cost and schedule estimates to other new production reactor options, if comparable information for the other options is readily available.

Our work consisted of a general review of both the estimating process and the reasonableness of (1) the capital cost estimates, (2) the supporting activity cost estimates, and (3) the completion schedule estimates for completing WNP-1 as a defense production plant. In addition, we performed a more detailed examination of the estimate related to installing electrical cable. During the course of our review, a question was raised regarding the cost and benefit of the proposed facilities to reprocess WNP-1 fuel. Consequently, we also reviewed the purpose and practicality of DOE's proposal to construct WNP-1 fuel-reprocessing facilities.

Our review did not include an analysis of the cost of acquiring WNP-1 from the Supply System, or of the life-cycle cost of completing and operating WNP-1 as a defense production reactor, or a comparison to other reactor options. DOE only recently (July 1988) completed a study which contained comparable cost estimates, including life-cycle costs, for each of its new production reactor options. The issue of acquisition of WNP-1 is discussed in appendix VI.

We found no basis to question either (1) the process used by DOE, its contractors, and subcontractors for estimating the WNP-1 completion cost and schedule or (2) the reasonableness of the estimates. However, potential legal, environmental, licensing, and testing uncertainties could delay the WNP-1 completion schedule and increase the capital and supporting activity costs.

[1]That document, WNP-1 Conversion, Total Project Cost, was prepared by R.L. Ferguson and Associates, Inc., a subcontractor to Westinghouse, who subsequently presented the report to DOE.

The estimates for WNP-1 completion include allowances for a new fuel-reprocessing facility. The estimated cost of this new facility is not significantly higher than the estimated cost of other options for handling the used ("spent") WNP-1 fuel. In addition, a fuel-reprocessing facility at Hanford could be used to process plutonium for weapons use if WNP-1 is operated for plutonium production.

WNP-1 Cost and Schedule Estimates

The March 1988 cost document estimates that completing WNP-1 for tritium production would cost approximately $2.6 billion. Table V.1 summarizes these cost estimates. As the table shows, about $1.9 billion of the $2.6 billion estimate is for capital costs for (1) completing construction of the reactor systems and turbine generator, (2) modifying reactor facilities, and (3) constructing tritium target and fuel fabrication and processing facilities.

Table V.1: Cost Estimates for Completing WNP-1 as a Tritium-Producing Reactor

Dollars in millions

	Cost estimates in 1987 dollars		
Capital costs:			
Reactor systems and turbine completion:			
Structures and improvements	$35		
Reactor/balance of plant equipment	209		
Heat rejection and turbine generator	154		
Electrical plant equipment	227		
Misc. plant equipment	16		
Construction facility equipment and services	194		
Engineering and home office services	97		
Field support and office services	147		
Subtotal reactor systems and turbine completion		**1,079**	
Modifications to existing facilities:			
Heat rejection facility	69		
Security system upgrade	66		
New simulator and training facility	46		
Reactor internals/control rod drive	62		
Advance safety upgrades	50		
Other modifications	13		
Subtotal modifications to existing facilities		**306**	
Process facilities:			
Tritium target fabrication	8		
Tritium target processing	121		
Fuel fabrication	17		
Fuel reprocessing	335		
Subtotal process facilities		**481**	
Total capital costs			**1,866**
Support activities:			
Development and testing	87		
Conceptual design	11		
Safety and environmental	82		
Start-up, training, and initial spares	397		
First core fuel	126		
Total support activity costs			**703**
Total costs			**$2,569**

According to a Westinghouse subcontractor, completing WNP-1 for tritium production will require 6 years. Table V.2 shows the major milestones in the subcontractor's March 1988 estimate, which Westinghouse subsequently presented to DOE. As the table shows, 22 months are allowed before construction could be restarted. During this time, the subcontractor estimates that (1) the environmental review process would be completed, (2) the plant would be acquired from the Supply System, and (3) design, development, and testing programs would be conducted. The first core is expected to be loaded into the reactor 63 months after the activities begin, and the reactor is expected to become fully operational after 72 months.

Table V.2: Milestone Estimates for Completing WNP-1 as a Tritium-Producing Reactor

Milestone:	Months from start
Begin acquisition proceedings, environmental, development and testing programs, and resumption of design activities	0
Restart construction	22
Fuel fabrication facility operational	36
Target fabrication facility operational	42
First core loaded into reactor	63
Reactor operational	72

The cost and schedule estimates are based on a series of studies conducted since 1981. These studies were as follows:

- In June 1981, the Supply System issued initial cost and schedule estimates for completing WNP-1 as a commercial reactor. These estimates, prepared by Bechtel Power and United Engineers and Constructors, were updated and issued by the Supply System in June 1982.
- In June 1984, the Supply System issued revised cost and schedule estimates for completing WNP-1 as a commercial reactor. This document, prepared by Bechtel Power and United Engineers and Constructors, contains the base estimates for the present WNP-1 completion cost estimates.
- In September 1986, the Supply System issued updated cost and schedule estimates, prepared by Bechtel Power and United Engineers and Constructors, for completing WNP-1 as a commercial reactor.
- In March 1987, DOE issued the Technical Feasibility Report. This report included the cost and schedule estimates prepared by Bechtel National, Inc., for completing WNP-1 for tritium production.
- In September 1987, Westinghouse issued a report entitled Production Reactor Capital Cost and Schedule Estimates. Prepared by Bechtel National, Inc., that report reviewed and updated the WNP-1 Technical Feasibility Report estimates and compared them with estimates for two other options for a new production reactor—the special water reactor at Hanford and the heavy water reactor at Savannah River.

- In April 1988, Westinghouse issued a report entitled, WNP-1 Conversion Total Project Cost. Prepared by R.L. Ferguson and Associates, Inc., in March 1988, that report presents the final cost and schedule estimates of $2.6 billion and 6 years. The estimates were developed from the results of the five previous studies and from additional contractor work.

Westinghouse and Westinghouse subcontractor officials responsible for developing the WNP-1 completion estimates are confident that the estimates are realistic. The capital cost estimates were developed with $266 million in contingencies to achieve a 90-percent confidence level. In other words, these officials believe there is a 90-percent probability that the actual WNP-1 capital cost to complete WNP-1 will be less than or equal to the estimated $1.9 billion.

Westinghouse, and Westinghouse subcontractor officials, cited the following reasons to believe that the capital cost estimates for completing WNP-1 for tritium production are achievable:

- The estimates are based on historical data from prior WNP-1 experience instead of on less accurate conceptual design information.
- An extensive construction restart readiness program has been maintained for the WNP-1 plant.
- WNP-1 is 63-percent complete, items with long acquisition times have been procured, and major pieces of equipment are either already installed or are stored on site.
- The WNP-1 reactor has been subject to the regulatory and licensing process for a commercial nuclear reactor, and much of the NRC licensing documentation has been completed.

Review Shows Estimates Appear Reasonable, but Other Problems May Exist

Our review did not disclose any reason to question the reasonableness of the methodology and support for the WNP-1 cost and schedule estimates. We interviewed the individuals responsible for developing the estimates and reviewed documentation of the estimating process. Although we did not perform a detailed examination of all of the components of the estimate, we did so for the estimate related to installing electrical cable. This is one of the larger items left to complete; about 6 million feet of electrical cable remain to be installed. A Westinghouse subcontractor told us that there is no material cost for the cable because the cable was purchased by the Supply System and is at the WNP-1 site. Therefore, we looked at (1) industry averages for the number of man-hours required to install one linear foot of electrical cable and (2) the electricians' wage rate for federal projects at Hanford. We found the WNP-1 estimated installation rate and electricians' wage rate to be comparable to or more conservative than the industry averages. In addition, we found the details of the WNP-1 estimate to be well documented and supported. While we are not in a position to project the confidence level of the WNP-1 estimate relating to installing electrical cable, we found the estimate to be reasonable.

Although we found no basis to question reasonableness of the methodology and support for the WNP-1 estimates, cost increases and delays in the schedule are possible because of potential technical, licensing, legal, and environmental review uncertainties. For example:

- Tritium target development may take longer and/or cost more than estimated. A question about the status of target pin development for a light water technology and, in particular WNP-1, was raised by the Energy Research Advisory Board. While Westinghouse has confidence in the design of the principal, or "reference" tritium target pin, it is also considering an alternate target. This WNP-1 target strategy reduces the risk of not having a target in time to meet the WNP-1 schedule. However, if additional testing of the reference target pin is required, contractor officials estimate that the tritium target development cost could increase from $66 million[2] to $119 million. If additional testing of the reference pin is required and the alternate target is developed and tested, the total target development and testing cost could be as much as $159 million. Other technical issues that need to be resolved are discussed in appendix III.
- The safety review may delay WNP-1 completion. According to a 1987 Academy report, the stated objective established by DOE for the defense production reactors is the achievement of a level of safety comparable to commercial nuclear power plants. However, the Academy report found a high degree of confusion both within DOE and among the Department's contractors concerning this safety objective. The uncertainty with regard to the regulatory environment under which any new production reactor would be built introduces corresponding uncertainty in estimating the capital cost and schedule. Other licensing issues that need to be resolved are discussed in appendix IV.
- Acquisition of the WNP-1 reactor may take longer than 22 months. There is a risk that a Federal District Court judgment on the price for WNP-1 could be in excess of congressionally authorized funding for acquisition of the WNP-1 facilities. No allowance for this case is included in the 22-

[2]The total project cost estimate of $2.6 billion includes an allowance for $66 million for development and testing of tritium target pins.

month acquisition schedule. Other legal issues that need to be resolved are discussed in appendix VI.

- The environmental review process may take longer than 22 months. Westinghouse subcontractors stated that 22 months is an optimistic schedule for the environmental review process.

Purpose and Practicality of Fuel-Reprocessing Capability

The specific purpose of fuel-reprocessing facilities for the WNP-1 reactor depends on whether the reactor is producing tritium or plutonium. Studies to complete WNP-1 focused on tritium production, but both tritium and plutonium are considered viable alternatives for production in the WNP-1 reactor.

- If the reactor produces tritium, the reprocessing facilities' primary purpose would be to recover the residual uranium left in the spent fuel elements. Plutonium is also produced in the fuel pins during tritium production. However, this plutonium is not suitable for weapons use and would be removed from the spent fuel pins to simplify waste disposal.
- If the reactor produces plutonium for weapons use, the purpose of reprocessing the spent fuel would be to recover the plutonium.

Cost Estimates for Reprocessing Facilities Raised to $335 Million

The DOE Technical Feasibility Report estimate of $217 million for WNP-1 reprocessing facilities is no longer valid. The $217 million was to construct additional facilities adjacent to a facility planned for and funded by another DOE reprocessing project at Hanford. This project, referred to as Process Facility Modification, was to be modified and used as the central facility of the WNP-1 reprocessing complex. It was to provide the capability to (1) receive, segment, and dissolve WNP-1 fuel and (2) remove and contain the residual uranium, tritium, and plutonium. However, in December 1987, the Process Facility Modification project was cancelled by DOE.

Since the Process Facility Modification project was cancelled, Westinghouse has proposed the construction of reprocessing facilities designed specifically for the WNP-1 plant. Westinghouse estimates that the new reprocessing complex will cost $335 million—$118 million more than the previous reprocessing approach.

Practicality of Reprocessing Spent Fuel

Westinghouse officials told us that the technology for reprocessing spent fuel elements has been in use at DOE production sites for 20 to 30 years. They also stated that the economics of reprocessing WNP-1 spent fuel and recovering uranium depends largely on (1) whether DOE needs additional uranium inventories and (2) the open market price of uranium. If a decision is made that reprocessing WNP-1 fuel is not cost effective, the capital cost of the WNP-1 proposal would be $335 million lower.

receives a sufficient amount of money—approximately $2.1 billion—to pay all of the principal on the outstanding bonds, plus accrued interest. If the Supply System sells (or otherwise voluntarily conveys) WNP-1 for less than that amount, such action would constitute an "event of default" under section 12.1 of the Bond Resolution, and the Bond Trustee could declare all bond principal immediately due and payable.

Condemnation by DOE, however, would not constitute an act of default under the terms of the Bond Resolution. Section 10.8(3) of the Bond Resolution provides that the transfer of WNP-1 or any portion thereof "through the operation of law" is permissible and does not constitute a default. If a transfer through operation of law occurs, any money received by the Supply System must be paid into the bond retirement account; but since such a transfer is not a default, the Board of Trustees could not accelerate the entire balance due on the bonds. Condemnation of WNP-1 would constitute a transfer "through the operation of law." Thus, the $2.1 billion of outstanding bond principal would not become immediately due and payable.

When DOE condemns real property, it can follow one of two alternative procedures.

- Without declaration of taking. Under 40 U.S.C 257, DOE files a condemnation action, which would then proceed to final judgment on the issue of the amount of "just compensation" to be paid the owner. However, until the amount of just compensation in this type of ordinary condemnation is determined by the court and paid by DOE, DOE would not take title to the property and would be free to abandon the condemnation attempt. If the proceeding is abandoned, DOE would be liable for reasonable costs, disbursements, and expenses, including attorneys, appraisal, and engineering fees incurred by the owner (42 U.S.C. 4654(a)).
- Declaration of taking. Alternatively, DOE could rely on the authority set forth in 40 U.S.C. 258a-258f—the so-called Declaration of Taking Act. Under these provisions, the government is authorized, once a condemnation proceeding is instituted, to file a declaration of taking that states the authority under which and the public use for which the property is to be taken, a description of the property being taken, and a statement of the amount of money estimated to represent just compensation. Once the declaration of taking is filed and the estimated just compensation is deposited with the court, title to the property vests in the government. At that time, the government becomes irrevocably obligated to pay the final judgment as to the amount of just compensation, even if that amount exceeds its own estimate. In light of the irrevocable nature of

the government's obligation to pay the ultimate award made by the court, the statute provides that a declaration of taking shall not be filed unless the head of the agency makes a determination that "the ultimate award probably will be within any limits prescribed by Congress on the price to be paid" (40 U.S.C. 258c).

Thus, the primary difference between an ordinary condemnation without declaration of taking and the declaration of taking condemnation procedure is that DOE could abandon an ordinary condemnation if it considered the amount of just compensation for WNP-1 as determined by the court to be excessive. But it could not do so if it filed a declaration of taking, even if the amount of just compensation greatly exceeded its own estimate or any congressionally imposed limitation.

The acquisition cost of WNP-1 is speculative at this time. The cost depends on the valuation approach which would be used by the court that would try the condemnation case. We did not attempt to estimate the acquisition cost. However, the cost could range from $30 million (salvage value) to $2.1 billion (total of the outstanding bonds).

Completion Not a Violation of Existing U.S. Laws

A second issue is whether the proposed completion of WNP-1 is prohibited by federal legislation. We found no relevant provision of U.S. law which would preclude completion of WNP-1 as a defense production reactor.

Completion Not a Violation of Non-Proliferation Treaty, but a Policy Question May Need to Be Resolved

It is the position of the United States Arms Control and Disarmament Agency, and the State Department, that the United States is not "precluded by treaty obligation or domestic law" from converting an uncompleted commercial nuclear power reactor to a defense production reactor. We agree with this position.

The Non-Proliferation Treaty, which went into effect on March 5, 1970, imposes different obligations on non-nuclear weapons states than on nuclear weapons states.

- Non-nuclear weapons states that are parties to the treaty undertake not to receive, manufacture, or otherwise acquire nuclear weapons or other nuclear explosive devices and not to receive any assistance in the manufacture of nuclear weapons or other nuclear explosive devices. In addition, non-nuclear weapons states that are parties to the treaty undertake to accept safeguards as set forth in an agreement with the International Atomic Energy Agency to verify the fulfillment of their treaty obligations "with a view to preventing diversion of nuclear energy from peaceful use to nuclear weapons or other nuclear explosive devices."

- Nuclear weapons states that are parties to the treaty, such as the United States, do not operate under such restrictions. The treaty does not require that the International Atomic Energy Agency safeguards be applied to nuclear weapons states, nor does it otherwise impose any limitations on the domestic nuclear activities of a nuclear weapon state that is a party to the treaty. Thus, the treaty would not in any way prohibit or restrict the conversion of WNP-1 to a defense production reactor.

While completing WNP-1 as a defense production reactor would not, in our opinion, be in violation of the Non-Proliferation Treaty, it may raise for the Congress policy questions. For example, the proposed action appears to blur the traditional, albeit not absolute, separation between peaceful uses of atomic energy and military use and, as a result, may be criticized on policy grounds.

Major Contributors to This Report

Resources, Community, and Economic Development Division, Washington, D.C.

Keith O. Fultz, Senior Associate Director, (202) 275-1441
James H. New II, Group Director
W. David Brooks, Assignment Manager
Dr. Duane G. Fitzgerald, Nuclear Engineer

Office of the General Counsel, Washington, D.C.

Alan N. Belkin, Attorney

Seattle Regional Office

Leonard L. Dowd, Regional Management Representative
Robert A. Higgins, Evaluator-in-Charge
Robert B. Arthur, Evaluator
Patricia Kimiko Yamane, Evaluator
Stanley G. Stenersen, Reports Analyst

Consultant

Dr. George W. Hinman, Nuclear Physicist

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