A CER TOPICAL REPORT

HISTORY OF 10CFR50, APPENDIX B, AND ITS IMPACT ON NUCLEAR POWER PLANT PERFORMANCE

NOVEMBER 1993

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ABSTRACT

This report traces the evolution of 10CFR50, Appendix B, *Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants*, from November 1966 to currently contemplated amendments to the Regulation. The Report assesses the impact of Appendix B on the nuclear industry by comparing the performance of nuclear plants built prior to the Regulation's publication to those built after its issuance. The Report evaluates, in detail, the history of three fuel reprocessing plants, 26 nuclear plants built prior Appendix B, nine plants licensed since the Regulation's publication, and five partially constructed plants that were cancelled due to quality assurance problems. It concludes that, though Appendix B had a significant positive impact on plant performance,.the Regulation contains several weaknesses. Section 6.0 of the Report evaluates the effect each of the weaknesses has had on past nuclear work, looks at comparable passages in other quality standards, and suggests changes to Appendix B and corresponding nuclear standards. Ten of the 22 weaknesses are considered minor, little more than irritants to those who must work with its criteria. However, five of the remaining 12 weaknesses are considered major and are singled out for further discussion in Section 7.0 of the Report.

ACKNOWLEDGEMENTS

I would like to thank my CER associates in Arlington, Virginia, who volunteered to give up their evenings and weekends to review various drafts of this report and share with me their ideas on how the Report could be improved. This includes Mike Donovan, Norm Frank, Marlin Horseman, Hugh Lentz, Ted Preisser, Tom Rodgers, Tom Swift, and Tricia White.

Samuel Walker, Nuclear Regulatory Commission historian, provided some much needed assistance in locating several important documents pertaining to the history of 10CFR50, Appendix B. His new book, *Containing the Atom*, was the source of the discussion in this report on the relationship between events at Oyster Creek and the development of Appendix B.

I am very grateful to Bill Morrison, Merritt Langston, Bob Minogue, and Jack Norris for sharing with me their understanding of events during 1968, 1969, and 1970. In many ways, this is as much their report as it is mine. I am especially grateful to Bill Morrison, the principal author of 10CFR50, Appendix B, for in addition to agreeing to be interviewed, giving up part of his Christmas holiday to review this report and provide me with written comments. Also, not only did Merritt Langston share with me his recollection of the evolution of Appendix B, he supplied me with specific details from personal files dating back to the late 1960s.

Considerable research went into this report. I am indebted to the staffs of The American Society of Mechanical Engineers, Arlington County, Fairfax County, George Mason University, Library of Congress, Midland Daily News, NRC Public Document Room, and U.S. Department of Energy libraries for the assistance they provided obtaining books, reports, and back issues of newspapers and periodicals. I am also indebted to the U.S. Council for Energy Awareness for permitting me to use their superb library. A special thanks goes to Erin Nagorski, the Council's dedicated Library Manager.

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Marc Meyer
Arlington, Virginia
November 1993

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HISTORY OF 10CFR50, APPENDIX B, AND ITS IMPACT ON NUCLEAR POWER PLANT PERFORMANCE

1.0 PURPOSE

This report traces the development of 10CFR50, Appendix B, *Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants*, to provide readers with an insight into the rationale behind the regulation. This report also looks into the question, "Did 10CFR50, Appendix B, improve the quality of nuclear facilities or simply delay completion of construction and drive up costs?" To answer the question, the report examines the performance of nuclear facilities licensed before and after the Regulation's issuance in June 1970. It is hoped that a better understanding of events leading up to the Regulation, the basis for its criteria, and 23 years of experience with the Regulation will lead to further improvements in codes, standards, and quality assurance programs developed and used within the nuclear industry.

2.0 SCOPE

The evolution of 10CFR50, Appendix B, began during an American Nuclear Society conference in November 1966 and ended in January 1982 with the publication of supplemental QA requirements based on lessons learned from a March 1979 accident at Three Mile Island 2. This report assesses the impact of Appendix B on the nuclear industry by comparing the performance of plants built prior to the Regulation's publication to those built after its issuance. It also looks into: *1)* the impact of Appendix B on quality at fuel reprocessing plants; *2)* possible links between nuclear power plant cancellations and Appendix B; and *3)* whether the permanent closure of plants licensed after June 1970 can be traced to problems with Appendix B.

3.0 BACKGROUND

3.1 BIRTH OF NUCLEAR POWER INDUSTRY

On December 20, 1951, at a U.S. Government nuclear reactor test site near Idaho Falls, Idaho, the Atomic Energy Commission's (AEC's) 0.15 MW Experimental Breeder Reactor No. 1 demonstrated that nuclear energy could be used to generate electricity.[1] Fifteen months later at the same test site, the AEC's S1W test reactor, a *Nautilus* prototype, successfully demonstrated that nuclear energy could be used to power submarines.[2]

On December 8, 1953, President Eisenhower challenged the world to use nuclear energy for peaceful, rather than military, purposes in his famous "Atoms-for-Peace" speech before the United Nations General Assembly. The next year, on August 30, Eisenhower signed the Atomic Energy Act of 1954 and, six days later, led ground-breaking ceremonies for the 60 MW Shippingport nuclear power plant.

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[1] Refer to page 1 of Supplement V to this report for further information on Experimental Breeder Reactor (EBR) No. 1.

[2] Jack Holl, Roger Anders, and Alice Buck, DOE/MA-0152, *United States Civilian Nuclear Power Policy, 1954-1984: A Summary History*, U.S. Department of Energy, Washington, DC, February 1986, pp. 2 & 35.

Based on its cooperative agreement with the AEC, Duquesne Light Company provided a site for Shippingport, $5 million in construction funding, and plant operating personnel. The AEC provided fuel for the reactor and the remaining $50 million needed to build the plant.[3]

On January 10, 1955, to further expand Eisenhower's Atoms-for-Peace policies, the AEC announced it would provide funding and other assistance to utilities interested in constructing a demonstration nuclear power plant. The plant could use any of seven types of reactors. Interested utilities were invited to submit proposals on how they would build and operate their plant and what type of assistance they needed from the AEC. The AEC accepted three proposals submitted in response to its January 10 invitation. Requests for additional proposals were solicited during September 1955, January 1957, and August 1962. In all, 14 plants were built under the AEC's Power Reactor Demonstration Program (PRDP). The largest plant was Haddam Neck, a 569 MW facility in Connecticut. The smallest was Piqua, an 11.4 MW facility in Ohio.[4,5]

Before construction of the PRDP plants could begin, the AEC had to develop regulations governing their design, construction, and operation. In January 19, 1956, 10CFR50 was amended to include rules for obtaining permits to build and licenses to operate nuclear power plants. Nothing in the new rules required that applicants have a quality assurance program.[6,7] A few months later, on May 4, Commonwealth Edison and Consolidated Edison received Construction Permits for Dresden 1 and Indian Point 1, respectively.[8]

The AEC also pursued using nuclear energy to power spacecraft. During 1959, it successfully tested a 50 MW(t) Space Nuclear Auxiliary Power reactor. Since then, nuclear reactors up to 600 MW(t) have been used to power 39 unmanned vehicles to distant planets and into deep space.[9,10]

3.2 RECOGNITION OF NEED FOR QUALITY ASSURANCE

3.2.1 Fermi 1

On August 16, 1966, a proposed amendment to 10CFR50 was issued for public comment. The amendment required that utilities submit a *Preliminary Safety Analysis Report (PSAR)* with each application for a Construction Permit and a *Final Safety Analysis Report (FSAR)* with each application for an Operating License. A description of the applicant's quality assurance program was not required in either the *PSAR* or *FSAR*.[11] Within months, there would be second thoughts.

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[3] Ibid, pp. 3 & 38.

[4] Ibid, pp. 4, 35, 36 & 39.

[5] Richard Hewlett and Jack Holl, *A History of the United States Atomic Energy Commission 1952-1960*, U.S. Department of Energy, Washington, DC, 1987, pp. XVIII-18 through 21.

[6] *Federal Register*, The National Archives of the United States, Washington, DC, January 19, 1956, pp. 355-360.

[7] With the amendment, the title of 10CFR50 changed from *Control of Facilities for the Production of Fissionable Material* to *Licensing of Production and Utilization Facilities*. The amended regulation added provisions for Construction Permits and expanded the scope of Operating Licenses to cover nuclear power plants as well as cyclotrons, test reactors, and radiographic equipment.

[8] Refer to pages 3 and 5 of Supplement V of this report for further information on Dresden 1 and Indian Point 1.

[9] G. Bennett, "The Safety Review and Approval Process for Space Nuclear Power Sources," *Nuclear Safety*, Washington, DC, January-March 1991, pp. 1 & 2.

[10] DOE/OSTI-8200, *Nuclear Reactors Built, Being Built, or Planned: 1989*, U.S. Department of Energy, Washington, DC, June 1990, p. III-6, 7 & 8.

[11] *Federal Register*, August 16, 1966, pp. 10892-10893.

On October 5, 1966, an unauthorized design change at the Fermi 1 nuclear power plant resulted in a partial meltdown of the reactor core. To the plant's owners, it was a particularly tough blow. After ten years of construction, Fermi 1 was finally beginning to produce electrical power.[12] The incident caused utilities to realize that something had to be done to improve nuclear safety and the probability that, after investing millions in design and construction, they would have a plant that produced electricity continuously and economically.

The need to do something became even more obvious a few weeks later upon issuance of a report on the status of the AEC's Power Reactor Demonstration Program. The report covered ten small (under 100 MW) PRDP reactors that had been built or were in the process of being built. Results were not encouraging. Many of the plants were experiencing problems with their reactor control rod drive mechanisms. This was either because of deficiencies in the mechanism's design or foreign objects left in the reactor during construction. The most perplexing problem was standard, off-the-shelf equipment that did not meet specified requirements. For example, heat exchangers were frequently shipped from manufacturers with defective welds, tube supports, and baffles; internal dirt and debris; and leaky tubes.[13]

By the time the report was issued, two of the ten PRDP plants (Hallam and Piqua) had been permanently shut down. Within a year, two more would be permanently closed (CVTR and Pathfinder) and, within another year, two more (Bonus and Elk River).[14] The typical plant cost $24.3 million to design and build and was in operation 2.64 years before being forced to close.[15]

Milton Shaw, Director, AEC Reactor Development and Technology Division, and James Ramey, AEC Commissioner were the featured speakers at the American Nuclear Society's November 1966 Conference. Milton Shaw spoke on the "AEC's Views on Quality Assurance in the Civilian Reactor Program." He emphasized the cost of bad quality, need for verification, and importance of traceability from installed hardware to corresponding inspection and test reports. He warned, "We cannot afford to jeopardize a technology effort because we are unable to procure ... a good heat exchanger, a good valve, or do a proper welding job." Commissioner Ramey spoke on "Quality Assurance as a Matter of Public Safety." He defined quality assurance as "all actions necessary to provide adequate confidence that the product, in this case a reactor, will operate satisfactorily in service." He laid out a three-step approach to quality assurance: *1)* establish general performance criteria; *2)* develop standards and practices for complying with specific criteria; and *3)* conduct reviews, surveillances, inspections, and audits to verify implementation.[16,17,18,19] Though the AEC hoped that nuclear

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[12] Refer to pages 14 and 15 of Supplement V to this report for further information on Fermi 1.

[13] COO-284, *Small Nuclear Power Plants*, Volume 1, U.S. Atomic Energy Commission, Chicago, IL, October 1966, pp. 1-4.

[14] Since PRDP plants were supposed to provide inexpensive electrical power to civilian populations, their reactors had to be safe and reliable. To accomplish this, PRDP engineers scaled-up reactors that had been successfully tested at Government installations during the late 1950s and early 1960s. Borax-5, a 2.6 MW boiling-water reactor with integral superheater that began operation in 1962, was the prototype for Bonus and Pathfinder. SRE, a 5.7 MW sodium-cooled reactor started up in 1957, was the prototype for Hallam and Fermi 1. EBWR, a 4.0 MW BWR that went operational in 1956, was the prototype for Elk River, Big Rock Point, and La Crosse. OMRE, an organic cooled and moderated reactor started up in 1957, and PRTR, a pressure-tube, heavy-water reactor started up in 1960 were, respectively, prototypes for Piqua and CVTR. GCRE, a gas-cooled reactor that started up in 1960, was the prototype for Peach Bottom 1 and Fort St. Vrain. Lastly, Shippingport, a pressurized-water reactor that began operation in 1957, was the prototype for Yankee Rowe, Haddam Neck, and San Onofre 1. Accordingly, the relatively poor performance of PRDP plants could not be attributed to the experimental nature of their reactors.

[15] Refer to Supplement V of this report for specific costs and dates these plants were closed.

[16] Spencer Weart, *Nuclear Fear, A History of Images*, Harvard Press, Cambridge, MA, 1988, pp. 306-307.

[17] Merritt Langston, "Quality Assurance Standards and Practices," *Nuclear Safety*, U.S. Atomic Energy Commission, Washington, DC, Nov.-Dec. 1971, pp. 549-550.

[18] *1966 Winter Meeting Transactions*, American Nuclear Society, Hinsdale, IL, 1966, pp. 407 & 410. © 1966 by American Nuclear Society

[19] Samuel Walker, *Containing the Atom*, University of California Press, Berkeley, CA, pp. 212 & 213.

utilities, contractors, and manufacturers would establish and implement effective quality programs, there was still no Federal regulation requiring assurance of quality.

3.2.2 Apollo 1

On January 25, 1967, a fire broke out in NASA's Apollo 1 space capsule during a ground test. The three astronauts inside were killed instantly. A special NASA inquiry board blamed the tragedy to "many deficiencies in design and engineering, manufacture and quality control."[20] NASA promptly began overhauling its requirements to clarify the relationship between safety, reliability and quality.[21] By June 1969, NASA Publication NPC-200-2, *Quality Assurance Provisions for Space System Contractors*, originally issued in 1962, was replaced with NHB-5300.4, *Quality Assurance Provisions for Aeronautical and Space System Contractors.* Sections 1B200 and 1B804 of NHB-5300.4 required that quality assurance programs contain provisions for "detection of actual or potential deficiencies, system incompatibility, marginal quality, and trends ... that could lead to unsatisfactory quality" and Material Review Boards comprised of NASA and contractor employees.

The Apollo accident awakened the AEC to the possibility of a similar disaster. Two weeks after the accident, during a hearing on a Construction Permit for Turkey Point 1&2, the Atomic Safety and Licensing Board (ASLB) quizzed the utility about "methods and standards of quality control" that would be used by contractors. It complimented the AEC and utility for "participating or cooperating in programs intended to define the standards and quality control procedures" to be used at the plant. Though impressed enough to grant the utility a Construction Permit, the ASLB was uneasy about some of the promises it received. The ASLB warned the utility that, to obtain an Operating License, it would need to have evidence procedures were actually developed and implemented.[22]

A month later, the AEC Advisory Committee on Reactor Safeguards (ACRS) expressed concern that construction of Browns Ferry 1&2 would begin without a commitment from the utility to develop and implement a quality assurance program. Recognizing that Browns Ferry would have the first nuclear reactors larger than 1000 MW, the ACRS wrote to Glenn Seaborg, AEC Chairman, that:

> *The Committee continues to emphasize the importance of* ***quality assurance*** *in fabrication of the primary system ... Because of the higher power level and advanced thermal conditions in the Browns Ferry Units, these matters assume even greater importance.*[22]

The Committee's advice and lessons learned from the Apollo 1 fire were not heeded. On March 22, 1975, a major fire occurred at Browns Ferry 1&2. Damage exceeded $10 million and closed the facility for over a year.[23] Browns Ferry 1&2 were shut down again, respectively, in March 1985 and September 1984, because of "safety and quality assurance concerns." Though Browns Ferry 2 was finally restarted during May 1991, Browns Ferry 1 is not expected to restart until 1996.[24,25]

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[20] John Wilford, "Apollo Fire Review Board Finds 'Many Deficiencies'; Calls for Safety Moves," *The New York Times*, New York, NY, April 10, 1967, pp. 1 & 29. © 1967 by The New York Times Company

[21] NUREG-1055, *Improving Quality and the Assurance of Quality in the Design and Construction of Nuclear Power Plants*, Nuclear Regulatory Commission, Washington, DC, May 1984, p. D-36.

[22] *Atomic Energy Commission Reports*, Volume 3, U.S. Government Printing Office, Washington, DC, 1968, p. 199 & 214.

[23] Robert Sawyer and James Elsner, "Cable Fire at Browns Ferry Nuclear Power Plant," *Fire Journal*, Boston, MA, July 1976, p. 5.

[24] Dave Flessner, "Back in Business," *The Chattanooga Times*, Chattanooga, TN, May 20, 1991, p. A1.

[25] "Brunswick added to list, Browns Ferry-2 removed," *Nuclear News*, La Grange Park, IL, August 1992, p. 25. © 1992 by American Nuclear Society

3.2.3 10CFR50, Appendix A

To improve the licensing process, the AEC appointed a seven-member Regulatory Review Panel chaired by William Mitchell, former AEC general counsel. In July 1965, the Panel completed its review. One of its recommendations was that the AEC develop, for use during ASLB Construction Permit hearings, general design criteria for nuclear power plants.[26,27] As a result, on November 22, 1965, the AEC developed and distributed 27 preliminary design criteria for public comment.[28]

Criterion 1(a), the first of the 27 criteria, required that plant features essential to the prevention of accidents be designed and constructed "to quality standards that reflect the importance of the safety function to be performed."[28] Dresden 2, which received a Construction Permit in January 1966, was the first nuclear power plant that had to comply with the criteria.[29]

In response to public comments, the AEC reorganized and divided the 27 preliminary design criteria into 70 criteria. On July 11, 1967, the criteria were issued for a second round of public comments as 10CFR50, Appendix A, *General Design Criteria for Nuclear Power Plant Construction Permits*. The proposed Appendix required that each of the criteria be addressed in the applicant's *Preliminary Safety Analysis Report*.[26,27] Criterion 1, "Quality Standards," greatly expanded on old Criterion 1(a) by requiring that:

> *Those systems and components ... essential to the prevention of accidents which could affect the public health and safety ... shall be identified and then erected to **quality** standards that reflect the importance of the safety function to be performed. Where ... codes and standards on design, materials, fabrication, and inspection are used, they shall be identified. Where adherence to such codes and standards does not suffice to assure a **quality** product in keeping with the safety function, they shall be supplemented or modified as necessary. **Quality assurance programs**, test procedures, and inspection acceptance levels to be used shall be identified. A showing of sufficiency and applicability of codes, standards, **quality assurance programs**, test procedures, and inspection acceptance levels used is required.*[30]

3.2.4 ASME Section III, Appendix IX

One of the "codes" the AEC had in mind when it wrote Appendix A was ASME Section III, *Code for Construction of Nuclear Vessels*. In 1955, the American Society of Mechanical Engineers (ASME) formed a committee to develop a special code for reactor vessels.[31] Representatives from the Atomic Energy Commission, the National Board of Boiler and Pressure Vessel Inspectors, utilities, and nuclear contractors served on the committee. ASME Section III was first issued for use on November 4, 1963.[32] Amendments were issued twice a year and Editions, which incorporated Amendments and other changes, were issued once every three years.

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[26] T. I. Cramer, "Standardization: one way to break the licensing logjam," *Power*, New York, NY, July 1967, p. 84. © McGraw-Hill, Inc.

[27] *Federal Register*, The National Archives of the United States, Washington, DC, July 11, 1967, p. 10214.

[28] *AEC Press Release H-252*, "AEC Seeking Public Comment on Proposed Design Criteria for Nuclear Power Plant Construction Permits," U.S. Atomic Energy Commission, Washington, DC, November 22, 1965.

[29] R. J. Bender, "Nuclear Notes," *Power*, New York, NY, February 1966, p. 92. © McGraw-Hill, Inc.

[30] When finally issued for use on February 20, 1971, Criterion 1 was retitled, "Quality standards and records," and expanded to require preparation and maintenance of records of items and activities important to safety.

[31] Robert Irving, "Why the ASME code is in a class by itself," *Iron Age*, Carol Stream, IL, January 17, 1977, p. 36.

[32] Prior to ASME Section III, reactor vessels were built to ASME Section VIII, *Pressure Vessels*.

ASME Section III did not contain quality assurance requirements when first published. This changed on December 31, 1967, when an Amendment was issued that contained a new Appendix IX, *Quality Control and Nondestructive Examination Methods*. Appendix IX required a "Quality (QA) Assurance Control Program" that included the following 15 basic elements:

1. *Organization* [IX-221(b)]
2. *QA Control Program* [IX-221(a)]
3. *Description of Procedures* [IX-221(d)]
4. *Drawings and Changes* [IX-221(c)]
5. *Receiving Examination* [IX-226(d)]
6. *Control, Identification & Marking* [IX-226/227]
7. *Manufacturing Fabrication Procedures* [IX-222]
8. *Examination* [IX-230/240]
9. *Testing* [IX-240]
10. *Calibration* [IX-250/260]
11. *Handling, Storage & Delivery* [IX-270]
12. *Component & Material Repair* [IX-223/226(e)]
13. *Corrective Action* [IX-224]
14. *Quality Control Records* [IX-225/226(c)]
15. *Quality Audits* [IX-221(d)4]

Appendix IX was the nuclear industry's first QA standard. To ensure compliance, Paragraph N-832 of ASME Section III required that "the Society" review and approve each reactor manufacturer's QA Control Program. This had to be done initially and every three years. Additionally, in accordance with longstanding ASME practices, Paragraph N-832 required that reactor manufacturers enter into a contract with an independent inspection agency, typically a major insurance company. It was the inspection agency's job to verify that Section III requirements, including QA Control Program requirements, were being implemented to on a day-to-day basis.

3.2.5 AEC Compliance Inspections

During 1967, the AEC became aware of defects in fuel assembly welds at Oyster Creek and Big Rock Point and mechanical problems that permanently closed the Pathfinder and Elk River reactors. During 1968, cracks were detected in Oyster Creek's reactor core shroud support and Ginna's personnel and equipment hatch frames buckled while injecting grout behind the frames.[33] To combat these problems, the AEC established an internal inspector training program and increased compliance inspections by 50 percent. By May 1968, the first AEC inspection team was trained and on its way to the Big Rock Point nuclear power plant near Charlevoix, MI.[34,35] A year later, the AEC began developing procedures for conducting compliance inspections.[36]

3.2.6 USS Scorpion

On May 21, 1968, the *USS Scorpion*, a nuclear submarine, sank in 10,000 feet of water about 400 miles southwest of the Azores. All 99 men on board were lost. The loss was a mystery because the *Scorpion* had supposedly just been reinspected and upgraded to incorporate new safety systems. This work had been ordered by the Navy after it lost the *USS Thresher*, another nuclear submarine, on April 10, 1963, due to a faulty design and defective welds.[37]

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[33] Refer to Supplement V of this report for additional details on these and other problems at the Big Rock Point, Oyster Creek, Pathfinder, Elk River, and Ginna nuclear power plants.

[34] *Fact Book for the Joint Committee on Atomic Energy*, U.S. Atomic Energy Commission, Washington, DC, July 1, 1974, pp. E-21 & 22.

[35] *Annual Report to Congress for 1968*, U.S. Atomic Energy Commission, Washington, DC, January 1968, p. 108.

[36] NUREG-1055, p. 1-8.

[37] Marc Meyer, *Improving Design Controls on Large Nuclear Projects*, CER Corporation, Las Vegas, NV, September 1990, p. 17.

Initial news releases suggested the *Scorpion* had experienced mechanical problems days prior to its sinking. A few months later, suspicions of quality defects were further fueled by a military Court of Inquiry that found the *Scorpion's* safety systems had never been upgraded. However, in 1985, a Virginia newspaper obtained several classified documents that pointed to a cause unrelated to problems with the submarine's mechanical safety systems. The documents indicated that *Scorpion* sank after an on-board torpedo exploded that the crew had been trying to disarm.[37,38]

3.2.7 ASLB Hearings

The day after the *Scorpion* incident, the ASLB concluded hearings on Northern States Power's application for Construction Permits for Prairie Island 1&2. The utility received a Construction Permit because, in part, the ASLB was pleased that:

> *The Applicant has established an adequate* ***quality assurance program*** *to assure conformance with recognized codes and good nuclear engineering practice. Under this program, all* ***quality assurance*** *will be monitored by the* ***quality assurance*** *section of the Applicant's* ***Construction Department*** *which will be staffed by* ***a quality assurance engineer****, test engineers, metallurgists, and inspectors for mechanical, electrical, and structural systems.*[39]

The Prairie Island hearing signalled a new position by the ASLB. This position was clarified and expanded upon during a hearing in Sacramento, California, on September 17, 1968, on a Construction Permit for Rancho Seco.[40] During the hearing the ASLB ruled that:[41]

> *[An Applicant must demonstrate it is] technically qualified to design and construct the proposed facility ... [It must show it understands the] undescribed technical aspects of* ***quality control and inspection programs****, ... operating procedures, [and] interpretations of the "state-of-the-art" as well as the timely results to be expected of research and development.*

The ASLB's timing was not purely coincidental. Five days prior to the Rancho Seco hearing, a few miles to the south, a fire broke out in San Onofre's switchgear room. It was the second switchgear fire at the plant that year, both the result of faulty wiring. The September fire was the most serious and closed the plant for six months.[42] The Associate Editor of *Power* magazine wrote:

> *In the nuclear scene, then, the peak of activity has shifted from specifying, purchasing and licensing to building a plant efficiently and economically. It is a matter of learning to "live nuclear." The emphasis has in large part fallen on* ***quality control****. Experience of others -* ***San Onofre*** *and* ***Oyster Creek*** *for example - teaches a hard lesson in light of the potential cost of $30-40,000/day for lost time. Utilities, as a result, are in the process of upgrading* ***quality assurance programs*** *in all areas: system and component design, fabrication, and plant assembly.*[43]

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[38] John May, *The Greenpeace Book of the Nuclear Age*, Pantheon Books, New York, NY, 1990, pp. 168-171. © 1989 by Greenpeace Communications Ltd.

[39] *Atomic Energy Commission Reports*, Volume 4, U.S. Government Printing Office, Washington, DC, 1973, pp. 124 & 125.

[40] *Federal Register*, DC, August 3, 1968, p. 11099.

[41] *Atomic Energy Commission Reports*, Volume 4, pp. 181-184.

[42] Refer to pages 16 and 17 of Supplement V of this report for more details on San Onofre 1.

[43] Sheldon Strauss, "1968 Energy-systems design survey: Nuclear-powered central stations," *Power*, New York, NY, October 1968, p. S-6. © 1968 by McGraw-Hill, Inc. [Citation by permission of copyright holder]

4.0 DEVELOPMENT OF APPENDIX B

4.1 REQUEST FOR QA CRITERIA

During a September 19-21, 1967, meeting of the ASLB Panel, the Panel asked and the AEC agreed to prepare quality assurance criteria that utilities would have to meet to obtain a Construction Permit or Operating License.[44,45] In November 1967, Edson Case, Director, Division of Reactor Standards, hired Wilbur (Bill) Morrison to write these criteria. Case knew Morrison from post-graduate naval construction and marine engineering classes they had taken at the Massachusetts Institute of Technology. During 1966 and 1967, Morrison was Nuclear Power Superintendent at the Navy's Charleston Shipyard and, from 1963 to 1966, he headed the Atomic Energy Commission's West Milton Field Office. While at West Milton, he participated in audits of contractors to verify they were complying with MIL-Q-9858A, *Quality Assurance Program Requirements.*[46,47,48,49]

Edson Case assigned Bill Morrison to work with Bob Minogue, Chief, Special Projects Branch. At the time, Minogue was under intense pressure to complete geological criteria for siting nuclear power plants.[50] Morrison was given responsibility for finalizing criteria which had been under development since November 1966. It required resolving review comments from the ACRS, various branches within the AEC, and outside consultants and U.S. Government agencies.[46,47,51]

Between September 1967 and April 1968, new quality problems kept surfacing with Oyster Creek's control rod drive housings. Then, in May 1968, further problems surfaced, defects in the plant's steam separator assemblies and core shroud support. The AEC needed quality assurance criteria that could be presented to Jersey Central Power & Light, Oyster Creek's owner.[52] Bill Morrison began work on the criteria immediately; however, progress was slow because he was also trying to finish his geological siting criteria assignment.[53] For the first few months progress was limited to tracking down and evaluating quality assurance criteria developed and used elsewhere.

4.2 ZION HEARINGS

4.2.1 Prehearing Conference

On September 10, 1968, the ASLB held a prehearing conference, in Washington, DC, on an application by Commonwealth Edison for a Construction Permit for Zion 1&2. John Buck (Automation

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[44] *Transcript of Prehearing Conference, Zion Station Units 1&2,* Ace Federal Reporters, Washington, DC, September 10, 1968, p. 35.

[45] *Annual Report to Congress for 1967,* U.S. Nuclear Regulatory Commission, Washington, DC, 1968, p. 306.

[46] Based on a December 4, 1992 interview with Bill Morrison.

[47] Personal correspondence from Bill Morrison dated December 22, 1992.

[48] Bill Morrison retired in 1986, however, does part-time consulting from his home in Rockville, MD. Edson Case passed away on September 15, 1991.

[49] Based on a December 8, 1992, interview with Bob Minogue, Morrison's supervisor during 1968-1970. Minogue is now retired and resides in Temecula, CA.

[50] The need for geological siting criteria was prompted by the cancellation of Bodega Bay in 1964 and Malibu in 1966 because of their proximity to active earthquake faults. Refer to Supplement VI for additional information on these two plants.

[51] Samuel Walker, pp. 108-111

[52] Samuel Walker, pp. 214, 215 & 219

[53] Comments on the siting criteria were not resolved and a final draft completed until January 1969. [Samuel Walker, p. 110]

Industries, Los Angeles, CA) and Steward Forbes (Phillips Petroleum, Idaho Falls, ID) represented the ASLB. They expressed reservations about the AEC's ability to conclude Zion had an acceptable quality assurance program. They told the AEC that, during the forthcoming evidentiary hearing, they wanted to hear about the criteria the AEC used to determine the acceptability of the Zion quality assurance program. John Buck reminded the AEC of the promise it made, during September 1967, to prepare criteria for reviewing quality assurance programs. He wanted to know if the criteria had been developed and, if not, why not.[54]

4.2.2 <u>First Evidentiary Hearing</u>

An evidentiary hearing was held in Waukegan, Illinois, on September 24, 25, and 26, 1968.[55] Buck and Forbes began questioning Zion's quality assurance program on September 25 and, due to the nature of the questions and answers, discussions carried over to the next day.

ASLB questions directed at the AEC were responded to by Charles Long and Voss Moore with limited support from Paul Check. All three men were technical specialists from the AEC's Division of Reactor Licensing.[56] Questions directed at Commonwealth Edison were responded to by Wallace Behnke with occasional help from Oliver Butler and Merle Goedgen.[57] Commonwealth Edison did not have a Quality Assurance Department representative at the hearing because no such department existed at the time.

Hearing highlights were as follows:[58,59]

a) **QA Criteria** The AEC informed the ASLB that it was still months away from having criteria it could use to review the acceptability of applicant quality assurance programs. John Buck said he was disturbed that, although NASA and the Navy had stringent quality assurance criteria, the AEC still had not developed comparable criteria. When asked about the possibility of "copying" the Navy's criteria, the AEC said it did not consider the criteria in MIL-Q-9858A, *Quality Assurance Program Requirements*, suitable for use on Zion or any other nuclear power plant without major modification. When asked about its compliance with MIL-Q-9858A, Commonwealth Edison told the ASLB that Zion's quality assurance program came close to but did not meet all of MIL-Q-9858A's criteria.

   Speaking in the AEC's defense, Commonwealth Edison cautioned the ASLB that:

   > *While criteria may be helpful, we cannot see how they can substitute for a judgement determination by the [AEC's] regulatory [staff] with respect to experience, competence and good management. In urging the regulatory staff to rush into drafting criteria, we feel there is a possibility the Board may run the risk of eliminating from the test of adequacy the professional judgement by the [AEC] of the character of the applicant. We should not lose this in our interest in criteria.*

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[54] *Transcript of Prehearing Conference, Zion Station Units 1&2*, September 10, 1968, pp. 13, 32 & 35.

[55] *Atomic Energy Commission Reports*, Volume 4, pp. 199, 200 & 204.

[56] Though well qualified technically, none of the three had prior quality assurance experience.

[57] Behnke was Assistant to the President, Butler was Assistant Vice President of Engineering & Construction, and Goedgen was a Project Engineer.

[58] *Transcript of Evidentiary Hearing, Zion Station Units 1&2*, Ace Federal Reporters, Washington, DC, September 25, 1968, pp. 336-371.

[59] *Transcript of Evidentiary Hearing, Zion Station Units 1&2*, Ace Federal Reporters, Washington, DC, September 26, 1968, pp. 522-529.

b) **Basis for AEC Review of QA Program** The AEC told the ASLB that it reviewed the Zion QA program from three perspectives: *1)* the organizational structure of the utility, reactor manufacturer, and architect/engineer; *2)* quality standards and industry codes that were being factored into purchase specifications, drawings, and other technical documents; and *3)* plans by the utility and key contractors for monitoring and auditing their work.

c) **Concrete Form Failure** John Buck asked the AEC whether it had reviewed the utility's nonconformance and corrective action procedures. He was told it had not. Buck turned to Commonwealth Edison and asked whether it had such procedures. The utility said procedures existed and briefly explained how they worked. Buck then informed a rather surprised audience that he had just visited Commonwealth Edison's Dresden 3 plant while concrete was being placed for the reactor building's foundation. As he approached the building, forms gave way and wet concrete poured out over workmen and a wide area of the foundation. Buck wanted to know how procedures planned for the Zion 1&2 would have handled this situation.

Commonwealth Edison said it doubted Zion procedures would have covered this particular situation in that a formwork failure, in its opinion, could not adversely impact the structural integrity of the plant's reactor buildings. This led Steward Forbes to ask who within Commonwealth Edison decides what is and isn't important and what type of system was in place that provided assurance decisions would be correct. The ASLB learned that Commonwealth Edison's "classification system" consisted of a combination of formal and informal practices, neither of which had been evaluated by the AEC. The ASLB was less than satisfied. To quote Steward Forbes:

> *I feel in the absence of such a plan that it becomes again an ad hoc procedure for each event and this depends heavily on the personal skill of the man who makes that decision and doesn't permit reviewers at any level to assess the adequacies of the program. It is essentially a "trust me" type of program. I find it impossible to make even a preliminary judgement on this other than a negative one and I don't understand how the [AEC] staff reached a positive conclusion on the basis of what has been submitted.*

d) **Procurement** The ASLB asked Wallace Behnke whether Commonwealth Edison had a checklist that was used to review procurement packages and specifications before they were issued to suppliers. Behnke replied, "Yes, we have such a form." The ASLB then asked, "Could we have the benefit of seeing what it looks like?" Behnke responded, "I am not proud to put this in the public record as yet because we don't think this represents our completed job in this area, but we have started on this task. We do have it in draft form." Further probing revealed that the AEC had not evaluated this aspect of the utility's quality assurance program.

e) **Design Reviews** The ASLB questioned Commonwealth Edison about the commitment in its *Guide to the Quality Assurance Program* to conduct design reviews. The ASLB asked if reviews were documented. The utility said they were. Further questioning found the process had not yet been proceduralized and the need to document reviews was at the reviewer's discretion.

In its report to the Commission, the ASLB characterized Commonwealth Edison's *Guide to the Quality Assurance Program* as a "statement of philosophy" rather than a viable quality assurance plan. It concluded that the basis for AEC approval of the *Guide* "was tenuous in view of the lack of criteria for its evaluation." When the hearing adjourned, Commonwealth Edison did not have a Construction Permit.[60]

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[60] *Atomic Energy Commission Reports*, Volume 4, p. 204.

4.2.3 Development of Zion Criteria

Following the hearing, the AEC assigned Merritt Langston to assist Bill Morrison develop criteria for evaluating the acceptability of the Zion quality assurance program. Merritt Langston was a quality assurance engineer with the AEC's Division of Reactor Development and Technology in Washington, DC. He had recently joined the AEC and had been given lead responsibility for the preparation of a new internal AEC standard, RDT F2-2, *Quality Assurance Program Requirements*.[61] Previously he had been with NASA's Space Nuclear Auxiliary Power Program including a tour of duty as Quality Assurance Manager at its Lewis Research Center.[62] During his tenure with NASA, Langston was also involved in upgrading NPC-200-2, *Quality Assurance Program Provisions for Space System Contractors*, to incorporate lessons learned from the Apollo 1 fire.[63,64]

An initial draft of the criteria was completed on October 3, 1968. The draft contained 16 criteria, A through P. Simultaneously, Commonwealth Edison began changing its QA Program to incorporate ASLB comments. On October 17, it requested that the ASLB reopen proceedings in order to hear new evidence regarding its Zion program. The ASLB agreed and scheduled a hearing for Washington, DC, on December 10, 1968. On November 12, the AEC completed a second draft of its review criteria.[62,65] The next day, Commonwealth Edison sent two new quality assurance documents to the AEC for consideration at the upcoming December 10 hearing. The documents, dated November 12, 1968, were titled, *Guide for the Quality Assurance for the Construction of Nuclear Generating Units* and *Zion Station Quality Assurance Plan* (hereafter called the *Zion QA Plan*).[66]

The AEC updated its review criteria to require a quality assurance program containing 15 criteria and reviewed Commonwealth Edison's new program documents against the criteria. These criteria are contained in Supplement I of this report along with notes on the source of each of the criteria. Six source documents are cited: *1)* ASME Section III, Appendix IX; *2)* MIL-Q-9858A; *3)* NHB 5300.4; *4)* RDT F2-2; *5)* 10CFR50, Appendix A; and the *6) Zion QA Plan*.

MIL-Q-9858A was the source of 63 percent of the criteria's requirements and 33 percent of its subtitles. Another important document was RDT F2-2, the source of 19 percent of its requirements and 14 percent of its subtitles. Interestingly, the *Zion QA Plan* was also an important document. It was the source of 33 percent of subtitles and, in part, one requirement. The similarity of the *Zion QA Plan* to the AEC criteria was not a coincidence. There were several reasons for this:

a) **MIL-Q-9858A** The *Zion QA Plan* was based on MIL-Q-9858A, modified as applicable for the utility business.[67] The AEC's criteria were also based on MIL-Q-9858A, modified as applicable for the nuclear power industry.

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[61] Milton Shaw characterized as "deplorable" the quality of work on the AEC's Advanced Test Reactor, completed during 1968 at the National Reactor Testing Station near Idaho Falls, ID. He ordered the development of RDT F2-2 and wanted it to be a quality assurance standard that could be imposed on contractors working on the AEC's new LOFT (Loss-of-Fluid Test) Facility, also located at the National Reactor Testing Station. [Samuel Walker, pp. 182, 183 & 213]

[62] Based on a January 10, 1992, interview with Merritt Langston.

[63] Based on a written statement of Merritt Langston's qualifications provided to the ASLB on December 17, 1968.

[64] Merritt Langston is currently employed by Science Applications International Corporation (SAIC) in Germantown, MD.

[65] *[Minutes of] Quality Assurance Subcommittee Meeting*, Advisory Committee on Reactor Safeguards, Washington, DC, February 5, 1969, p. 1.

[66] *Federal Register*, November 26, 1968, p. 17668.

[67] *Transcript of Evidentiary Hearing, Zion Station Units 1&2*, Ace Federal Reporters, Washington, DC, December 17, 1968, p. 553.

b) **Navy and NASA Influence** Commonwealth Edison consulted Navy and NASA quality assurance experts during development of the *Zion QA Plan*.[68] The AEC also used Navy and NASA quality assurance experts to develop its criteria.

c) **ASLB Influence** Both the AEC and Commonwealth Edison factored into their respective documents the quality assurance philosophy that Buck and Forbes expressed at ASLB hearings held on September 25 and 26, 1968.

d) **Precedence** The *Zion QA Plan* had already been accepted by the AEC and was superior to any other plan previously accepted by the ASLB.[69] Significantly different criteria would have been without precedent and led to finding the *Zion QA Plan* unacceptable. Rather than distance itself from the *Plan*, the AEC adopted those portions it considered to be a model for other utilities.

4.2.4 <u>Zion Facility Survey</u>

During December 2, 3, and 4, the AEC visited: *1)* the Zion construction site; *2)* the fabrication facilities of Chicago Bridge & Iron who was responsible for Zion's containment liner; and *3)* Sargent & Lundy's engineering offices. The AEC survey team evaluated the Zion quality assurance program against the 15 review criteria contained in Supplement I.[70]

The survey team consisted of Langston, Morrison, Paul Check, Charles Long, and Harold Thornburg. Check, Long, and Thornburg were assigned to the team because of their expertise in, respectively, nuclear, mechanical, and chemical engineering.[71,72]

The team found 7 of its 15 quality assurance criteria were being effectively implemented. Of the remaining eight criteria, evidence existed that six would be effectively implemented in time to support scheduled design, manufacturing, and construction activities. In most cases, either the criteria were being informally implemented while procedures were still being developed or procedures were in place but work had not yet started. For Criteria 5, "Design Reviews," and 13, "Corrective Action," the AEC survey team found implementation unsatisfactory; however, they received assurances from Commonwealth Edison that changes would be made to correct identified deficiencies.[73] With these assurances, the AEC concluded that:

> *Commonwealth Edison's Quality Assurance Plan, ... with its emphasis on documentation and verification, provides assurance of quality. Adequate control is being exercised for the work now in progress, although this control in some cases is not fully documented or implemented.*[74]

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[68] Ibid, p. 554.

[69] Ibid, p. 555.

[70] *Regulatory Staff Evaluation of Commonwealth Edison's Quality Assurance Program for the Zion Station*, U.S. Atomic Energy Commission, Washington, DC, December 17, 1968, p. 1.

[71] Based on written statements of the qualifications of Check, Long, and Thornburg as provided to the ASLB on December 17, 1968.

[72] *Transcript of Evidentiary Hearing, Zion Station Units 1&2*, December 17, 1968, pp. 621 & 622.

[73] Regarding Criterion 5, there were instances where design reviews had not been conducted or, if conducted, documentation of the reviews was either missing or inadequate. Regarding Criterion 13, the status of corrective action was not being tracked and documentation of deficiencies did not clearly describe either the adverse condition or resulting corrective action.

[74] *Regulatory Staff Evaluation of Commonwealth Edison's Quality Assurance Program for the Zion Station*, p. 22.

4.2.5 Second Evidentiary Hearing

A week prior to the second evidentiary hearing, the ASLB announced it would have to reschedule the hearing for December 17, 1968.[75] Merritt Langston and Bill Morrison attended the hearing as expert witnesses for the AEC. As before, John Buck and Steward Forbes represented the ASLB.

The ASLB was concerned that, even though the AEC survey team found quite a few instances where procedures and documentation were lacking, somehow it had concluded that the Zion quality assurance program was adequate. The ASLB asked if the AEC considered procedures and documentation to be just a good idea or an essential requirement. Langston and Morrison replied that, where required procedures were lacking, evidence existed that Commonwealth Edison was actively developing procedures and they were scheduled to be issued in a matter of days or weeks.[76]

The ASLB asked the AEC whether it looked into the quality of work done between July 1968, when work first started, and November 15, 1968, when Commonwealth Edison started imposing quality assurance program requirements on its contractors. Merritt Langston said both he and Bill Morrison had looked into this matter, and the only problem they found, of any significance, was a lack of documentation of design reviews.[77]

The hearing ended with assurances that the AEC would conduct regular audits of Commonwealth Edison to verify scheduled procedures were being developed and effectively implemented.[78] Nine days after the hearing, Commonwealth Edison received a Construction Permit for Zion 1&2.[79]

4.3 ISSUANCE FOR PUBLIC COMMENT

4.3.1 Growing Anti-Nuclear Sentiment

On December 17, 1968, the same day hearings were taking place on a Construction Permit for Zion 1&2, an amendment was issued to 10CFR50 requiring that utilities submit a *Preliminary Safety Analysis Report (PSAR)* with each application for a Construction Permit. Section 50.34(a)7 of the amendment required that the *PSAR* contain a "description and evaluation of the **quality assurance program** to be applied to the design, fabrication, construction, and testing of the structures, systems, and components of the facility."[80]

The publication of a regulation requiring a description of nuclear utility quality assurance programs made it even more important that AEC criteria exist on what constituted an acceptable program. The need for these criteria was further prompted by the publication of Sheldon Novick's *The Careless Atom* and remarks in *Forbes* by Phillip Sporn, former head of American Electric Power.

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[75] *Federal Register*, December 3, 1968, p. 17929.

[76] *Transcript of Evidentiary Hearing, Zion Stations 1&2*, December 17, 1968, pp. 625 & 626.

[77] Ibid, pp. 629-634.

[78] Ibid, pp. 672 & 673.

[79] NUREG-1350, *Nuclear Regulatory Commission Information Digest*, Volume 2, U.S. Nuclear Regulatory Commission, Washington, DC, March 1990, p. 88.

[80] *Federal Register*, December 17, 1968, p. 18611.

In the November 15, 1968, issue of *Forbes*, Phillip Sporn said the nuclear industry was moving too fast and quality assurance programs, especially inspection and testing practices, were inadequate. He warned utilities that, "We rushed into the Apollo program and incinerated three astronauts. Then we took some time out and really did an engineering job and had a successful Apollo 7. **We are going to have some accidents at atomic plants**."[81]

The Careless Atom was published in January 1969.[82,83] It was the first anti-nuclear publication to receive national attention. Sheldon Novick played on the public's fear of the "invisible menace," the radioactive isotope. To quote the *The New York Times*:

> *"The Careless Atom" explores the nature of the public's risk, both from the reactor explosion ... and radioactive pollution of the environment. Mr. Novick tells the tale of Bodega Head, Calif., where Pacific Gas and Electric tried to build a nuclear-powered electric generating plant only 1,000 feet from the San Andreas earthquake fault. He recounts potentially* ***disastrous accidents*** *at Lagoona Beach, Mich. [**Fermi 1**]; Chalk River, Ont.; Cumberland, England; and elsewhere... He points out that atomic-powered generators only become profitable when they are huge; and when they are huge, their malfunctioning will have huge consequences.*[84]

4.3.2 Assignment of Responsibilities

After the Zion hearings, Bill Morrison was assigned the job of upgrading the AEC's quality assurance criteria to include industry lessons learned. Milton Shaw appointed an industry advisory committee to provide Morrison with this input. He had his Assistant Director, Jack Crawford, sit in on committee meetings which were chaired by Stu Knight of Idaho Nuclear, National Reactor Test Station. There were about eight committee members including Fred Hannon of Union Carbide, Oak Ridge National Laboratory, and Jack Norris, Westinghouse, Hanford.[46,62,85]

The criteria went through many revisions. Due to the technical advisory committee's desire for more detail and documentation, the criteria became longer and longer.[86] Each major revision was sent to the advisory committee and Merritt Langston for review and comment.[46,62]

While most within the AEC agreed on the need for quality assurance, there was considerable debate over whether the criteria belonged in an internal AEC staff position paper or the *Code of Federal Regulations (CFR)*. If placed in the *CFR*, the criteria would be "mandatory" whereas, if placed in a staff position paper, they would serve as "guidance" to both AEC licensing personnel and nuclear utilities. As late as February 5, 1969, the issue was still being debated.[86] However, due to increasing pressure from the public, ASLB, and his staff, Harold Price, the AEC's Director of Regulation, finally decided on mandatory QA criteria in the form of a new Appendix B to 10CFR50.[49] This would require more than simply searching out and replacing every "*should*" in the Zion quality assurance criteria with a "*shall*." For starters, it would mean soliciting and incorporating input from interested

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[81] "Atomic Accidents", *Forbes*, New York, NY, November 15, 1968, p. 58. [Excerpt by permission of *Forbes* magazine © Forbes, Inc, 1968]

[82] Sheldon Novick, *The Careless Atom*, Houghton Mifflin, New York, NY, 1969.

[83] *1969 Book Review Index*, Gale Research Company, Detroit, MI, 1970, p. 439.

[84] John Leonard, "The Invisible Menace," *The New York Times*, New York, NY, March 10, 1969, p. 43. © 1969 by The New York Times Company [Excerpt by permission of The New York Times Company]

[85] Based on a January 10, 1992, interview with Jack Norris.

[86] *Minutes of Quality Assurance Subcommittee Meeting*, U.S. Atomic Energy Commission, Washington, DC, February 5, 1969, pp. 1 & 2.

members of the public, nuclear power industry, and affected government agencies. Creating a new regulation would be a lengthy and complicated process.

4.3.3 <u>Sources of Input</u>

Table 1 of this report identifies various documents that influenced the shape of the proposed new regulation. The most important was RDT F2-2, *Quality Assurance Program Requirements*, an internal standard, applicable to AEC development and test reactors, that was being written under Merritt Langston's direction. It was based on over 20 years of first-hand Commission experience with the design, construction, and operation of development and test reactors. Over time, RDT F2-2 became the source of about 38 percent of the requirements in Appendix B.

Another important source document was MIL-Q-9858A, *Quality Assurance Program Requirements*. This military specification had been around since 1963 and, though initially controversial, its requirements were being successfully implemented by an enormous network of small manufacturers and large companies whose existence depended on U.S. Government defense contracts. Eventually, it would become the source of about 29 percent of the criteria in Appendix B.

Indeed, the *Federal Register* attributed requirements in Appendix B to experience gained by the AEC with its own reactors, "work under the cognizance of the Department of Defense and the National Aeronautics and Space Administration [NASA]," and "cooperative Atomic Energy Commission-industry efforts."[87] The NASA work that went into Appendix B included a final draft of NHB-5300.4, *Quality Assurance Provisions for Aeronautical and Space System Contractors*. It accounted for about 8 percent of the criteria in Appendix B. Merritt Langston, who helped write NHB-5300.4, provided input on those sections of the Regulation that borrowed from NASA requirements.

The "cooperative effort" mentioned in the *Federal Register* was the assistance provided to the AEC by the industry advisory committee appointed by Milton Shaw. The nuclear industry had two other forms of input to the Regulation: *1)* review comments on the Regulation after it was issued for public comment, as will be discussed in Paragraph 4.4.1, and *2)* the nuclear power industry's quality assurance standard, ASME Section III, Appendix IX, *Quality Control and Nondestructive Examination Methods*. As shown in Table 1, about 8 percent of the requirements in Appendix B were based on material in Appendix IX of ASME Section III. Presumably, this was as a result of suggestions from the industry advisory committee.

The industry advisory committee felt its input was being ignored. Its biggest concerns with the proposed new Regulation were its requirements for controlling design activities and nonconforming hardware. The Regulation's proposed design control requirements could not be compared to those in existing industry standards because there were none.[88] In addition, its nonconformance control and corrective action requirements exceeded those currently in use in the industry.[89] To ease the committee's concerns, an agreement was reached with Clifford Beck, Deputy Director of Regulation, to implement Appendix B on a trial basis at Surry 1&2, a nuclear plant under construction about 125

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[87] *Federal Register*, April 17, 1969, p. 6599.

[88] As can be seen from Table 1 of this report, the design control requirements in Appendix B were borrowed from RDT F2-2 which, at the time, was still under development and would not be issued until June 1969.

[89] Bill Morrison and Bob Minogue told the author that they believed an organization's quality assurance program could only be as effective as its nonconformance control and corrective action procedures. They did not want to compromise what they regarded as the "heart and soul" of the proposed Regulation.

miles south of Washington, DC. Trial implementation was to take place following the Regulation's release for public comment and prior to its issuance for use.[46,49,85]

During March 1969, the draft Regulation was presented to and approved by the Commissioners and the Arabic designators on criteria were changed from Roman numerals.[62,90,91] A month later, on April 17, Appendix B was issued for public comment. Comments were due June 16, 1969.[92]

4.4. RESOLUTION OF COMMENTS

4.4.1 Reviewers

The draft Regulation attracted 147 comments from 18 different reviewers. Table 2 lists reviewers and summarizes comments. Comments were submitted by five engineer/constructors, five reactor manufacturers, five utilities, two consultants, and the Atomic Industrial Forum (AIF), a professional society. Seven organizations that provided comments also reviewed the draft Regulation for the AIF, thus, in effect, commenting on the document twice. These reviewers included American Electric Power, Babcock & Wilcox, Consolidated Edison, Gilbert Associates, Ralph Parsons Company, Stone & Webster, and Westinghouse.[93] Others who participated in the AIF review were Battelle Memorial Institute; Bechtel; Burns & Roe; Ebasco; Murray Joslin, Chairman, ASME N45 Nuclear Standards Committee; Philadelphia Electric; Southern Nuclear Engineering; and Stoller Associates.

What was surprising were the number of major nuclear utilities and contractors who chose not to comment on Appendix B: Sargent & Lundy (Bailly, Elk River, Dresden 2&3, Fermi 2, Fort St. Vrain, La Crosse, Quad Cities 1&2, and Zion 1&2), Commonwealth Edison (Dresden 1, 2 & 3; Quad Cities 1&2; and Zion 1&2), Tennessee Valley Authority (Sequoyah 1&2 and Browns Ferry 1, 2 & 3), Consumers Power (Big Rock Point, Midland 1&2, and Palisades), and Duke Power (Oconee 1, 2 & 3). Conspicuous by their absence were comments from the Edison Electric Institute, American Nuclear Society, and Institute of Electrical and Electronics Engineers. These three professional organizations were heavily involved in developing standards used in the nuclear industry.

4.4.2 Comments

Table 2 of this report shows the distribution of public comments on the proposed new regulation. Of 147 comments, 51 (35 percent) were incorporated. Westinghouse had the most comments and the most incorporated. Criterion III, "Design Control," received 27 comments, more than any of the other criterion. Ten of the 27 comments were incorporated, again, more than for any other criterion. Supplement II shows how the AEC factored public comments into the text of the Regulation.

None of the 18 generic comments were incorporated: three bemoaned the amount of documentation required; three remarked the criteria were too general; and two others complained they were too specific. There was no pattern to the other ten generic comments.

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[90] Presumably, the change was made to prevent confusion with the general design criteria in 10CFR50, Appendix A, which were identified with Arabic numerals.

[91] Samuel Walker, p. 220.

[92] *Federal Register*, April 17, 1969, pp. 6599-6602.

[93] Four individuals who served on the Atomic Industrial Forum review team also prepared review comments for their employer. The four were Paul Dragoumis of American Electric Power, Sherman Goodman of Gilbert Associates, Stanley Hellman of Ralph Parsons, and Larry Minnick of Yankee Atomic Electric.

Of 14 comments on the Introduction to Appendix B, three were incorporated. The first sentence of Appendix B was revised to require that *PSARs* contain a "description" rather than "description and evaluation" of the utility's quality assurance program. Though 6 of the 14 comments on the Introduction objected to applying the Regulation to operating power plants, the AEC disagreed after referring the issue to the American Nuclear Society's Subcommittee ANS-3, "Reactor Operations." The Subcommittee agreed that Appendix B should be applied to operating nuclear power plants.[94]

The requirement for design reviews received the most comments: four concerned reviewer independence; three requested allowing alternate calculations or qualification tests in lieu of design reviews; and six sought clarification of the level of detail expected during design reviews. One individual sent the AEC a four-page letter on why design reviews should be by "*other than the organization or group that performed the design.*" Though this particular public comment was not incorporated, Criterion III was modified to permit, in addition to design reviews, other forms of design verification.[95]

In addition to public comments, the AEC solicited and received comments from the ACRS and Sid Bernsen, Chairman, ASME N45 Ad Hoc Committee on Quality Assurance.[96] Bernsen's comments were mostly favorable. The ACRS's comments were less positive; nevertheless, during a February 1970 meeting, the ACRS accepted the AEC's proposed resolution of its comments.[97,98]

4.4.3 <u>Trial Use at Surry</u>

Virginia Electric & Power Company (VEPCO) received a Construction Permit for Surry 1&2 during June 1968.[99] VEPCO's general contractor, Stone & Webster, immediately began construction using a nuclear quality assurance program it had developed a year earlier. After Appendix B was issued for public comment, Stone & Webster started upgrading its program and, by January 1970, the program met the intent of the draft Regulation.[100] In February 1970, Stone & Webster hired a Welding Superintendent, Carl Houston, and began welding. The same month, VEPCO assigned a resident QA Supervisor to Surry, and Stone & Webster formed a Quality Assurance Department that was independent from its Construction and Engineering Departments.[101,102,103] Based on nine AEC audits conducted between April 1969 and April 1970, Surry's quality assurance program appeared to be in general compliance with 10CFR50, Appendix B.[104]

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[94] W. McCool to Distribution, "Amendment to 10CFR Part 50: Quality assurance Criteria for Nuclear Power Plants, *AEC Memorandum*, April 28, 1970, pp. 3 & 4.

[95] See Paragraph 5.2.4 for more on Criterion III design verification requirements.

[96] The ASME N45 Ad Hoc Committee on Quality Assurance (N45-3.70) was formed during May 1969. It included representative from the AEC, utilities, reactor suppliers, engineering firms, and construction companies. [Stanley Marash, "Quality Assurance Systems Requirements for Nuclear Power Plants - Part 1," *Journal of Quality Technology*, Milwaukee, WI, July 1973, p. 132.]

[97] W. McCool to Distribution, April 28, 1970, pp. 6 & 7.

[98] J. Rodgers to H. Hill, A. O'Kelly, and J. Hendrie, "Summary of the One-Hundred-Eighteenth ACRS Meeting, February 5-7, 1970," *ACRS Memorandum*, February 20, 1970, p. 16.

[99] NUREG-1350, pp. 85 & 86.

[100] *Supplemental Information Before the U.S. Atomic Energy Commission* [Prepared responses to questions from the ASLB at a March 10, 1972, Prehearing], Virginia Electric & Power Company, Surry, VA, March 1972, p. 26.

[101] Ibid, p. 29.

[102] *Testimony of Applicant's Witnesses Before the U.S. Atomic Energy Commission*, Virginia Electric & Power Company, Surry, VA, March 20, 1972, p. 24.

[103] *Transcript of Hearing in the Matter of Surry Power Station, Unit 1*, Ace Federal Reporters, Washington, DC, March 20, 1972, p. 163.

[104] *Supplemental Information Before the United States Atomic Energy Commission*, pp. 29 & 30.

4.4.4 Issuance for Use

On June 16, 1970, Harold Price presented the final proposed Regulation to Commissioners Glenn Seaborg, James Ramey, Theodore Thompson, and Clarence Larson for their approval. Thompson asked about the reasonableness of the requirement in Criterion VII that, before installing material or equipment, documentary evidence of acceptability had to be available at the nuclear power plant site. Price replied that a written statement of compliance from the supplier could meet the intent of this particular requirement. Thompson was satisfied and the four Commissioners voted to approve the publication of 10CFR50, Appendix B.[105]

On June 27, 1970, Appendix B to 10CFR50 was issued for use. To accommodate the change, Section 50.34 of 10CFR50 was simultaneously amended to require that *Preliminary* and *Final Safety Analysis Reports* describe how the applicant's quality assurance program satisfies the requirements of Appendix B. Compliance with the Regulation became mandatory on July 27, 1970.[106]

4.4.5 Epilogue

On July 6, 1970, Carl Houston, who resigned from Stone & Webster in late April, wrote to the AEC about defects in safety-related piping welds at Surry 1. In February 1971, VEPCO hired Southwest Research Institute (SWI) to re-examine 650 questionable welds in seven different piping systems. Six months later, SWI reported that 15 percent of the welds contained defects requiring repairs. Radiographs and other nondestructive examination methods used by SWI found microfissures, a lack of fusion, and overgrinding of welds.[107,108,109]

The adequacy of reactor cooling system welds was the major point of contention during hearings held in March 1972 on an Operating License for Surry 1. Carl Houston was the main witness for the Commonwealth of Virginia which was opposed to the License.[110] VEPCO voluntarily committed to examine selected welds at three times the frequency required by ASME Section XI, *Rules for In-service Inspection of Nuclear Reactor Coolant Systems.* The ASLB was impressed by VEPCO's commitment and thorough investigation of welding allegations. Having received the requisite assur-ances that Surry 1 would be operated in a safe manner, the ASLB issued VEPCO a License along with the following sage advice:[111]

> *This proceeding highlights the paramount importance of effective quality assurance ... programs and the imperative need for such programs from the very inception of a project. The hearing record provides a graphic illustration of inadequate implementation of an effective quality assurance ... program during the early but vital phase of plant construction and **it should serve as an object lesson for all applicants, the nuclear industry and the Atomic Energy Commission**.*

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105 *[Minutes of] Regulatory Meeting 285, June 16, 1970*, U.S. Atomic Energy Commission, Bethesda, MD, undated, p. 6.

106 *Federal Register*, June 27, 1970, pp. 10498-10501.

107 *Transcript of Hearing in the Matter of Surry Power Station, Unit 1*, p. 175.

108 *United States Atomic Energy Commission Report in the Matter of Surry 1 Nuclear Power Station*, U.S. Atomic Energy Commission, Washington, DC, February 23, 1972, pp. 17 & 18.

109 Resignation letter from Mr. Houston to C.J. Bradford of Stone & Websier, April 20, 1970

110 *Transcript of Hearing in the Matter of Surry Power Station, Unit 1 , p. 102.*

111 *Atomic Energy Commission Reports*, Volume 4, U.S. Government Printing Office, Washington, DC, 1973, pp. 825-828.

4.5 AMENDMENTS

4.5.1 Fuel Reprocessing Plants

On April 10, 1971, the AEC issued for public comment an amendment that expanded the scope of 10CFR50, Appendix B, to include spent fuel reprocessing plants.[112] At the time, West Valley was the nation's only operating fuel reprocessing plant; two others, Morris and Barnwell, were under construction. The amendment was issued for use on September 11, 1971, without any changes, and compliance with its provisions became mandatory on October 11, 1971.[113]

West Valley was closed in early 1972 for modernization and, because of rigorous new AEC licensing regulations, never reopened. The Morris facility was completed in late 1972 but, because of design deficiencies, never became operational. Construction on Barnwell was terminated in 1977, with the plant about half completed, because of President Carter's new nuclear policies. Further information on these three plants, the only fuel reprocessing plants to advance beyond engineering to construction, is contained in Supplement III. At present, no new plants are planned.

4.5.2 Organizational Relationships

On April 19, 1974, the AEC issued for public comment a proposed amendment to Criterion I, "Organization," of 10CFR50, Appendix B. The amendment was in response to concerns identified by the Atomic Safety and Licensing Appeal Board (ASLAB) during October 1973 about organizational relationships at the LaSalle 1&2 and Midland 1&2 nuclear power plants.[114] At both plants, site quality control personnel reported to a resident construction superintendent.[115] The ASLAB ruled this was inconsistent with Criterion I of 10CFR50, Appendix B, which required that personnel responsible for verifying the quality of work be independent of those responsible for performing the work.[116]

Numerous changes were made to the proposed amendment in response to public comments, the most significant being the addition of a new fourth and fifth sentence to Criterion I that defined the terms "safety related functions" and "quality assurance functions." With these changes, the amendment was issued for use on January 20, 1975, and compliance with its provisions became mandatory on February 19, 1975.[115]

What was most surprising about the outcome was, if anything, the amendment seemed to legitimize rather than prohibit the type of organizational structures that had been in place at LaSalle 1&2 and Midland 1&2. The eighth sentence of the amended Criterion I reasoned that:

> *Because of the many variables involved, such as number of personnel, the type of activity being performed, and the ... locations where activities are performed, the organizational structure for executing the quality assurance program may take on many forms provided that the persons and organizations assigned quality assurance functions have [the] required authority and organizational freedom.*

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112 *Federal Register*, April 10, 1971, pp. 6903 & 6904.

113 *Federal Register*, September 11, 1971, p. 18301.

114 *Federal Register*, April 19, 1974, pp. 13974 & 13975.

115 *Federal Register*, January 20, 1975, pp. 3210C-3211D.

116 *Atomic Energy Commission Reports*, Volume 6, U.S. Government Printing Office, Washington, DC, 1974, pp. 816-820.

The intent of the amendment was to reduce the height of the wall between "quality assurance" and "production" personnel. Its author, Bill Morrison, wanted quality assurance to be a team effort.[47,117] Though the amendment relaxed the organizational independence requirements of Criterion I, nuclear utilities and suppliers continued establishing separate QA departments. This growth in separate QA departments resulted from guidance that appeared in the *Federal Register* with the new amendment. The *Federal Register* referenced the AEC's "Rainbow Books" which recommended that quality assurance directors report to the same level of management as directors of the company's engineering, manufacturing, or construction departments, as applicable. Consequently, the QA director usually ended up reporting to either the company president or a senior vice president.[118]

4.5.3 Three Mile Island Accident

On March 28, 1979, Three Mile Island 2 experienced a partial core-melt, the worst accident ever at a civilian U.S nuclear power plant.[119] The Nuclear Regulatory Commission (NRC)[120] immediately stopped evaluating seven pending Construction Permits including a Permit for eight floating plants. The next 15 months was spent looking into the cause of the accident. During June 1980, the NRC issued NUREG-0660, *NRC Action Plan Developed as a Result of the TMI-2 Accident*. Four months later, the NRC announced it would be changing its licensing requirements.[121]

During early 1981, the NRC held public meetings on its proposed new requirements and, on March 23, 1981, issued a draft for public comment. Included in the proposed Regulation, to be added to 10CFR50.34, "Contents of applications; technical information," were new QA requirements.[122] Forty-three (43) reviewers commented on the draft Regulation. Five reviewers (ASME, Bechtel, Gilbert, Stone & Webster, and TVA) commented on its quality assurance requirements. Though three reviewers recommended placing the proposed new QA requirements in Appendix B, the NRC declined without explaining the basis for its reluctance.[123]

The new Regulation was issued on January 15, 1982, as 10CFR50.34(f), "Additional TMI-related requirements."[124] It was applicable to all nuclear power plants licensed after February 16, 1982, and contained 149 words of new quality assurance requirements.[125] The text of the QA requirements appear in Supplement IV along with notes explaining the basis for selected requirements and changes that occurred as a result of public comments.

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[117] In the January 20, 1975, *Federal Register* (p. 3210C), Bill Morrison wrote, "The greater the independence or separation, for example, the more difficult it may be in some instances to maintain lines of communication in identifying quality problems and initiating corrective action."

[118] The AEC's "Rainbow Books" included the "Gray Book," WASH-1283, *Guidance on Quality Assurance Requirements During the Design and Procurement Phase of Nuclear Power Plants*, June 7, 1973, and Revision 1, May 24, 1974; "Orange Book," WASH-1284, *Guidance on Quality Assurance Requirements During the Operations Phase of Nuclear Power Plants*, October 26, 1973; and "Green Book," WASH-1309, *Guidance on Quality Assurance Requirements During the Construction Phase of Nuclear Power Plants*, May 10, 1974. The color of their covers were gray, orange, and green, respectively.

[119] Refer to Paragraph 6.3.5 and Supplement VI for further information on Three Mile Island 2.

[120] The Energy Reorganization Act of 1974 abolished the Atomic Energy Commission (AEC). On January 19, 1975, the Nuclear Regulatory Commission was established and took over the AEC's regulatory responsibilities. The Energy Research and Development Administration (ERDA) was established to handle the AEC's other work. In 1977, ERDA became the Department of Energy.

[121] *Federal Register*, October 2, 1980, pp. 65247 & 65248.

[122] *Federal Register*, March 23, 1981, pp. 18045, 18046 & 18048.

[123] *Federal Register*, January 15, 1982, pp. 2289, 2290 and 2296-2298.

[124] Ibid, p. 2286.

[125] These 149 words represent about 5.3% of the 5.7 pages of new text in 10CFR50.34(f).

Placing nuclear power plant QA requirements in a location other than Appendix B was an experiment that failed. As evidenced by the following, the industry has essentially ignored the QA requirements contained in 10CFR50.34:

a) **NRC** When developing QA requirements for high-level waste repositories (10CFR60), spent fuel shipping casks (10CFR71), and independent spent fuel storage facilities (10CFR72), the NRC passed over the QA requirements in 10CFR50.34.

b) **Codes & Standards** Over a decade later, nuclear industry codes and standards have not been revised, nor are revisions pending, to incorporate the QA requirements of 10CFR50.34.

c) **Utilities** Though basically prohibited by 10CFR50.34, nuclear utilities have been dismantling their QA Departments and reassigning inspection, testing, and other QC functions to line organizations responsible for the work being performed. This is being done with the NRC's knowledge and consent in an effort to give line managers the "tools" needed to attain quality.

4.5.4 Counterfeit and Fraudulent Parts

In January 1985, a small Houston-based distributor of industrial fasteners publicly questioned the engineering capability of commercially available fasteners.[126] The Industrial Fasteners Institute investigated the charges by collecting a sample of three-hundred SAE J429, Grade 8, bolts and nuts from suppliers on the Atlantic, Gulf, and Pacific Coasts; along the Great Lakes; and in the Mississippi River Basin. Fifty (50) bolts and seven nuts were drawn from this sample and tested during April 1986. Only 11 of the 50 bolts and 2 of the 7 nuts met specifications. The Industrial Fastener Institute estimated that the United States used about 1.5 billion Grade 8 bolts each year and that millions of nonconforming bolts were being installed in applications that posed a threat to life and property. The Industrial Fastener Institute sent its test report to the U.S. Customs Service with a recommendation that it "conduct an immediate and sweeping investigation of all bolts in bonded warehouses and in transit or at various ports of entry."[127]

News of substandard bolts and other parts eventually reached the NRC. The NRC requested that utilities physically test a small sample of fasteners in their inventories. About 10 percent of the tested fasteners failed to meet specifications. During 1988 and 1989, the NRC issued ten bulletins covering counterfeit and fraudulent fasteners, pipe fittings, electrical fuses, circuit breakers, structural steel shapes, and valves. A total of 72 of 113 operating nuclear plants were found to have counterfeit or fraudulent parts of one type or another. Suppliers were prosecuted and seven utilities were fined for violations of the procurement control requirements of 10CFR50, Appendix B.[128]

On March 6, 1989, the NRC published an "Advanced Notice of Proposed Rulemaking" in the *Federal Register*. The notice requested comments on the need to amend Criteria III, IV, VII, and XV to Appendix B, to prevent the inadvertent use of counterfeit and fraudulently marked parts.[129]

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126 Raymond Klempin, "Imported bolts come under attack," *Houston Business Journal*, Houston, TX, January 21, 1985, pp. 1, 10 & 11.

127 *Research Report on False Grade 8 Engineering Performance Marks on Bolting and Improper Marking of Grade 8 Nuts*, Industrial Fasteners Institute, Cleveland, OH, April 4, 1986, pp. 1-5.

128 GAO/RCED-91-6, *Counterfeit and Substandard Products Are a Governmentwide Concern*, U.S. Government Accounting Office, Washington, DC, October 16, 1990, pp. 13, 18, 19, 26 & 41.

129 *Federal Register*, March 6, 1989, pp. 9229-9233.

The NRC received 64 sets of comments on its notice. Most of the comments strongly opposed additional regulations and, instead, recommended that the NRC endorse nuclear industry codes and standards. The Electric Power Research Institute (EPRI) had taken the lead in marshalling a consensus within the nuclear community and developing guidance documents on how to prevent the inadvertent use of counterfeit and fraudulent parts. The first EPRI guideline contained recommendations for using commercial-grade hardware and the second contained recommendations for purchasing and receiving nuclear hardware.[130] By January 1990, all nuclear utilities were i nplementing the first guideline and, by July 1992, were implementing the second guideline.[131] Based on this and related industry initiatives, the NRC dropped its plans to amend 10CFR50, Appendix B.[132]

4.5.5 Performance-Based Requirements

There is pressure on nuclear utilities to lower operating and maintenance costs. This has spawned a move toward "performance-based" quality assurance, programs that focus on substance (end product quality) rather than form (incidental administrative details and paperwork). Nuclear utilities want changes to codes, standards, and regulations that encourage or require performance-based quality assurance programs. In theory, this would result in greater assurance of quality and lower operating and maintenance costs. At least one utility group has asked the NRC to amend Appendix B to make it more performance-based.[133] Though the NRC supports this concept, it is unlikely Appendix B will be amended before 1997. The NRC is working with limited funds, has many other priority projects, and sees nothing in the current Appendix B that stops utilities from factoring performance-based concepts into their quality assurance programs.[134]

4.6 SHIFTS IN REQUIREMENTS

4.6.1 General

Table 3 of this report identifies the number of words in each of the 18 criteria in Appendix B at its inception and with each change up to through January 1982. Though, alone, words are not criteria, together they form phrases that are requirements. In general, lengthy criteria tend to be more important and difficult to satisfy than those with few words. Years have been spent studying these words and writing codes and standards that represent the nuclear industry's understanding of their intent. Nuclear utilities and suppliers have invested millions of dollars preparing QA manuals and procedures designed to address requirements within these codes and standards. Thirty (30) words in a criterion can translate into 300 words in a corresponding standard and 3000 words in a procedure. Thus, a slight shift in the wording of a criterion can have a profound impact on codes and standards and trigger extensive changes to thousands of QA manuals and procedures.

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[130] The two guidelines were EPRI NP-5652, *Guideline for the Utilization of Commercial Grade Items in Nuclear Safety Related Systems*, Palo Alto, CA, March 1981, and EPRI NP-6629, *Guidelines for the Procurement and Receipt of Items for Nuclear Power Plants*, Palo Alto, CA, January 1990. EPRI NP-6629 incorporates by reference EPRI NP-6630, *Guidelines for Performance-Based Supplier Audits*, Palo Alto, CA, January 1990.

[131] GAO/RCED-91-6, pp. 27 & 28.

[132] Based on discussions during September 1992 and January 1993 with NRC and industry representatives working on nuclear quality assurance codes, standards, and guidelines.

[133] On March 26, 1992, the Nuclear Management and Resources Council (NUMARC) wrote to the NRC recommending that 10CFR50 Appendix B, be "updated for consistency with performance based regulations and with new quality concepts."

[134] Monti Dey, NUREG/CP-0129, *Workshop on Program for Elimination of Requirements Marginal to Safety*, U.S. Nuclear Regulatory Commission, Washington, D.C, September 1993, pp. 7-19, 119, and B-9.

4.6.2 1968 - 1969

As can be seen from Table 3, criteria used by the AEC to evaluate the *Zion QA Plan* did not include requirements later contained in Criteria IX, XI, and XIV. These criteria were added before 10CFR50, Appendix B, was issued for public comment during April 1969, and currently account for 280 of its 648 words on construction and manufacturing controls. This omission is difficult to explain in that corresponding criteria were contained in MIL-Q-9858A, the primary source document used during development of QA criteria for Zion. Also, though the *Zion QA Plan* did not cover Criterion XIV, it thoroughly addressed the requirements of Criteria IX and XI.[135]

There was an enormous increase in requirements going from the draft criteria used on Zion to the draft Regulation issued for public comment in April 1969. The Zion draft contained 450 words whereas the public comment draft had 1746 words, a 288 percent increase. This increase brought the level of detail in 10CFR50, Appendix B, much closer to but still short of that in MIL-Q-9858A and NHB 5300.4, the other two Government quality assurance regulations.

The April 1969 increase in requirements had its greatest impact on Criterion III, "Design Control". Over 180 words were added to Criterion III and its share of Appendix B requirements jumped from 6.7 to 12.1 percent. Because the total length of Appendix B grew by 180 words, as a percentage of the whole, requirements associated with administrative and procurement activities decreased by 5.0 and 2.0 percent, respectively.

4.6.3 1970 - 1982

Resolution of public comments resulted in increasing the Regulation by 233 words prior to issuance in June 1970. Again, the biggest change was in Criterion III which increased by 94 words. The largest decrease was in Criterion I which lost 43 words. This resulted from relocating the last two sentences of Criterion I, regarding management assessments, to Criterion II. The 94-word increase in Criterion III was due to a combination of factors including: *1)* public comments requesting alternate design verification methods; *2)* the need to establish a tie to 10CFR50, Appendix A, by mentioning something about quality standards; and *3)* lessons learned during the Zion hearings about the necessity of controlling interfaces between the utility, architect/engineer, reactor manufacturer, and other organizations with design responsibility.

Another shift in requirements took place in January 1975, upon issuance of a second amendment to 10CFR50, Appendix B. The change added 170 words to Criterion I, more than doubling its length, and made it the second longest of the eighteen criteria.

The last shift occurred in January 1982 with the addition of a set of new TMI-related requirements to 10CFR50.34. The new Regulation added 149 words to the body of QA requirements in 10CFR50. At least indirectly, it added 121 words of text to Criteria I, II, and III, the three longest Criterion in Appendix B. Most importantly and as discussed in Paragraph 4.5.3, burying the new QA requirements in 10CFR50.34 made the requirements far too easy to overlook and ignore.[136]

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[135] *Zion Station Quality Assurance Plan*, Commonwealth Edison, Chicago, IL, November 12, 1968, pp. 28, 29 & 32.

[136] Though the QA requirements in 10CFR50.34(f) only apply to plants that obtained Construction Permits on or after February 16, 1982, there has been virtually no movement by either the NRC or nuclear utilities and suppliers to embrace the requirements. Normally the NRC encourages voluntary compliance and industry codes and standards are updated to incorporate and interpret the requirements.

5.0 WEAKNESSES

5.1 INTRODUCTION

5.1.1 General

The nuclear industry has had considerable difficulty trying to interpret 10CFR50, Appendix B, and establish QA programs that meet its 18 criteria. This has been due to weaknesses in the Regulation's structure and language. These weaknesses include redundancy, undefined terms, illogically grouped criteria, and poorly balanced or missing requirements. Appendix B was stitched together out of material borrowed from other documents. Pieces didn't always fit.

5.1.2 Government Studies

Early in 1973, Manning Muntzing, AEC Director of Regulation,[137] requested a study of how effectively the criteria of Appendix B were being implemented by nuclear utilities.[138] The study, completed in June 1973, three years after the Appendix B was issued for use, found the Regulation was poorly understood and implementation was inadequate.[139]

To improve implementation, Muntzing announced that the AEC would begin: *1)* considering an inadequate QA program description as, by itself, grounds for rejecting an application for a Construction Permit; *2)* requiring that utilities successfully demonstrate their QA programs during start-up testing to obtain an Operating License; and *3)* holding conferences in Atlanta, Philadelphia, Denver, Newark, Chicago, and San Francisco to explain Appendix B to nuclear utilities and contractors.[132] During July 16-20, 1973, the QA conferences covered design and procurement, during November 26-29, 1973, they covered plant operation, and during June 10-13, 1974, they covered construction.[140] While helpful, the conferences did not change the Regulation's inherent weaknesses.

During 1977, the NRC Division of Project Management sponsored a three-month study of QA practices in the nuclear industry. A final report, NUREG-0321, *A Study of the Nuclear Regulatory Commission Quality Assurance Program*, was issued in August 1977. Though the study found numerous weaknesses in Appendix B, industry implementation, and NRC oversight of compliance with the Regulation, few of its suggestions were adopted. Undoubtedly this cool reception was, at least in part, due to the fact that: *1)* the study was by a team whose members, collectively, had zero prior nuclear power plant experience; and *2)* findings in the report were based on confidential interviews including meetings with Dan Ford of the Union of Concerned Scientists.[141]

On January 4, 1983, Congress directed the NRC to study how to improve the quality of nuclear power plant design and construction. The request was in response to a March 1979 accident at

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137 During January 1973, Manning Muntzing replaced Harold Price as AEC Director of Regulation.

138 Manning Muntzing was concerned about a decline in the performance of operating nuclear power plants and increase in violations of regulations. During 1973, AEC inspectors reported 298 violations of regulations with about 25 percent representing deviations from quality assurance requirements. ["Nuclear Plant Availability is Dwindling, says Muntzing," *Nucleonics Week*, New York, NY, May 16, 1974, pp. 1 &2] © McGraw-Hill, Inc.

139 *Annual Report to Congress for 1973*, U.S. Atomic Energy Commission, Washington, DC, 1974, pp. 67 & 68.

140 *Fact Book for the Joint Committee on Atomic Energy*, U.S. Atomic Energy Commission, Washington, DC, July, 1, 1974, pp. E-48, 51 & 55.

141 NUREG-0321, *A Study of the Nuclear Regulatory Commission Quality Assurance Program*, U.S. Nuclear Regulatory Commission, Washington, DC, August 1977, bibliographic data sheet and pp. 7-10, 12 & 17.

Three Mile Island 2 followed by a rash of significant quality assurance problems at the Diablo Canyon, Marble Hill, Midland, South Texas and Zimmer nuclear power plants.[142]

The NRC completed an initial report, NUREG-1055, *Improving Quality and the Assurance of Quality in the Design and Construction of Nuclear Power Plants*, and submitted it to Congress on April 4, 1984. NUREG-1055 (p. 2-39), often called "The Ford Amendment Study," concluded that:

> *... the primary cause of the quality problems in the nuclear industry was shortcomings in management. Real improvements to address this root cause must come from industry itself. The NRC cannot write a regulation that will achieve good utility management [and] ... cannot inspect quality into the plant.*[143]

NUREG-1055 contained many lesser findings and recommendations, most of which were directed at the Commission. With a few notable exceptions, its recommendations have been successfully implemented. Exceptions are discussed in Paragraphs 5.2.4, 5.2.6, 5.4.4, and 5.5.2, below.

5.1.3 Industry Codes and Standards

NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities*, was initially published by ASME in August 1979. It consolidated eight QA standards developed between 1971 and 1978 and was endorsed by the NRC during August 1985.[144,145] NQA-1 is updated annually and represents the nuclear industry's attempt to expand on and interpret the requirements of Appendix B. NQA-1 Basic Requirements 1 through 18, parallel, respectively, Criteria I through XVIII of Appendix B. NQA-1 Supplements and Appendices contain, respectively, supporting requirements and guidance.

Subsections 5.2 through 5.5, below, will discuss specific weaknesses in Appendix B. As appropriate, the Subsections will mention whether an Appendix B weakness carried over into NQA-1 or whether, in clarifying the intent of Appendix B, NQA-1 managed to neutralize the weakness. The Subsections will also sometimes reference three other widely-recognized quality standards, ISO 9001, *Quality Systems - Model for Quality Assurance in Design/Development, Production, Installation, and Servicing*, March 1987; ISO 9004, *Quality Management and Quality System Elements - Guidelines*, March 1987; and DOE Order 5700.6, *Quality Assurance*, Revision C, August 1991.

ISO 9001 and 9004 are international quality standards. ISO 9001 has been incorporated into the laws of eighteen European countries.[146] DOE Order 5700.6 was originally written to replace RDT F2-2 when, in 1977, the U.S. Department of Energy (DOE) inherited the AEC's research, production,

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142 Public Law 97-415, *NRC Authorization Act for Fiscal Years 1982 and 1983*, United States Congress, Washington, DC, January 4, 1983.

143 This rebutted a 1978 Government Accounting Office (GAO) recommendation that the NRC increase its presence at nuclear power plants in order to inspect quality into plants. It was followed, a year later, by a GAO recommendation that the ceiling on NRC fines be greatly increased. Both recommendations were acted on. Refer to EMD-78-80, *The Nuclear Regulatory Commission Needs To Aggressively Monitor And Independently Evaluate Nuclear Powerplant Construction*, dated September 7, 1978, and EMD-79-9, *Higher Penalties Could Deter Violations Of Nuclear Regulations*, dated February 16, 1979.

144 NQA-1 consolidated N45.2, *Quality Assurance Program Requirements for Nuclear Facilities*, 1977, and seven "N45.2 Daughter Standards." These standards were N45.2.6, *Qualification of Inspection, Examination, and Testing Personnel for Nuclear Power Plants*, 1978; N45.2.9, *Requirements for the Collection, Storage, and Maintenance of Records for Nuclear Power Plants*, 1974; N45.2.10; *Quality Assurance Terms and Definitions*, 1973; N45.2.11, *Quality Assurance Requirements for the Design of Nuclear Power Plants*, 1974; N45.2.12, *Requirements for Auditing of Quality Assurance Programs for Nuclear Power Plants*, 1977; N45.2.13, *Quality Assurance Requirements for Procurement of Items and Services for Nuclear Power Plants*, 1976; and N45.2.23, *Qualification of Quality Assurance Program Audit Personnel for Nuclear Power Plants*, 1978. © American Society of Mechanical Engineers

145 Regulatory Guide 1.28, *Quality Assurance Program Requirements (Design and Construction*, U.S. Nuclear Regulatory Commission, Washington, DC, Revision 3, August 1975.

146 "EUROPE 1992: Its Effect on International Standards," *Quality Progress*, Milwaukee, WI, June 1990, p. 31.

and production reactors. The Order currently applies to all DOE-funded programs, nuclear and non-nuclear, that are do not fall under the NRC's jurisdiction. Also, the current Order departs from earlier versions by replacing reference to NQA-1 with "performance-based" criteria.

5.2 REDUNDANCY

5.2.1 General

Quality assurance manuals and procedures are usually organized to acknowledge and satisfy requirements in the same order they appear in Appendix B. Because of the redundancy between criteria in Appendix B, the danger exists that different approaches will be taken to satisfy the same or closely related requirements. Examples of this redundancy and problems are provided below.

5.2.2 Organization

The third sentence of Criterion I reads:

> *The authority and duties of ... organizations performing activities affecting the safety related functions of structures, systems, and components shall be clearly established and delineated in writing.*

The third sentence of Criterion II reads:

> *The applicant shall identify ... the major organizations participating in the program, together with the designated functions of these organizations.*

NQA-1 eliminated the redundancy in Appendix B by: *1)* requiring in Basic Requirement 1 documentation of each organization's "functional responsibilities [and] levels of authority," and *2)* avoiding mention in Basic Requirement 2 of organizational responsibilities. Though not specifically required, most companies document the functional responsibilities of both their internal organizational units and principal contractors, especially direct-support contractors.

5.2.3 Special Processes

The seventh sentence of Criterion II reads:

> *The program shall take into account the need for **special** controls, **processes**, test equipment, tools, and skills to attain required quality and the need for verification of quality by inspection or test.*

The above requirement seems to cover the same basic topic as Criterion IX which states:

> *Measures shall be established to assure that **special processes**, including welding ... , are controlled and accomplished by qualified personnel using qualified procedures ...*

This redundancy also appears in NQA-1 Basic Requirements 2 and 9. "Special controls" are controls that require qualified procedures. According to NQA-1 Supplement S-1, "special processes" are those requiring special equipment or skills. In actual practice, most QA programs focus on Criterion IX and pay little attention to the special process requirements in Criterion II.

5.2.4 Design Verification

The sixth sentence of Criterion III reads:

> *The design control measures shall provide for verifying or* ***checking the adequacy*** *of design, such as by the use of design* ***reviews****, by the use of alternate or simplified calculations, or by the performance of a suitable testing program.*

The second sentence of Criterion VI states:

> *These measures shall assure that documents, including changes, are* ***reviewed for adequacy*** *and approved for release ...*

Similar language appears in Basic Requirements 3 and 6. On July 15, 1986, ASME attempted to clarify the relationship between the two Requirements in *NQA Interpretation QA86-012*. The *Interpretation* read:

> *[V]erification can be accomplished on an individual basis or as part of a broader design verification activity... It is the responsibility of the design organization to define the requirements for review and approval of individual design analyses and calculations, and the relationship of these reviews in the design process to required design verifications. If the review and approval of individual design analyses and calculations satisfy the requirements [of NQA-1 Supplement 3S-1], an additional verification of those design analyses and calculations is not required.*

A few months later, on September 30, 1986, ASME tried to explain the difference between "verifying" and "checking" in *NQA Interpretation QA85-009*. The explanation read:

> *"[V]erification and "checking" are intended to be synonymous terms which represent the same requirement. If the checking process complies with all the design verification requirements of NQA-1 Supplement 3S-1 ..., the process qualifies as design verification. To the extent that the process does not accomplish the above, it must either be supplemented by appropriate actions so that the aggregate process does accomplish the above, or the design verification must be accomplished by other appropriate means such as ... performance of a suitable testing program.*

The authors of Appendix B never foresaw or intended to permit the use one review to satisfy both Criteria III and VI. The design review requirements in Appendix B were based on Paragraph 3.5 of RDT F2-2 and, to a lesser extent, Paragraph 1B301 of NHB 5300.4. These two source documents required formal design reviews and document reviews. Formal design reviews were conducted to "qualify" a completed design prior to its release for use. To avoid having to "swallow the elephant in one bite," they were conducted at key design milestones as well as at the end of final design.[147] Document reviews were performed on individual design documents as they were completed. Their purpose was to catch errors and omissions as soon as they occurred and prior to using one design document as input to another. Design errors, like viruses, tend to spread to other documents and, unless quickly identified, can be costly and time-consuming to correct. Thus, an important secondary purpose of document reviews was to minimize the rework necessary to correct problems identified during design reviews, qualification testing, or verification using alternate calculations.[49]

Because of the above *NQA Interpretations* and tempting schedule and financial incentives, design organizations often try to use a single review, called a "design verification review," to satisfy Basic

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[147] NASA and the AEC required that both design and quality assurance personnel participate in formal design reviews.

Requirements 3 and 6.[148] NQA-1 Supplement 3S-1 requires that personnel engaged in such reviews verify that: *1)* design documents and procedures address all applicable organizational interfaces; *2)* inputs were correctly selected and incorporated into the design; *3)* assumptions are reasonable and provisions exist for reverifying assumptions, if necessary, as the design matures; and *4)* appropriate design methods were used and output is reasonable compared to input.

A "design verification review" in accordance the above requirements invites the following problems which, if repeated across a range of documents, could be devastating:

a) **Assumptions and Organizational Interfaces** Design organizations usually have a generic interface control procedure and a technical procedure that requires that originators identify assumptions that must be reverified at a later date. Because interface controls already exist in procedures, verification personnel see no need for further requirements in design documents. Assumptions are rarely reverified. First, document originators seldom require reverification. Second, even when required, few design organizations have the type of comprehensive configuration management system needed to ensure timely reverification of assumptions. Eliminating milestone design reviews does away with periodic evaluations of the validity of assumptions and the impact of organization changes on design interfaces.

b) **Math Errors** Supplement 3S-1 does not require checking for math errors; it requires looking at the "reasonableness" of output. Though computers complete most design calculations, there are still a significant number of "hand" calculations in a plant's design. NQA-1 Supplement 6S-1 requires checking the "correctness" of information in documents. A "reasonableness" review only makes sense if documents have already been reviewed for correctness.

c) **Acceptance Criteria** Supplement 3S-1 does not require verifying that output documents contain test and inspection acceptance criteria. This information is required by Criteria III and V.[149] NQA-1 Supplement 6S-1 requires evaluating the "completeness" of information in documents. Not looking for omissions during design reviews only makes sense if this was already done during earlier reviews.

Between 60 and 80 percent of the cost of a project is fixed during design, and up to 40 percent of all quality problems can be attributed to design deficiencies. A 1986 study found that errors in original design documents were the second leading reason for reactor scrams.[150] What is most significant about this finding is that it is based on conditions at nuclear power plants seven years after the accident at Three Mile Island 2 and a major effort by the NRC and utilities to reevaluate the technical adequacy of plant designs. The Ford Amendment Study concluded that:[151]

> *The design area has received little inspection attention in the past, and recent experience has suggested that it should receive greater attention. This design inspection program also uses the team approach and encompasses the total design process on a selected system, from formulating design and A&E criteria through development and translating the design to actually performing site construction.*

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148 For a detailed discussion of "formal design reviews" as conceived by the authors of Appendix B and "design verification reviews" as currently practiced in the nuclear power industry refer to: John Burgess, *Design Assurance for Engineers and Managers*, Marcel Dekker, Inc, New York, NY, 1984, pp. 167-180.

149 See Paragraph 5.2.5 for related weaknesses.

150 Marc Meyer, pp. 3 and 30.

151 NUREG-1055, p. 7-13 & 14.

Though the NRC has implemented the Ford Amendment Study's recommended approach to verifying design adequacy, others have not followed suit. For the most part, formal design reviews are only conducted when specifically requested by the NRC.[151] The requirements of Appendix B and NQA-1 should be amended to: *1)* delete reference to "checking;" *2)* require both design verification and document reviews; *3)* require that, when used, design reviews take place periodically during original design and subsequent changes; and *4)* place more emphasis on verification of designs using qualification testing. This is by no means a new idea. At least one internal NRC study and one industry study has resulted in similar a recommendation.[152,153] Design reviews are inherently subjective and, compared to qualification tests, the quality of design reviews are far more difficult to control.

5.2.5 Acceptance Criteria

The ninth sentence of Criterion III requires:

> ***Design*** *control measures shall be applied to* ***items*** *such as the ... delineation of* ***acceptance criteria*** *for inspections and tests.*

Reference to acceptance criteria also appears in the second sentence of Criterion V and the first sentence of Criterion XI which read:

> *Instructions, procedures, and* ***drawings*** *shall include appropriate ...* ***acceptance criteria*** *for determining that important* ***activities*** *have been satisfied* [Criterion V]. *A test program shall be established to assure that all testing [is] in accordance with written test procedures which incorporate the requirements and* ***acceptance limits*** *contained in applicable* ***design*** *documents* [Criterion XI].

The relationship between Criteria III, V, and XI is confusing both here and in NQA-1. One possible interpretation is that Criteria III and XI apply to the acceptance of items while Criterion V applies to the acceptance of activities. This requires some stretching, however, since the "drawings" mentioned in Criterion V usually depict items and seldom contain criteria for accepting activities.

In actual practice, most companies focus on Criterion V and apply it to both items and activities. In doing so, there is a tendency to overlook the Criterion III requirement that design controls be applied to the development of test and inspection acceptance criteria. This can be attributed to the following:

a) **NQA-1** Basic Requirement 3 and Supplement 3S-1 do not require including acceptance criteria in design documents. An addenda to Supplement 3S-1 is being prepared to correct this.

b) **Procedures** Since tests are usually conducted by QC personnel, companies assign the development of test procedures to their quality assurance rather than their engineering department. Accordingly, criteria placed in test procedures, which are not considered design documents, are seldom subject to design control.

ISO 9004 requires including acceptance and rejection criteria in *specifications*, *drawings*, and *purchase orders.* These documents are regarded as being separate and distinct from *quality policies and procedures.* Clarification is needed in Appendix B and NQA-1 of the type of criteria that needs to be included in design documents versus procedures and purchase orders.

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[152] NUREG-0321, pp. 35-37.

[153] Thomas H. Lee, Ben C. Ball, and Richard D. Tabors, *Energy Aftermath*, Harvard Business School Press, Boston, MA, 1990, pp. 126 & 127.

5.2.6 Document Changes

The last sentence of Criterion III reads:

> *Design changes ... shall be subject to design control measures commensurate with those applied to the original design and shall be approved by the organization that performed the original design unless the applicant designates another responsible organization.*

The last sentence of Criterion VI contains the following requirement:

> *Changes to documents shall be reviewed and approved by the same organizations that performed the original review and approval unless the applicant designates another responsible organization.*

Criteria III and VI repeat each other in that both require that changes to documents be approved by the same organizations that approved the original documents. NQA-1 Supplements 3S-1 and 6S-1 offer little in the way of clarification.

Small organizations generally have a single procedure, based on the requirements of Criterion VI, for changing all their documents including design documents. Large organizations sometimes have: *1)* one procedure that covers changes to plans and procedures; and *2)* one or more configuration management procedures used to control changes to design documents.

The Ford Amendment Study had the following observations and recommendations on the subject of controlling and managing change:[154]

> *Quality problems in design were directly attributable to changes in the design basis and inadequate management oversight of the design process, including implementation of quality assurance controls over the design process ... [T]he NRC should examine the change management process itself, both within the NRC and nuclear industry, to evaluate the impact of changes on the ... regulatory and project management structure. The goal of this examination would be to develop and further guidelines for controlling excessive change and better management of necessary change. The aerospace industry's apparent successful approach to configuration management should be a principal focus of study ...*

Aerospace configuration management (CM) programs usually require the following controls:

a) **Prior Approval of Changes** In addition to requiring review and approval of completed changes, CM procedures require review and approval of changes before they are initiated. To proceed with a change, a change request form must be approved. The form must describe the change, discuss the reason for the change, identify its impact on other documents, and justify the time and money needed to process and implement the change.

b) **Status Tracking Systems** CM procedures require tracking the status of planned changes to documents until finally issued. For example, a change to a design specification could affect related details on a shop drawing. CM procedures would permit issuing an "emergency change" to the specification prior to changing the drawing with the proviso that a "Hold" be placed on affected portions of the drawing and the planned change be tracked until issued.[155,156]

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[154] NUREG-1055, pp. 2-6 & 6-8.

[156] Typically a *Change Notice* would be issued with the specification that identified and placed a "Hold" on affected portions of interfacing documents. A computer data base would track all the identified Holds. Procedures would require that QC personnel access the computer and check the status of Holds before using a document as a basis for inspection or testing.

Though the NRC completed a study of NASA's configuration management practices, nine years have passed without any change to the relevant passages of Appendix B and NQA-1.[157] Nevertheless, ASME is slowly moving forward with a new NQA-1 Supplement 3S-2, "Supplemental Requirements for Configuration Management."[158] ISO 9004, Subsection 8.8, already requires the application of configuration management principles to design changes.

5.2.7 Identification and Control

Appendix B contains the following overlapping requirements:

> *These identification and control measures shall be designed to prevent the use of incorrect or defective materials, parts, or components.* [Criterion VIII, last sentence]

> *These measures shall provide for the identification of items which have satisfactorily passed required inspections and tests, where necessary to preclude inadvertent bypassing of such inspections and tests.* [Criterion XIV, second sentence]

> *Measures shall be established to control materials, parts, or components which do not conform to requirements in order to prevent their inadvertent use or installation.* [Criterion XV, first sentence]

The above requirements, which also appear in corresponding NQA-1 Basic Requirements and Supplements, should be consolidated into a single requirement or be reworded to draw a sharper distinction between requirements. For example, since Criterion XV already requires controlling defective items, the last sentence in Criterion VIII could be rewritten to read, "These identification and control measures shall be designed to prevent inadvertently using the wrong items."

5.3 TERMINOLOGY

5.3.1 General

In some cases, Appendix B terms are used that need to be defined; in others, terms are used incorrectly or the same term is used two different ways. Terms used in Appendix B are not defined in Appendix B or elsewhere in the Regulation. Though NQA-1 Supplement S-1 defines many of the terms used in Appendix B, the definitions create as many problems as they solve. Examples of these problems are provided below.

5.3.2 Items

Criteria VIII and XV use the term *items* to mean *materials, parts, or components.* This is consistent with the definition in NQA-1 Supplement S-1. In the ninth sentence of Criterion III, *items* is used to mean *design activities and considerations.* NQA-1 Basic Requirement 3 does not use the word *item* and NQA-1 Supplement 3S-1 uses the term correctly.

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[156] A good "emergency change" procedure reduces nonconformances by reducing the temptation to knowingly violate an obsolete requirement in order to avoid shutting down operations until the requirement can be revised.

[157] Marc Meyer, p. 6.

[158] Based on information obtained by the author as a member of ASME's NQA Standards Coordinating Subcommittee.

5.3.3 Measures

Eleven of the eighteen Appendix B criteria start with off with the words, "Measures shall be established ..." For seven of these eleven criteria, the next sentence also contains the word *measures*. Supplement S-1 does not define "measures," and NQA-1 Basic Requirements do not use the term. Since Webster's dictionary lists 17 definitions of the term "*measure*"[159] one has to look to the remaining seven Appendix B criteria for clues on which definition applies. Five of the criteria start off requiring a *program* or *system*. This suggests a *measure* is something similar, specifically, "a procedure, course of action, or step."

In the initial drafts of Appendix B, the word "*system*" appeared wherever "*measures*" now appears. The ACRS objected to using the term in two different ways, that is, to mean either "an established way of doing things" and "a group of components acting together to perform a single function." Bill Morrison had to find another word to obtain their endorsement of the draft Regulation.[46,47]

5.3.4 Instructions

The term "*instructions*" appears in Criteria II, III, V, XIII, and X. Though NQA-1 Basic Requirements use the word "*instructions*" in the same manner, it is not defined in NQA-1 Supplement S-1.

Criterion XI requires *test procedures*, and Criterion XIII requires *inspection instructions*. In actual practice, *specifications* identify required tests, inspections, methods, and acceptance criteria. Written procedures are developed to control both inspections and tests. As appropriate, *instructions* are also developed to provide further directions on particular requirements in procedures.

The term *instructions* does not mean either *procedures* or *specifications* because Criterion III contains the phrase "specifications, drawings, procedures, and instructions." Ruling out specifications creates a significant terminology problem because Criterion V requires that "instructions, procedures, and drawings" contain acceptance criteria. At least in theory, placing acceptance criteria in specifications, which is normal industry practice, would not satisfy the requirements of Criterion V.

5.3.5 Equipment

Criteria VIII and XIV use the phrase "materials, parts, and components," Criterion III uses the phrase "materials, parts, and equipment," and Criteria IV, VII, XIII, and XVI opt for "materials and equipment" without mentioning "parts." Though these same terms are used in NQA-1 Basic Requirements they are not defined in Supplement S-1.

Based on the above, it is logical to assume that *equipment* means permanently installed *component*. Unfortunately, Appendix B and NQA-1 confuses matters by introducing the term *test equipment* in Criterion II and Basic Requirement 2, respectively. To further confuse matters, Appendix B also uses *test instrumentation* in Criterion II and *testing devices* in Criterion XII.[160]

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159 *Webster's New World Dictionary of the American Language*, Simon and Schuster, New York, NY, 1980, p. 880

160 Valves and other types of plant *equipment* are "*items*" that must be purchased in accordance with Criteria IV and VII. Micrometers and other types of *test equipment*, used to evaluate and accept plant *equipment*, are not "*items*" and do not need to be purchased in accordance with Criteria IV and VII. However, all test equipment, regardless of how purchased or otherwise obtained, must be controlled in accordance with Criterion XII.

5.3.6 <u>Audit Procedures</u>

Though the second sentence of Criterion XVIII clearly states procedures are unnecessary if audit checklists are used, according to Bill Morrison, this is <u>not</u> what was intended. According to Morrison, a procedure is always required that describes the organization's generic audit process. In addition, if checklists are not used, a procedure must be developed that takes the place of the checklists.[47] The requirement to use audit checklists came from Paragraph 8.2 of RDT F2-2, and the option to use procedures came from Paragraph 7.9 of Commonwealth Edison's *Zion QA Plan.*

NQA-1 Basic Requirement 18 and Supplement 18S-1 mimic Appendix B by requiring written audit procedures or checklists without explaining what is meant by "procedures." Furthermore, though Supplement 18S-1 and ISO 9004 also require the development of "audit plans," ISO 9004 requires neither checklists nor procedures.

5.4 GROUPING OF REQUIREMENTS

5.4.1 <u>General</u>

The decision to group Appendix B requirements into 18 criteria was somewhat arbitrary. It could have just as easily been 10, 12, or 24 criteria.[48] For example, DOE Order 5700.6, which is patterned after Appendix B, contains 10 criteria. Subsection 17.3 of NUREG-0800, *Standard Review Plan*, dated August 1990, contains 24 criteria and supplemental guidance to NRC staff personnel assigned to review QA program descriptions in *Safety Analysis Reports.*[161]

5.4.2 <u>Criterion IV, Procurement Document Control</u>

Criterion IV should be incorporated into Criteria V, VI, or VII. Advantages to this approach would be as follows:

a) **Criterion V, Instructions Procedures, and Drawings** Combining Criteria IV and V would consolidate requirements related to establishing criteria for the acceptance of items and services.

b) **Criterion VI, Document Control** Combining Criteria IV and VI would eliminate confusion over whether Criterion V applies to procurement documents. Most feel Criterion VI excludes procurement documents because it uses the phrase "such as instructions, procedures, and drawings". Though procurement documents are reviewed and approved in accordance with NQA-1 Supplement 4S-1, their distribution is seldom controlled. Procurement documents should be subject to controlled distribution. This is the approach used in DOE Order 5700.6.[162]

c) **Criterion VII, Purchased Items and Services** This would place all of the procurement control requirements of Appendix B under a single criterion. This is the approach used in ISO 9004.[163]

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[161] Another example is International Atomic Energy Agency Standard IAEA 50-C-QA, *Code on the Safety of Nuclear Power Plants: Quality Assurance*, 1978. By consolidating Criteria II and V, IV and VII, VIII and XIII, and X, XI, and XII of Appendix B, the authors of the IAEA *Code* arrived at 12 criteria. Page 27 of the IAEA *Code* identifies Bill Morrison as one of its co-authors.

[162] Refer to Paragraph 4(a)2 of Attachment I, "Guidance for Developing and Implementing Quality Assurance Programs," to DOE Order 5700.6.

[163] Refer to Section 9, "Quality in Procurement," of ISO 9004.

5.4.3 Criterion XIII, Handling, Shipping, and Storage

Criterion XIII requires controlling "the handling, storage, shipping, **cleaning**, and preservation of material and equipment." When necessary, it requires providing "special protective **environments**."

The fifth and six sentences of Criterion II, "Quality Assurance Program," contain related but slightly different requirements. They require controls that include "suitable **environmental** conditions for accomplishing the activity, such as adequate **cleanness**."

Criterion XIII applies to the cleaning and protection of hardware. Criterion II applies to the cleaning and protection of work areas, in other words, it applies to "housekeeping." The AEC considered this topic important enough to extract from the nuclear industry a commitment to develop a housekeeping standard. In 1973, the American Society of Mechanical Engineers published ANSI N45.2.3, *Housekeeping During the Construction Phase of Nuclear Power Plants.*[164] The American Nuclear Society incorporated operating plant housekeeping requirements into ANS-3.2, *Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants.*[165]

The fifth and sixth sentences of Criterion II seem out of place because, unlike other sentences in Criterion II, they do not contain general administrative requirements. For example, their requirements apply to the cleanliness of shelving in an electrical parts warehouse, but not to the cleanliness of desks in a design office. Moving the housekeeping requirements in these sentences to Criterion XIII would help people better understand the intent of their requirements.

5.4.4 Criterion XV, Nonconforming Materials, Parts, and Components

A powerful case can be made for combining Criterion XV and Criterion XVI, "Corrective Action," as done in DOE Order 5700.6. Advantages would be as follows:

a) **Consolidation** Criterion XVI requires establishing measures to assure "defective material and equipment, and nonconformances are promptly identified and corrected." Merging Criteria XV and XVI would place all rules for controlling nonconformances under a single criterion.

b) **Terminology** Merging Criteria XV and XVI would result in more consistent terminology. For example, Criterion XV uses the phrase *nonconforming materials, parts, and components* whereas Criterion XVI uses *defective material and equipment* and *nonconformances.* As such, Criterion XVI inadvertently implies "defective" items are not "nonconforming" items subject to the requirements of Criterion XV.

c) **Control** Criterion XV applies only to permanent plant materials, parts, and components. The requirement in Criterion XV to control nonconformances in order to prevent their inadvertent use should also apply to nonconforming design documents, test instruments, and other "things" that are not permanent plant items. This is a requirement of DOE Order 5700.6.[166]

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[164] ANSI N45.2.1, *Cleaning of Fluid Systems and Associated Components for Nuclear Power Plants*, was developed to cover cleaning the inside and outside surfaces of piping systems.

[165] The housekeeping requirements of ANSI N45.2.3 are now in Part 2.3 of NQA-2. The housekeeping requirements of ANS-3.2 are in Paragraph 5.2.10 of the current, April 1989, revision of the standard.

[166] Refer to Requirements 6(b)and (c) and also Paragraphs 3(e) and (g) of Attachment I to the Order.

d) **Trending** The Ford Amendment Study found that:[167]

In the past, neither utilities nor the NRC have done well in analyzing the root causes of quality problems. [Utilities] should develop trend analysis capabilities of their own, improve their ability to determine the root cause of identified problems, and do more of both of these in a timely manner. One cause of this slowness has been [an] inability to synthesize scattered bits of information into a comprehensive picture...

Appendix B is silent on trending. Though NQA-1 Basic Requirements and Supplements are also silent on the subject, in an April 1991 addendum, limited guidance on trending was included in a new NQA-1 Appendix 16A-1, "Nonmandatory Guidance on Corrective Action." Respectively, Subsection 3.1 and Paragraph 3.2.3 read:

*Conditions adverse to quality should be reviewed to determine the existence of **trends**. The significance of identified **trends** should be classified ...*

*In classifying conditions adverse to quality, the review should consider repetition of specific conditions adverse to quality, as well as the relationship or similarity between different conditions in a manner and at a frequency that assures significant quality **trends** are identified and evaluated ...*

Some organizations only trend selected hardware problems, such as weld defects; some only trend the root cause of deficiencies; some only trend significant adverse conditions; and others trend all adverse conditions. Combining Criteria XV and XVI would make it clear that adverse conditions, whether pertaining to hardware or procedural matters, need to be trended. Also, it would provide the NRC and nuclear industry with one more chance to decide on a reasonable, performance-based trending requirement.

5.5 BALANCE

5.5.1 General

Table 3 shows that 41 percent of Appendix B is devoted to requirements relating to program administration. Next are requirements related to construction and manufacturing processes, 30 percent; design activities, 14 percent; procurement activities, 11 percent; and corrective action, 4 percent. Closer scrutiny indicates the length of requirements are not necessarily commensurate with their overall importance and, in some cases, requirements are missing. Examples are provided below.

5.5.2 Management

The Ford Amendment Study's principal finding concerned shortcomings in utility management. To quote NUREG-1055:[168]

In some organizations, management views QA as being responsible for quality and fires the QA manager if quality is not achieved. This study concluded that too often top management assessed blame in the wrong place and fired the wrong person(s). Top management, and through them, intermediate

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167 NUREG-1055, pp. 2-42 and 7-8.

168 NUREG-1055, pp. 2-7, 2-8, and 2-41.

management and the workers, are primarily responsible for quality. Past NRC reviews of CP [Construction Permit] applicants did not deal substantively with management experience or capability either in an overall sense or in the context of QA program effectiveness. The study found that deficiencies in utility and project management were root causes of the major quality-related problems experienced and that in such projects, problems in the quality program were often accompanied by deficiencies in other management aspects including planning, scheduling, procurement, and oversight over contractors. ***The study established a strong correlation between the effectiveness of the QA program and the effectiveness of overall project management.*** *This study recommends that future CP applicants be required to meet this criterion.*

Though Criterion I accounts for a third of the program administration requirements in Appendix B, it says nothing about management's responsibilities. Every American quality standard published since the Ford Amendment Study has had a section devoted to management's quality assurance responsibilities.[169]

In addition to the "management assessments" required by Criterion II of Appendix B, ISO 9001 requires that management "define and document its policy and objectives for, and commitment to, quality." This requirement is elaborated on in ISO 9004. Criterion I of Appendix B and NQA-1 Basic Requirement 1 should be amended to incorporate NUREG-1055 recommendations by emphasizing management's quality assurance responsibilities.

5.5.3 Design Control

Appendix B needs to expanded to place more emphasis on controlling the quality of technical data obtained during the characterization of potential plant sites and to keep pace with the expanding role of computers in plant design and operation. Specific recommendations are as follows:

a) **Siting** Appendix B does not say it applies to the siting of nuclear power plants. Siting criteria in 10CFR100 and Appendix Q to 10CFR50 say nothing about quality assurance; they are primarily technical in nature. The Introduction to Appendix B should be expanded to say it applies to "plant siting" in addition to "designing, purchasing, ... refueling, and modifying." Criterion III should include requirements for collecting site data that will be used as: *1)* a basis for selecting a suitable plant site, or *2)* final technical input during the design of permanent plant hardware.

   NQA-1 Basic Requirement 11 requires that tests "to collect data, such as for **siting or design input**, shall be planned, executed, documented, and evaluated." This requirement is not elaborated on in NQA-1 Supplements and Appendices.[170,171]

b) **Computers** Appendix B never mentions the terms *computer code*, *computer program*, or *computer software*. Computers are now an essential, integral part of the design process and the

[169] This includes the following standards: *1)* Section 10 of DOE Order 5700.6; *2)* Section 4.0 of ISO 9004, *Quality Management and Quality System Elements - Guidelines*; *3)* Section 5.0 of ASME MCS-1, *Management Control System*, dated May 1990; and *4)* Criterion 1.1 of the U.S. Department of Commerce's *1992 Malcolm Baldrige National Quality Award Criteria*, dated December 1991.

[170] Geological siting activities are covered by Part 2.20 of NQA-2, *Quality Assurance Requirements for Nuclear Power Plants*. However, Part 2.20 does not cover other siting activities such as topographic surveys, collection of meteorological data, and characterization of rivers and bodies of water on or adjacent to the proposed plant site.

[171] Consideration should be given to merging NQA-2 Part 2.20 with NQA-3, *Quality Assurance Program Requirements for the Collection of Scientific and Technical Information for Site Characterization of High-Level Nuclear Waste Repositories*, and then expanding NQA-3 to cover the siting of nuclear power plants, independent spent fuel storage facilities, and high-level waste repositories.

operation of a nuclear power plant. They are used to store, manipulate and plot technical data; model complex engineering problems; perform mathematical calculations; produce drawings; and control operating power plant equipment. The consequences of errors in computer programs can be enormous.[172] Criterion III should be expanded to include requirements for controlling computer programs. The requirements should apply to programs used to design the plant and programs installed in and used to operate permanent plant equipment.[173]

5.5.4 <u>Safety Analysis Reports</u>

10CFR50.55(e) requires that nuclear utilities promptly notify the NRC of major design and construction deficiencies.[174] Specifically, the NRC needs to hear about any significant departure from "criteria and bases stated in the ***safety analysis report.***" To satisfy this requirement, procedures usually require that deficiency reports be reviewed against the rules of 10CFR50.55(e). This works if: *1)* personnel evaluating deficiency reports have a copy of and are familiar with the *Safety Analysis Report (SAR)*, and *2) SAR* requirements match those in controlled design documents.

SARs fit into a special class of documents known as "licensing documents." Because they are not "design documents," they escape Appendix B design control requirements.[175] *SARs* are generally prepared by licensing personnel borrowing information from controlled design documents. Ideally, as design documents are revised, *SARs* are updated to keep pace with design changes. Whether this actually happens, changes are correctly incorporated, and happens in a timely manner is usually off-limits during QA audits. Also off-limits are audits to verify that personnel are familiar with requirements in *SARs* and superseded pages in *SARs* are replaced with updated pages.[176]

Criterion II requires that the, "The applicant ... [list] the structures, systems, and components to be covered by the quality assurance program..." This list, known as a "Q-List," appears in the utility's *SAR*, not its QA Program Manual. Thus, if an item is not on the List, it is very possible that the design and construction of the item will not be audited, inspected, or otherwise verified. The consequences of using an incomplete or obsolete *SAR* Q-List can be enormous.[177]

On March 13, 1979, the NRC shut down five nuclear power plants (Beaver Valley 1, FitzPatrick, Maine Yankee, and Surry 1&2) due to faulty algebra in software used to calculate stresses in piping systems. The plants remained out of service for about three months while stresses were recomputed and piping systems modified. ["Faulty Stress Codes Shut Down Five Reactors for Months," *Nucleonics Week*, New York, NY, March 15, 1979, p. 1; and "No Substantial Differences Between Old and New Seismic Codes, S&W Says," *Nucleonics Week*, New York, NY, May 24, 1979, p. 1] © McGraw-Hill, Inc.

Though Appendix B does not mention the need to control computer programs, the nuclear industry has numerous standards on this subject. Control of computer programs is covered in NQA-1 Supplements 3S-1 and 11S-2, NQA-2 Part 2.7, and several standards published by the American Nuclear Society (ANS) and Institute of Electrical and Electronics Engineers (IEEE) including ANS-10.4, *Guidelines for Verification and Validation of Scientific and Engineering Computer Programs for the Nuclear Industry*, and IEEE 1012, *Software Verification and Validation Plans*.

milar requirements appear in 10CFR21, which applies to nuclear utilities and to companies supplying hardware to operating nuclear power plants or plants der construction. Though 10CFR21 does not specifically mention *SARs*, it requires that the NRC receive notification of any condition "that could contribute xceeding of a safety limit as defined in the [*SAR's*] technical specifications ..."

FR50.9(a) requires that, "*Information provided to the Commission by an applicant for a license ... be complete and accurate in all material respects.*" s not the same as requiring that *SARs* and other documents containing licensing information be developed under a quality assurance program meeting quirements of 10CFR50, Appendix B.

based on the author's own experience and *FSAR* inconsistencies identified at Midland 1&2 during early 1980. At Midland 1&2, the utility's project told a local newspaper reporter that, "*We installed the [soil] materials without knowing what it said in the FSAR. Our guys did not check the speci- against the FSAR.*" [Paul Rao, "Consumers denies lying to NRC on soils issue," *Midland Daily News*, Midland, MI, January 4, 1980, p. 1]

of a March 1979 accident at Three Mile Island 2, 10CFR50.34 was amended to require that license applications contain sufficient information that the quality assurance (QA) list required by Criterion II ... includes all systems, structures, and components important to safety." Refer to 4.5.3 and 6.3.5 and Supplement IV for more on this amendment and the Q-List problem that contributed to the 1979 accident.

operation of a nuclear power plant. They are used to store, manipulate and plot technical data; model complex engineering problems; perform mathematical calculations; produce drawings; and control operating power plant equipment. The consequences of errors in computer programs can be enormous.[172] Criterion III should be expanded to include requirements for controlling computer programs. The requirements should apply to programs used to design the plant and programs installed in and used to operate permanent plant equipment.[173]

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SARs fit into a special class of documents known as "licensing documents." Because they are not "design documents," they escape Appendix B design control requirements.[175] *SARs* are generally prepared by licensing personnel borrowing information from controlled design documents. Ideally, as design documents are revised, *SARs* are updated to keep pace with design changes. Whether this actually happens, changes are correctly incorporated, and happens in a timely manner is usually off-limits during QA audits. Also off-limits are audits to verify that personnel are familiar with requirements in *SARs* and superseded pages in *SARs* are replaced with updated pages.[176]

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172 On March 13, 1979, the NRC shut down five nuclear power plants (Beaver Valley 1, FitzPatrick, Maine Yankee, and Surry 1&2) due to faulty algebra in software used to calculate stresses in piping systems. The plants remained out of service for about three months while stresses were recomputed and piping systems modified. ["Faulty Stress Codes Shut Down Five Reactors for Months," *Nucleonics Week*, New York, NY, March 15, 1979, p. 1; and "No Substantial Differences Between Old and New Seismic Codes, S&W Says," *Nucleonics Week*, New York, NY, May 24, 1979, p. 1] © McGraw-Hill, Inc.

173 Though Appendix B does not mention the need to control computer programs, the nuclear industry has numerous standards on this subject. Control of computer programs is covered in NQA-1 Supplements 3S-1 and 11S-2, NQA-2 Part 2.7, and several standards published by the American Nuclear Society (ANS) and institute of Electrical and Electronics Engineers (IEEE) including ANS-10.4, *Guidelines for Verification and Validation of Scientific and Engineering Computer Programs for the Nuclear Industry*, and IEEE 1012, *Software Verification and Validation Plans.*

174 Similar requirements appear in 10CFR21, which applies to nuclear utilities and to companies supplying hardware to operating nuclear power plants or plants under construction. Though 10CFR21 does not specifically mention *SARs*, it requires that the NRC receive notification of any condition "that could contribute to exceeding of a safety limit as defined in the [*SAR's*] technical specifications ..."

175 10CFR50.9(a) requires that, "*Information provided to the Commission by an applicant for a license ... be complete and accurate in all material respects.*" This is not the same as requiring that *SARs* and other documents containing licensing information be developed under a quality assurance program meeting the requirements of 10CFR50, Appendix B.

176 This is based on the author's own experience and *FSAR* inconsistencies identified at Midland 1&2 during early 1980. At Midland 1&2, the utility's project manager told a local newspaper reporter that, "*We installed the [soil] materials without knowing what it said in the FSAR. Our guys did not check the specifications against the FSAR.*" [Paul Rao, "Consumers denies lying to NRC on soils issue," *Midland Daily News*, Midland, MI, January 4, 1980, p. 1]

177 As a result of a March 1979 accident at Three Mile Island 2, 10CFR50.34 was amended to require that license applications contain sufficient information to ensure "*that the quality assurance (QA) list required by Criterion II ... includes all systems, structures, and components important to safety.*" Refer to Paragraphs 4.5.3 and 6.3.5 and Supplement IV for more on this amendment and the Q-List problem that contributed to the 1979 accident.

Appendix B should be amended to add to Criterion III the following sentence which is essentially the same as that deleted from Appendix B after it was issued for public comment in April 1969:[178]

> *In addition to verification of the design, the applicant shall be responsible for verifying that the design is correctly described in the license application and assuring that the* ***Safety Analysis Report*** *is current and accurately incorporates information from supporting design documents.*

The above requirement would improve the current tenuous relationship between plant design documents, licensing documents, and reports to the NRC required by 10CFR50.55(e). It would also improve the NRC's confidence in technical information in *Safety Analysis Reports.*

5.5.5 Order-Entry

Appendix B was written to impose quality assurance requirements on nuclear utilities. Because of this perspective, it is silent on some activities performed by contractors that can affect the quality of materials, equipment, and services they supply to the nuclear industry. The most important of these is translating pertinent technical and quality assurance requirements from the buyer's procurement documents to internal controlled documents and distributing the documents to all those within the supplier's organization who have responsibility for the quality of the purchased item or service. This is typically called an *order-entry system.*

Because they contain labor rates, fees, and sensitive information, procurement documents are normally not copied and distributed to everyone who needs to comply with their requirements. Instead, a select group of individuals is charged with the responsibility of gleaning applicable requirements from the buyer's order and transferring them to internal work orders and similar supplier-controlled documents. Order-entry documents should be independently reviewed against the buyer's procurement documents before being approved and distributed for internal use.

Subsection 4.3 of ISO 9001 has order-entry requirements. NQA-1 Basic Requirements and Supplements do not require that suppliers of items and services have a order-entry system. Criterion IV and NQA-1 Basic Requirement 4 should be amended to require that procurement documents contain order-entry requirements.[179]

5.5.6 QA Program Documents

The first sentence of the Introduction and second sentence of Criterion II read:

> *Every applicant for a construction permit is required ... to include in its preliminary safety analysis report a description of the quality assurance program...* [Introduction] *The program shall be documented by written* ***policies***, ***procedures***, *or* ***instructions*** *and shall be carried out ... in accordance with those* ***policies***, ***procedures***, *and* ***instructions***. [Criterion II]

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178 Refer to Note 30 in Supplement II of this Topical Report for details on this sentence. Bill Morrison told the author that, though not absolutely certain, he deleted the sentence because it obviously had been misplaced. In his opinion, it belongs in 10CFR50.34 which contains requirements for prepering *SARs.* If this was the reason at the time, the sentence was never relocated to 10CFR50.34.

179 The identification of customer requirements and factoring such requirements into internal specifications is an important part of Total Quality Management. Malcolm Baldrige Award examiners have 28 criteria worth 1000 points that they consider when evaluating companies competing for the Award. Three criteria, having a combined value of 95 points, pertain to identifying and improving on customer requirements.

Criterion V requires:

> *Activities affecting quality shall be prescribed by documented* ***instructions****,* ***procedures****, or* ***drawings*** *of a type appropriate to the circumstances and shall be accomplished in accordance with these* ***instructions****,* ***procedures****, or* ***drawings****.* ***Instructions****,* ***procedures****, or* ***drawings*** *shall include appropriate quantitative or qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished.*

NQA-1 Supplement S-1 defines a *procedure* as, "A document that specifies or describes how an activity is to be performed." Neither Appendix B nor NQA-1 contain a definition of *policies, instructions,* or *drawings.* ISO 9001 and ISO 9004 describe the difference between *quality policies, quality procedures,* and *work instructions.* NQA-1 Supplement S-1 needs to define *policies* and *instructions* if it elects to continue using these two terms.[180]

Most companies have a "**policy** statement," signed by the CEO, which identifies the purpose of the QA Program and management's QA responsibilities. The statement appears in a QA Manual that describes the company's organization, identifies the scope and purpose of the QA Program, and serves as a road map to implementing **procedures**. While ISO 9004 requires a QA Manual, NQA-1 Basic Requirement 2 requires a "documented quality assurance program." NQA-1 Supplements and Appendices contain **no** further requirements or guidance on how to document a QA program.

Appendix B and NQA-1 require that **procedures**: *1)* describe how activities affecting quality are to be performed; and *2)* include criteria for accepting such activities. Despite the historically critical role procedures have played in successful and unsuccessful nuclear quality assurance programs, NQA-1 contains **no** further requirements or guidance on the preparation of procedures. This silence has had a negative impact on nuclear power plant performance. A recent NRC study concluded that, between January 1984 and July 1988, an inadequate level-of-detail in procedures was the leading cause of abnormal or unusual operating occurrences at nuclear power plants. This study followed up on and supported the conclusions of a 1985 NRC study which found that:[181]

> *[T]he procedures that do exist are often of such poor quality that personnel avoid or refuse to use them. In general, maintenance procedures are poorly written and difficult to follow. The adequacy of existing procedures constitutes the single largest reason cited by supervisors for their unwillingness to encourage procedure use.*

Though further requirements may not necessary, guidance is certainly needed. The guidance should be similar to that in Paragraph 5.2.5 and Subsection 5.3 of ISO 9004. It should include a discussion of what is the appropriate level-of-detail in implementing procedures.

5.5.7 Surveillances

During the development of 10CFR50, Appendix B, Merritt Langston recommended adding surveillance requirements to the Regulation.[62] AEC contractors had been using surveillances to control activities at its research and development reactors.[182] His suggestion was not accepted because

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180 Refer to Paragraph 5.3.4 for a related discussion about "instructions."

181 Douglas Wieringa, Christopher Moore, and Valerie Barnes, *Procedure Writing*, Battelle Press, Columbus, OH, 1993, pp. 4, 5 & 59.

182 Refer to Paragraphs 4.9 and 7.7 of RDT F2-2.

surveillances were not used in Admiral Rickover's Naval Reactors Program. Bill Morrison wanted to stay with terms and verification methods that he, Edson Case, and others in the AEC Division of Reactor Standards were personally familiar with and had confidence in.[47,183]

NQA-1 Supplement S-1 defines *surveillance* as, "The act of monitoring or observing to verify whether an item or activity conforms to specified requirements." In actual practice, surveillances are used to control processes such as maintenance and document control, and inspections are used to accept items. Surveillances are conducted at a predetermined frequency. Inspections are conducted at predetermined hold or witness points during manufacturing and construction.

Though NQA-1 defines *surveillance*, the term is never used in NQA-1 Basic Requirements and, in NQA-1 Supplements, it is mentioned only briefly in Supplement 7S-1. A new NQA-1 Appendix 2A-5, "Nonmandatory Guidance on Surveillances," is being written to correct this situation.[158] As a minimum, Appendix B should recognize surveillances as an important verification technique.

5.5.8 Operation and Maintenance

The Introduction to Appendix B says it applies to nuclear power plant operation and maintenance. Criterion XI requires "**preoperational tests and operational tests**;" Criterion XIV requires that measures "be established for indicating the **operating** status of structures, systems, and components ... such as by tagging valves and switches to prevent inadvertent **operation**;" and Criterion XVII requires that nuclear power plant records include "**operating logs**." Similar requirements, pertaining to plant "**maintenance**," cannot be found within the Regulation's eighteen criteria.

RDT F2-2, a primary source document during preparation of Appendix B, had five pages of criteria on the "operation, maintenance, and modification" of AEC reactors.[184] It could be argued that further reference in Appendix B to operation and maintenance could inadvertently lead readers to believe they require more controls than other activities.[185] For example, though the Introduction to Appendix B says it applies to fabricating, erecting, and installing, the text of Appendix B criteria do not mention these activities. This silence has not confused people who had to apply the Regulation to work at manufacturing shops and construction sites.[47,186]

After issuance in 1970, it soon became apparent AEC staff and utility personnel were having lots of trouble interpreting and applying Appendix B to work at operating nuclear plants. To clarify matters, in 1972 the American Nuclear Society published ANS-3.2, *Administrative Controls and Quality Assurance for the Operating Phase of Nuclear Power Plants*. The AEC endorsed ANS-3.2 in Regulatory Guide 1.33, *Quality Assurance Program Requirements (Operations)* and, in October 1973, issued WASH-1284, *Guidance on Quality Assurance Requirements During the Operations Phase of Nuclear Power Plants*. WASH-1284 referred to and expanded on Regulatory Guide 1.33. A month later, the AEC hosted one-day conferences at its regional offices on QA during plant operation.[47,140]

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[183] Bill Morrison and his managers, Bob Minogue and Ed Case, came to the AEC from Rickover's Naval Reactors program. They understood MIL-Q-9858A and were familiar with Navy verification methods such as reviews, inspections, tests, and audits.

[184] RDT F2-2, pp. 7-1 through 7-5.

[185] As mentioned in Paragraph 4.4.2, many utilities and contractors objected to applying the Regulation to operating nuclear power plants. None of those who commented on the draft Regulation said it needed additional text explaining its implementation during plant operation and maintenance.

[186] Bill Morrison told the author that, in retrospect, he would have mentioned both activities far more often had he foreseen the need to do so. However, though he agrees people have had trouble recognizing its applicability to operating plants, he feels the problem is chiefly perception. Training will do more to change this perception than additional words in Appendix B.

Seven paragraphs of quality assurance requirements in RDT F2-2 were devoted to establishing and implementing "methods for assuring ... requirements of the maintenance program are fulfilled." Improper maintenance and premature wear has been the primary reason for reactor scrams and system failures.[187] Surprisingly, 75 percent of unplanned plant shutdowns are due to equipment failures in poorly maintained balance-of-plant systems.[188,189]

In July 1992, the NRC added to 10CFR50 a new Section 50.65 which requires that utilities monitor the maintenance of plant equipment to minimize the likelihood of failures caused by improper preventive maintenance.[190] The regulation is designed to provide the NRC additional assurance that aging equipment will perform as required over the remaining life of our 109 operating nuclear power plants. In a related move, during May 1992, NQA-2 was amended to include a new Part 2.18, "Quality Assurance Requirements for Maintenance of Nuclear Facilities." Its requirements differed from those in ANS-3.2, stymieing industry's attempt to standardize maintenance requirements.[191] The two societies, ANS and ASME, need to agree on one maintenance standard.

The latest version of Regulatory Guide 1.33, dated February 1978, endorses ANS-3.2 with five exceptions. In April 1989, ANS-3.2 was revised to address the NRC's concerns. Both documents are now being updated to incorporate lessons learned from the accident at Chernobyl[192] and operating American nuclear power plant experience since the accident at Three Mile Island 2.[158]

The next amendment to Appendix B should say more about operation and maintenance. Topics that should be considered for inclusion in the amendment are training, readiness reviews, preparation and control of operating procedures, security, outages, in-service inspection, emergency planning, plant modifications, and surveillances of maintenance programs required by 10CFR50.65.[193]

5.5.9 Decommissioning

Even though Appendix B does not state it applies to decommissioning, the NRC expects compliance with its requirements.[194] Unfortunately, Appendix B and NQA-1 have little to offer those looking for definitive criteria that are clearly applicable to decommissioning. To fill this vacuum, ASME's Nuclear Quality Assurance Committee is preparing a new NQA-1 Appendix on decommissioning.[158]

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187 Dean Gano, "Root cause and how to find it," *Nuclear News*, La Grange Park, IL, August 1987, p. 42. © 1987 by American Nuclear Society

188 GAO/RCED-91-36, *NRC's Efforts to Ensure Effective Plant Maintenance Are Incomplete*, U.S. Government Accounting Office, Washington, DC, December 1990, pp. 18 and 25.

189 Although this seems to speak well for the effectiveness of Appendix B, as discussed in Paragraph 5.5.4, it raises some thought-provoking questions about the adequacy of NRC Q-Lists. For example, how often have defective balance-of-plant systems over-stressed and caused the failure of Q-List components?

190 E. G. Silver, "Recent Developments," *Nuclear Safety*, Washington, DC, January-March 1992, pp. 137 and 145.

191 Although Paragraphs 5.2.7.1 and 5.3.8 of ANS-3.2 contain extensive maintenance requirements, the requirements in NQA-2 for "corrective maintenance" far exceed those in ANS-3.2.

192 The NRC published its study of the Chernobyl accident in April 1989 as NUREG-1251, *Implications of the Accident at Chernobyl for Safety Regulation of Commercial Nuclear Power Plants in the United States*. In turn, NUREG-1251 refers to NUREG-1250, *Report on the Accident at the Chernobyl Nuclear Power Station*, January 1990. NUREG-1250 (p. 3-25) discusses quality control problems the Soviets had welding the reactor's zirconium fuel elements. NUREG-1251 (pp. 1-2 through 1-4) discusses deviations from approved operating procedures just prior to the accident.

193 10CFR50.65 does not contain quality assurance requirements.

194 The Introduction to NQA-1 recognizes this by stating, "This Standard sets forth requirements for the establishment and execution of quality assurance programs for ... decommissioning of nuclear facilities." Also, Page 17.3-3 of NUREG-0800, *Standard Review Plan*, directs NRC staff personnel to apply Appendix B requirements to decommissioning.

In June 1988, 10CFR50 was amended to include nuclear power plant decommissioning requirements in a new Section 50.82.[195] The Regulation required that, to retire a plant, the utility had to turn over to the NRC its Operating License and a Decommissioning Plan. Though the Regulation did not contain specific QA criteria, it required that Decommissioning Plans include, "A description of ... quality assurance provisions [that will be put] in place during decommissioning."

Decommissioning a 1000 MW nuclear power plant is estimated to cost about $150 million, take 15 years to complete, and result in the removal of 2000 truck-loads of contaminated debris.[196] One of the more worrisome radionuclides that must be dealt with during decommissioning is Nickel-59 which has a half-life of 80,000 years.[197]

Of 20 permanently closed nuclear power plants mentioned in Table 4, sixteen (16) have yet to be fully decommissioned.[198] By the year 2010, eight more plants will probably be retired.[199] Due to the hugh backlog of decommissioning work facing the industry and dangers the work poses to clean-up crews and the public, Appendix B should be amended to include quality assurance criteria applicable to decommissioning. The criteria should be referenced in 10CFR50.82.

5.6 SUMMARY

Many of the weaknesses discussed above are little more than irritants to those who must work with Regulation's criteria. Some weaknesses, such as those described in Paragraphs 5.2.4, 5.5.2, and 5.5.8, are clearly far more serious. With other weaknesses, such as those in Paragraphs 5.2.5 and 5.5.4, it is difficult to gauge their impact on nuclear power plant performance. Section 6.0 looks at the affect 10CFR50, Appendix B, has had on plant performance and identifies problems that could have resulted from weaknesses discussed in Section 5.0.

6.0 PLANT PERFORMANCE

6.1 INTRODUCTION

6.1.1 Comparison of Old and New Plants

There are currently 109 licensed nuclear power plants operating in the United States. Six of these plants were operating at the time Appendix B, went into effect in July 1970. Also, 20 licensed plants have been shut down, 15 that were licensed prior to and five after July 1970. Thus, a total of 128 plants have received Operating Licenses since the first, Dresden 1, received an Operating License during September 1959.[200]

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195 Simultaneously, a new Section 50.75 was added to 10CFR50 containing detailed requirements on the format and content of cost estimates to be included in Decommissioning Plans.

196 John Gaunt and Neil Numark, *Decommissioning of Nuclear Power Facilities*, The World Bank, Washington, DC, April 1990, pp. 3, 6, and 21.

197 Richard Worsnop, "Will Nuclear Power Get Another Chance?," *Editorial Research Reports*, Washington, DC, February 22, 1991, p. 126.

198 Only EBR-1, Shippingport, SL-1, and Elk River have been fully decommissioned.

199 Twelve nuclear power plants have Operating Licenses that will expire by 2010. The U.S. Department of Energy estimates that seven of these plants will be retired and five will have their Licenses extended. Additionally, it is estimated that Browns Ferry 3, which has been shut down since March 3, 1985, will not be restarted. [DOE/EIA-0527, *Assumptions for the Annual Energy Outlook 1993*, U.S. Department of Energy, Washington, DC, January 8, 1993, p. 90].

200 Refer to page 3 of Supplement V for further information on Dresden 1.

One method of assessing the impact of Appendix B, is to compare the performance of all 21 plants licensed prior to July 1970 to the performance of all 108 subsequently licensed plants. Table 4 makes such a comparison using the following performance characteristics:

a) **Build Time** This is an indication of construction problems. In theory, a strong quality assurance program minimizes delays by reducing rework. Table 4 shows that while plant size almost quadrupled after June 1970, the time required to build plants only doubled. This occurred during a period when utilities were being bombarded with new regulations. Though this improvement may have been the result of quality assurance, it may also have resulted from "economies-of-scale" and years of experience building smaller nuclear power plants.

b) **Lifetime Capacity Factor** This is an indication of problems with plant design and equipment. Table 4 shows a 39 percent improvement in Lifetime Capacity Factors[201] after July 1970. This is especially significant considering today's nuclear power plants have more equipment and more opportunities for things to go wrong. Though this improvement may have been because of better quality assurance, it may also have resulted from incorporating into designs and maintenance manuals years of lessons learned from operating smaller nuclear plants.

c) **Cumulative SALP Rating** In theory, utilities that received Operating Licenses prior to July 1970 were slow to recognize and embrace the need for formal quality assurance and this manifested itself in the form of poorer SALP (Systematic Assessment of Licensee Performance) Ratings.[202] Not too surprising, Table 4 shows that plants licensed after Appendix B was published have had superior SALP Ratings. Again, it is not possible to prove this difference is due to quality assurance because one could argue, with only six old plants, the sample size is too small to have any statistical validity.

6.1.2 Public Citizen's Ranking of Plants

Since the early 1980's, the Public Citizen has been ranking the performance of licensed nuclear power plants. The Public Citizen is an organization, founded by Ralph Nader in 1974, that is strongly opposed to building further nuclear power plants and continuing operation of existing plants. Table 5 shows Public Citizen's ranking of nine plants licensed before the issuance of Appendix B and the first four licensed after its issuance. The Table shows that, in general, plants licensed before Appendix B performed poorer than plants licensed later.

Individual rankings should be only be considered rough indicators of plant performance for reasons discussed in Notes 6 and 7 of the Table and, more importantly, because they do not consider performance prior to 1980. For example, while Table 5 shows San Onofre 1 consistently out-performing Haddam Neck, the reverse has been actually the case.[203] When ranking these and other plants, the Public Citizen did not look at initial plant cost and the past operating performance of each of the nine listed plants.

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[201] A plant's Lifetime Capacity Factor is how much electricity the plant produced divided by how much it could have produced had it operated continuously at full design power.

[202] Cumulative SALP Ratings are based on annual NRC inspections performed since 1980. The national average is 1.80. Scores over 1.90 are indicative of past performance problems while scores under 1.70 are indicative of superior plant management practices.

[203] Both plants began operation in 1967. Though San Onofre 1 is 23% smaller than Haddam Neck, it took 37% longer to build. Its Lifetime Capacity Factor is 30% lower than that of Haddam Neck. Whereas San Onofre has an mediocre Cumulative SALP Rating, Haddam Neck's Cumulative SALP Rating is excellent. See Table 6 for details.

6.2 PERFORMANCE MODEL

6.2.1 Basis

To avoid confusing performance improvements that could be attributed to changes in design, technology, or plant size with those that could be attributed to 10CFR50, Appendix B, a model was developed that compared the performance of the last four plants licensed prior to July 1970 with the first four plants licensed after June 1970. The principle behind the model was that, by measuring the following characteristics for each of these eight plants, it would be possible to determine the relative impact of Appendix B on their performance:

a) **Initial Expense** The time and cost required to build a plant should be proportional to its generating capacity (MW).[204] Taking a tip from the old adage "time is money," the model weighted construction duration and cost equally. This was primarily because information on older plants was so sketchy it was impossible to "level" costs to account for inflation, etc.

b) **Electrical Output** A plant should generate electricity at near capacity for its full design life. The model considered both the operating life of the plant and its Lifetime Capacity Factor in order to establish its electrical performance.

c) **Pain & Agony** The model took into consideration the trouble the plant caused the utility, NRC, and the public. This included high operating and maintenance costs, regulatory problems, major repairs and modifications, adverse publicity, lawsuits, accidents that threatened health and safety, and excessive decommissioning costs. So as not to unfairly penalize older plants exposed to years of potential problems, the model considered the: *1)* number and actual or potential impact of "major problems" and, *2)* number of years the plant was in operation.

Each of the above characteristics was graded on a 1 to 10 scale with 1 being an ideal plant. All three characteristics were weighted equally; for example, a plant that cost twice what it should have scored the same and was considered equal to one that produced half the electricity it should have. To create a scoring benchmark, 22 first-generation nuclear plants were added to the database. This included 13 PRDP plants; four utility-financed plants (Dresden 1, Humboldt Bay, Indian Point 1, and Saxton); two large unlicensed plants (Hanford-N and Shippingport); a large test reactor (WTR); the world's first nuclear power plant (EBR-1); and a small military nuclear power plant (SL-1).

6.2.2 Results

The history of each of the 30 plants mentioned above was researched and relevant performance data incorporated into Supplement V of this report. This data is summarized in Table 6. Data from Table 6 and Supplement V was then applied to the model and plants ranked in order of performance, worst to best. Final results appear in Table 7.

Table 7 shows that the first four plants licensed after issuance of Appendix B (Robinson 2, Point Beach 1, Millstone 1, and Monticello) performed better than all but one of the last four licensed prior to its issuance (Oyster Creek, Nine Mile Point 1, Ginna, and Dresden 2). In fact, these first four plants out-performed 22 of the 26 plants completed prior to the Regulation's issuance.

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[204] DOE/EIA-0485, *An Analysis of Nuclear Power Plant Construction Costs*, U.S. Department of Energy, Washington, DC, 1990

One of the questions that had to be answered in evaluating results from the model was, "How could issuance of 10CFR50, Appendix B, have improved the quality of plants licensed after but designed and built prior to its issuance?" Construction of Oyster Creek, Nine Mile Point 1, **Dresden 2**, Ginna, and **Millstone 1**, was underway at the time of the Apollo 1 fire and a near meltdown at Fermi 1. A few weeks later, the Atomic Energy Commission starting talking about the need for quality assurance, first at an ANS meeting and later at ASLB hearings.[205] Construction on Robinson 2, Point Beach 1, and Monticello started about this time, just as the nuclear industry was being caught by the quality assurance movement that led to issuing the draft Regulation in April 1969.

This answer prompted yet another question, "Why and how did issuance of Appendix B improve the performance of **Millstone 1**, but not **Dresden 2**? Construction of both plants began in 1966 and both began producing electricity during 1970.

Again, the answer was hidden among events leading up to the Regulation's issuance. When issued for public comment in April 1969, nearly every major nuclear contractor and utility reviewed the Regulation to gauge its impact on their current and future work. This included Ebasco, designer and builder of Millstone 1 and Robinson 2, and Yankee Atomic Electric, the parent utility that owned Millstone 1. Absent from the list of reviewers was Sargent & Lundy and Commonwealth Edison, respectively, the designer and owner of Dresden 2 and Zion 1&2. It was the lack of an acceptable quality assurance program at Zion 1&2 that accelerated the development of Appendix B.[206] This is why and how Millstone 1 benefitted from Appendix B, but not Dresden 2. While some hesitated, others immediately began implementing the draft Regulation.

6.2.3 Anomalies

The most obvious anomaly in the model's results is the poor performance of San Onofre 1 relative to Haddam Neck which began generating electricity a few days after San Onofre 1. Most probably this can be attributed to differences in Bechtel's and Stone & Webster's QC (quality control) programs. San Onofre 1 was designed and built by Bechtel, and Haddam Neck was designed and built by Stone & Webster.

During the mid to late 1960s, Stone & Webster developed a quality program based on naval reactor QA practices.[207] According to one AEC Commissioner, "In those days, Stone & Webster had the reputation of being the outstanding nuclear architect/engineer."[208] In part this was because Stone & Webster's nuclear projects were staffed with personnel who previously worked at Shippingport or Navy shipyards along the East Coast.[209] Officers from Admiral Rickover's Naval Reactors Program, renowned for their attention to detail, oversaw work at Shippingport and instilled in contractors an appreciation for safety and meticulous engineering.[210]

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205 Refer to Paragraphs 3.2.1 and 3.2.2 for further information on this subject.

206 Refer to Subsections 4.2 and 4.4, respectively, for further information on Zion's quality assurance program and organizations who commented on the draft Regulation. Zion 1&2 and Dresden 2&3 are currently on the NRC's list of nine "problem" plants.

207 E. M. Marselli, "How quality assurance assures quality in nuclear and other installations," *Power*, New York, NY, April 1969, pp. 82-84. © McGraw-Hill, Inc.

208 Karen Fitzgerald and Glenn Zorpette, "The Shoreham Saga," *IEEE Spectrum*, New York, NY, November 1987, p. 26. © 1987 by IEEE

209 Based on the author's experiences as a Stone & Webster employee from 1969-1974.

210 Francis Duncan, *Rickover and the Nuclear Navy*, Naval Institute Press, Annapolis, MD, 1990, pp. 196-199 and 241-245.

Bechtel's QC program took longer to mature. This is borne out by the problems experienced at EBR-1, Peach Bottom 1, Hallam, and other Bechtel plants built prior to the issuance of Appendix B in April 1969.[211,212]

6.3 PREMATURELY SHUT DOWN PLANTS

6.3.1 General

Table 4 shows that 5 percent of the 108 plants licensed after issuance of Appendix B have been prematurely closed as compared to 71 percent of the 21 plants licensed prior to its issuance. This speaks well for the impact of 10CFR50, Appendix B, on the nuclear industry.

The longest that any of the closed plants operated was 31 years. The average was 10 years for plants licensed both before and after issuance of Appendix B. Typically, nuclear power plants are designed to operate for 40 years.

The five plants licensed and permanently closed after issuance of Appendix B were Rancho Seco, Trojan, Fort St. Vrain, Three Mile Island 2, and Shoreham. The history of each plant is contained in Supplement VI. These histories were compiled to determine why the plants were shut down and whether the root cause of any of the closures was inadequate requirements in Appendix B.

6.3.2 Rancho Seco

Rancho Seco was permanently closed on June 7, 1989, after 15 years of operation. Closure was mandated by a local public referendum.[213] The public had lost faith in the ability of the utility to safely operate the plant.

The plant's Lifetime Capacity Factor was 36.1 compared to an average of 64.0 for plants licensed after June 1970. In part, this low Capacity Factor was due to violations of operating procedures which drew a $375,000 fine and resulted in a 27 month outage. The NRC placed Rancho Seco on its list of problem plants, and the utility unsuccessfully tried to sell the plant. In early 1989, the plant was restarted and quickly shutdown after experiencing further operating problems. A utility-funded oversight group urged the NRC to take action that would keep the plant closed until management reforms could be instituted.

Rancho Seco had a dismal Cumulative SALP Rating of 2.00. Though SALP teams found problems just about everywhere, their most frequent findings were in plant operations, radiological controls, and quality programs. Physically, there was nothing to prevent the plant from being operated safely. If Appendix B failed, it was because it was silent on the subjects of deficiency trending (Paragraph 5.4.4), management QA responsibilities (see Paragraph 5.5.2), and QA criteria applicable to plant operation (see Paragraph 5.5.8).

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211 Based on Table 7, Bechtel plants completed prior to April 1969 averaged 21.4 points. Stone & Webster plants averaged 17.9 points.

212 Major changes have taken place within the nuclear power industry and Stone & Webster and Bechtel. Undoubtedly, both companies will continue to change in order to take advantage of new technologies and management concepts. Accordingly, these observations should not be interpreted as characterizing either organization's current quality assurance program or, for that matter, their relative nuclear capabilities since April 1969.

213 The plant had successfully withstood a similar referendum one year earlier. [Jane Gross, "Voters to Decide Fate of Nuclear Plant," *The New York Times*, New York, NY, May 28, 1989, p. 20]. © The New York Times Company

6.3.3 Trojan

Trojan was permanently closed on November 9, 1992, after 16 years of operation. The plant was closed because studies found it would be cheaper to obtain electricity from other sources than to replace the plant's steam generators and complete other modifications needed to keep it in operation.[214,215] The plant was located close to abundant and relatively cheap sources of hydroelectric power and high-grade coal.

The plant's Lifetime Capacity Factor was 52.0, well below the national average of 64.0. In part, this low Capacity Factor was the result of lengthy outages to redesign and modify the plant's control room and overhaul its leaking steam generators. With over $900,000 in NRC fines, Trojan had the distinction of being one of the most heavily fined plants in the United States. If the Regulation failed, it was because of its weak design verification requirements (see Paragraph 5.2.4) and poorly-defined management QA responsibilities (see Paragraph 5.5.2).

6.3.4 Fort St. Vrain

Fort St. Vrain was permanently closed on August 18, 1989, after 12 years of operation. It was a PRDP plant, the second with a gas-cooled reactor.[216] The reactor was ordered in March 1965, two years before QA requirements were added to the ASME Section III Code. The plant was closed because it was unreliable and had high operating and maintenance costs.

The plant was on the NRC's list of 16 "problem plants." Its Cumulative SALP Rating was 2.07, the worst cited in this report. Though the NRC found problems during each of its SALP inspections, findings were most frequent in plant operations, maintenance, and licensing.

Fort St. Vrain was designed by Sargent & Lundy.[217] The plant took three times longer to build than planned and never met design expectations - as borne out by a Lifetime Capacity Factor of 14.7.[218] Its design problems can only partially be attributed to Appendix B; it was designed prior to the Regulation's issuance. Where Appendix B failed was its weak management responsibilities (see Paragraph 5.5.2) and operation and maintenance QA criteria (see Paragraph 5.5.8).

6.3.5 Three Mile Island 2

Three Mile Island 2 was permanently and unexpectedly shut down on March 28, 1979, six months after it first began operation. It was closed following a partial meltdown of its reactor core, the worst accident ever at a licensed American nuclear power plant.

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214 During the last six years of its operating life, three public referendums had been placed on the ballot to close the plant. Though opposition was fierce, the first two were successfully defeated. Trojan was permanently closed just before the third referendum was put to a vote. [Mary O'Driscoll, "Trojan Closure Reignites Steam Tube Debate," *The Energy Daily*, Washington, DC, January 6, 1993, p. 2].

215 Because the plant was a "marginal" performer, the nuclear power industry did not rally around Trojan and try to prevent its closure. Undoubtedly, its association with the film *The China Syndrome* and history of fines and drug problems further hurt its cause. The nuclear industry felt that, based on this and a lack of Federal, State, and community support, the plant was not salvageable.

216 The other plant with a gas-cooled reactor was Peach Bottom 1.

217 As discussed in Paragraph 6.2.2, Sargent & Lundy also happened to be the designer of Zion 1&2 and Dresden 2.

218 The plant was on-line for only 4.6 of the 11.7 years it was in operation.

The plant was originally planned as Oyster Creek 2 but, in December 1968, the proposed plant was moved to a site near Middletown, PA.[219] A Construction Permit was received during November 1969, seven months prior to issuance of 10CFR50, Appendix B.

President Carter appointed a 12-member commission, headed by John Kemeny, to investigate and determine the reasons for the accident. It found that, though the utility had a QA program that covered plant operation, it was seriously deficient. Appropriate QA requirements were not passed on to equipment suppliers and significant deficiencies were not reported to the NRC. There were not enough QC inspectors and, due to errors in classifying plant hardware, the program had not been applied to two important components whose failure ultimately resulted in the accident.[220]

The Kemeny Commission found longstanding and serious problems with equipment maintenance that should have been identified and corrected prior to the accident. The problems were not noticed earlier because NRC and utility inspectors focused on paperwork rather than hardware - as was the custom throughout the nuclear industry at that time.[221,222]

The Regulation's weak design control and *SAR* requirements probably explains why the utility did not notify the NRC of major deficiencies and why plant systems were misclassified (see Paragraphs 5.2.4 and 5.5.4). A failure to identify management QA responsibilities and QA criteria applicable to plant operation and maintenance may have contributed to the poor maintenance and understaffing that existed prior to the accident (see Paragraph 5.5.2 and 5.5.8).

6.3.6 Shoreham

Shoreham was permanently shut down on May 26, 1989, after four years of operation. It generated electricity for only about 30 hours. It was shut down because of public opposition to utility plans for evacuating Long Island during a plant emergency.

The plant experienced horrendous schedule delays, cost overruns, and opposition from anti-nuclear groups and State and local governments. Overruns of \$5.2 billion[223] were mostly due to lawsuits by plant opponents and the utility's slow response to changes in NRC regulations. Few overruns were due to design or construction problems. Start-up testing went smoothly and, in April 1989, the plant received a full-power license. A month later, near bankruptcy, the utility permanently closed the plant in response to promises of financial relief from the State of New York.

If Appendix B failed, it was its weak design control requirements, as related to plant siting, and lack of management responsibilities (see Paragraphs 5.5.2 and 5.5.3). Shoreham's Long Island location, approved by the NRC in April 1973, was its eventual downfall. In the event of a major accident, local residents would have had to been evacuated by sea or through the congested streets of Brooklyn and Manhattan. Utility management did not realize, until too late, that they had to convince more than just the NRC of the plant's safety and reasonableness of evacuation plans.

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219 WASH-1208, *Status of Central Station Nuclear Power Reactors Significant Milestones*, Atomic Energy Commission, Washington, DC, June 1974, p. 3.

220 "Kemeny Commission Special, Transcript of the Draft Report," *Nucleonics Week*, New York, NY, October 29, 1979, pp. 1-12. © McGraw-Hill, Inc.

221 Ibid., pp. 10-11.

222 Frank Hawkins, NUREG/CR-5151, *Performance-Based Inspections*, U.S. Nuclear Regulatory Commission, Washington, DC, June 1988, pp. 1 and 2.

223 At \$5.48 billion, Shoreham was the most expensive nuclear plant ever built. Its initial estimated cost was \$241 million.

6.3.7 Discussion

Table 8 ranks the performance of the above five plants using the model and performance characteristics described in Subsection 6.2. The plant with the best performance was Trojan, and that with the worst was Shoreham. If the five plants were added to the 30 plants listed in Table 7, Shoreham would appear at the top of the list, the worst of all 35 plants. The other four would rank, worst to best: *5)* Three Mile Island 2, *9)* Fort St. Vrain, *16)* Rancho Seco, and *22)* Trojan. Looking at it another way, three of the closed plants would be in the company of the ten worst plants and none would be with the ten best plants.

Three of the five closed plants, Trojan, Fort St. Vrain and Three Mile Island 2, had problems that could be attributed to deficiencies in design. However, Fort St. Vrain and Three Mile Island 2 had reactors that were ordered prior to the publication of ASME Section III quality assurance requirements,[224] designs that were completed prior to the initial draft of Appendix B,[225] and Construction Permits that were issued prior to the Regulation's final publication. Thus, while loop-holes in the Regulation's criteria may have allowed "pre-existing" design deficiencies to escape unchallenged, during 1970 nuclear utilities were hardly ready for even tighter requirements. They had their hands full trying to understand and staff up to implement the Regulation's new design control requirements. Irrespective of how Criterion III was worded, their initial and continuing focus would have been to control on-going and new design activities rather than review previously completed work.

Shoreham appears to be a special case. Unlike the other four plants, it had few fines and maintenance and operating problems. Had Shoreham been sited in a more suitable location, it may have been completed years earlier and still be in operation. This problem and operating and maintenance problems occurred several years after the Regulation's publication for use and appear to be due to weaknesses in its criteria. Past operating and maintenance deficiencies will most likely continue to result in high electrical costs and premature plant closings. Nine Mile Point 1 will be permanently closed during 1995, about 14 years early, and Browns Ferry 3, which shut down during 1985 after eight years of operation, will probably never be restarted.[199,226]

6.4 CANCELLED PLANTS

6.4.1 General

Table 4 identifies 21 nuclear power plants licensed prior to June 1970. Another 14 plants[227] never made it this far; they were cancelled while their Construction Permits were still under review at the Atomic Energy Commission. An annotated listing of the 14 plants is contained in Supplement VII. Site selection problems were, far and away, the most frequent reason for cancellations. Nine plants were cancelled because of siting problems and five due to rising costs.

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224 As discussed in Paragraph 3.2.4, ASME Section III quality assurance requirements were first published in December 1967.

225 The design of Fort St. Vrain was essentially complete by the time it received a Construction Permit in September 1968. Likewise, the design of Three Mile Island 2 was essentially complete by the time its twin, Three Mile Island 1, received its Construction Permit in May 1968. Though Rancho Seco also received a Construction Permit prior to the Regulation's issuance for public comment, as discussed in Paragraph 3.2.7, the ASLB took a strong interest in the utility's "quality control and inspection programs."

226 As mentioned in Supplement V, Nine Mile Point 1 will be closed because of high operating and maintenance costs. As discussed in Paragraph 3.2.2, Browns Ferry 3 was shut down along with Browns Ferry 1&2 because of "safety and quality assurance concerns."

227 Supplement VII lists eleven nuclear power stations; however, three of these stations were for two plants. Thus, a total of fourteen plants were cancelled during the period in question.

Table 9 lists 118 nuclear plants that have been cancelled since Appendix B was published in June 1970. Utilities had already placed orders for reactors. The NRC authorized work to proceed on 44 plants and, on 28 of plants, construction was underway. Additionally, within the next few years, three more cancellations are expected: Bellefonte 2, 60 percent complete; Perry 2, 57 percent complete; and WNP 3, 76 percent complete.[228] Thus, while the NRC issued 107 Operating Licenses after June 1970, 121 nuclear power plants have been or will be cancelled before getting this far in the licensing process.

The majority of the 118 cancellations were due to overly optimistic estimates of construction costs or future electrical needs, a lack of community support for nuclear power, or a reluctance to continue on in a volatile regulatory environment.[229] Only five cancellations, Marble Hill 1&2, Midland 1&2, and Zimmer, were due to quality assurance problems. The NRC thoroughly investigated the reason for quality problems at these three stations during its Ford Amendment Study.[230] A chronological history of problems at Zimmer, Marble Hill, and Midland appears in Supplement VIII, and the following paragraphs summarize these histories.

6.4.2 Zimmer 1

Construction of Zimmer 1 was terminated on January 21, 1984, with the plant 97 percent complete. Cincinnati Gas & Electric was the owner, Sargent & Lundy was the designer, and H.J. Kaiser Corporation was the builder.

Construction at Zimmer began in January 1972. In November 1982, the utility was fined $200,000 for violations of Appendix B requirements, the largest fine ever of a plant under construction. The NRC reported that it had found evidence of harassment of QA personnel and deficiencies in welding and installed of electrical cable. In November 1982, the NRC halted all construction due a variety of quality problems including deficiencies in structural steel welds and improper record-keeping. The utility dismissed Kaiser and hired Bechtel to take over plant construction. During August 1983, an independent management audit concluded that the quality problems at Zimmer were primarily due to management's tendency to place cost and schedule considerations ahead of quality, inadequate procedures, and a lack of documentation. Five months later, the utility decided to convert Zimmer to a coal-fired power plant. The conversion was successfully completed in late 1990.

The estimated cost of Zimmer increased from $240 million to $3.1 billion when it was cancelled. Cincinnati Gas & Electric spent $1.72 billion on Zimmer plus another $1.1 billion converting it to a coal-fired plant. An Ohio Public Utility Commission study determined that utility mismanagement had resulted in $775 million being wasted on design and construction rework. Cincinnati Gas & Electric sued Kaiser, Sargent & Lundy, and General Electric (the reactor manufacturer) and recovered a total of $56 million in out-of-court settlements. In turn, stockholders sued the utility and, in 1985, agreed to an out-of-court settlement of $2.0 million.

If Appendix B contributed to problems at Zimmer, it was weaknesses in the areas of management's QA responsibilities (see Paragraph 5.5.2) and, to a lesser extent, design verification (see Paragraph 5.2.4), trending deficiencies (see Paragraph 5.4.4), and procedures (see Paragraph 5.5.6).

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[228] DOE/EIA-0527, *Assumptions for the Annual Energy Outlook 1993*, U.S. Department of Energy, Washington, DC, January 8, 1993, p. 90.

[229] DOE/EIA-0392, *Nuclear Power Plant Cancellations: Causes, Costs, and Consequences*, U.S. Department of Energy, Washington, DC, April 1983, p. 14.

[230] NUREG-1055, pp. 3-4, 5, and 6; 4-10, 11, and 15 through 21; A.7 through 11; A.32 through 38; and B.84, 85, 87, and 88.

6.4.3 Marble Hill 1&2

Construction was terminated on January 16, 1984, with Units 1 and 2 about 60 and 37 percent complete, respectively. Public Service Indiana was the utility and Sargent & Lundy was the designer. A number of small specialty contractors reported to the utility who was the project's general construction manager.

Construction had began in April 1978 and was halted by the NRC in August 1979 because of widespread and severe "honeycombing" in concrete, quality problems with installed piping and structural steel, deficiencies in protective coatings, and inadequate staffing and management of construction activities. During the 16 months that construction was stopped, Marble Hill restructured its project management, records, and QA programs.[231] Though construction resumed in December 1981, it was permanently halted three years later when Public Service Indiana ran out of money.

Following cancellation, Public Service Indiana was sued by stockholders and Wabash Valley Power and settled the suits out of court for a total of $195 million. Both plants were abandoned, and Public Service Indiana wrote off $2.7 billion in construction costs. If Appendix B could be faulted, it would be its silence on the subjects of deficiency trending and management's QA responsibilities (see Paragraphs 5.4.4 and 5.5.2).

6.4.4 Midland 1&2

Construction was terminated on July 16, 1984, with Units 1 and 2 each about 85 percent complete. Consumers Power was the utility and Bechtel was the designer/builder.

Construction began in December 1972. Ten months later, Consumers Power was embroiled in a dispute with the AEC over rebar splice quality and the independence of Bechtel QC inspectors.[232] The AEC ordered the utility to "show cause" why all site construction should not be stopped. The dispute was quickly settled and work allowed to continue; however, between 1973 and 1978, quality problems were reported with the installation of rebar, tendon systems, and containment liner plate.

In September 1978, work was again halted after Bechtel detected excessive settlement of the plant's diesel generator building. Fifteen (15) months later the NRC stopped work associated with correcting the settlement problems in order to more thoroughly evaluate the situation and determine appropriate corrective action. The NRC was concerned that excessive settling had been detected in other plant buildings, the settlement was cracking walls, and workers were tunneling under buildings to remove and replace poorly compacted fill materials.

In December 1982, work was halted for a third time and, two months later, Consumers Power was fined $120,000 following a six-month NRC investigation. The NRC found numerous instances of unreported deficiencies and an enormous backlog of uninspected work. This backlog was the result of postponing inspections, without documenting results, if "too many" deficiencies were identified. Inspections would resume after inspectors were notified that the undocumented deficiencies had been corrected. Following the NRC fine, all construction stopped except for repairs to previously completed work.

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231 NUREG-1055, p. A9.

232 Refer to Paragraph 4.5.2 for more about this incident.

On October 6, 1983, work at Midland resumed, however 16 days later was stopped a fourth time after problems were found with field changes to drawings. Nine months later, on the verge of bankruptcy, Consumers Power cancelled the plant. The cost of Midland 1&2 had risen from an initial estimate of $267 million to $6.0 billion.

At the time it was cancelled, Consumers Power had spent $4.2 billion on the plant and was engaged in a $440 million lawsuit with Dow Chemical, a junior partner in the plant. The utility managed to convince Dow to finance part of an additional $800 million needed to convert Midland to a gas-fired plant.[233] The conversion was successfully completed in April 1990.

As discussed in Paragraph 4.5.2, a 1973 dispute over the independence of Midland QC inspectors prompted an amendment to Appendix B that doubled the length of the Criterion I. While the amendment clarified some requirements, its length suggested independent verification was a cornerstone requirement.[234] Management believed that all it had to do to have quality was establish an independent QA Department. Besides over-emphasizing independent verification, Appendix B could be faulted for failing to identify the need for deficiency trending, management's QA responsibilities, and requirements for controlling *SARs* (see Paragraphs 5.4.4, 5.5.2, and 5.5.4).

6.4.5 Discussion

If one considers Appendix B applicable to the siting of nuclear plants, early plants were as susceptible to quality lapses as those cancelled in the 1970s and 1980s. However, because regulatory, economic, and political conditions were more favorable then, once a Construction Permit was issued, plants were built and operated with virtually no organized opposition.[235]

Plant siting issues, a major reason for cancellations during the 1960s, were seldom heard of during the 1970s and 1980s. Improvements in siting nuclear plants cannot be attributed to the issuance of 10CFR50, Appendix B. They were mainly due to the publication of definitive AEC siting criteria during the early 1970s. In July 1969, the AEC provided utilities with draft seismic and geological criteria[236] and, by September 1971, utilities also had draft environmental criteria.[237]

During the early 1980s, there was a tremendous increase in welding problems. At plant after plant, including Marble Hill and Zimmer, inspectors were busy rejecting what were later determined to be acceptable welds. A special Nuclear Construction Issues Group traced the problems to tolerances in industry codes used by welding inspectors. The problems ceased after the codes were revised

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[233] Dow Chemical's portion of the investment was $115 million. ["The Midland Conversion Deal," *Nuclear News*, La Grange, IL, March 1987, p. 28] © 1987 by American Nuclear Society

[234] As shown in Supplement IV of this report, adding Paragraph f(3)(iii)(A) to 10CFR50.34 further reinforced the notion that personnel responsible for verifying quality must report to a separate and organizationally independent QA Department.

[235] For example, the 1960 explosion at SL-1 resulted in three fatalities. A small anti-nuclear group formed soon afterwards and unsuccessfully tried to delay start-up of the Elk River nuclear power plant. Few news organizations covered the accident. On the other hand, the 1979 accident at Three Mile Island received worldwide attention even though there were no fatalities. The mishap fueled a growing and well-funded network of anti-nuclear organizations.

[236] AEC siting regulations were added as Appendix A, "Seismic and Geological Siting Criteria for Nuclear Power Plants," to 10CFR100, *Reactor Site Criteria*. An initial draft was completed in March 1969. Utilities received copies for informal comment during a July 1969 meeting in Bethesda, MD. Issuance for formal public comment was delayed until November 1971 to give the U.S. Geologic Survey time to complete supporting seismic and geological research.

[237] On July 23, 1971, the U.S. Appeals Court in the District of Columbia ruled, in what has become known as the *Calvert Cliffs Decision*, that applications for Construction Permits must include an Environmental Raport and the AEC must establish regulations for reviewing such Reports against the requirements of the National Environmental Policy Act. On September 9, 1971, the AEC issued preliminary criteria for preparing Environmental Reports. The criteria were modified and issued for formal public comment on December 1, 1971.

and new training programs were instituted.[238] One of the best was an American Welding Society "Welding Inspector Qualification and Certification Program" that premiered January 26, 1985.[239]

Three generic quality-related problems played a major role in demise of Zimmer 1, Marble Hill 1&2, and Midland 1&2: *1)* management personnel that did not understand the importance of an effective quality assurance program; *2)* a large number of quality allegations; and *3)* recurring deficiencies due to inadequate corrective action.[240] Lessons learned are contained in Section 7.0 below.

7.0 <u>CONCLUSIONS</u>

7.1 IMPACT ON PLANT PERFORMANCE

As can be seen from Tables 4 and 7, Appendix B had an enormous impact on the performance of nuclear plants. In addition to drastically reducing reactor scrams,[241] it resulted in improved electrical production.[242] Plants that went on line during the 1950s and 1960s were every bit as expensive and time consuming to build as those completed after issuance of Appendix B. Though durations and costs sky-rocketed during the 1970s and 1980s, increases would have been sooner and more rapid without Appendix B. Zimmer, Marble Hill, and Midland serve as grim reminders of the cost of repetitive nonconformances and rework.

Five (5) percent of the plants licensed after issuance of Appendix B have been prematurely closed as compared to 71 percent of the plants licensed prior to its issuance. For plants built before and after the Regulation, the average length of time closed plants operated was ten years. The average age of plants operating today is 15 years. Experts estimate that over the next 17 years, only two to three of these plants will be prematurely closed - another testament to the positive impact that Appendix B has had on plant performance.[199,226,243]

Whereas 4 of 26 reactors experienced partial core-melts during the 19 years prior to Appendix B, only one of 108 reactors has suffered a similar fate in the 23 years since its issuance.[244] Without the Regulation, a major disaster may have occurred several years before the partial core-melt at Three Mile Island. This would have lead to a hugh cry for stronger assurance of quality in nuclear power plant design, construction, and operation. Even without a disaster, the nuclear industry would have been dragged into the total quality management (TQM) movement of the early 1980s. Nuclear utilities that chose not to establish a TQM program would have probably been forced to do so by cost and safety conscience public utility commissions. Appendix B moved the clock ahead on the inevitable, and the American public greatly benefitted.

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[238] Personal correspondence from Roger Reedy dated May 24, 1993.

[239] *AWS QCI-85 Standard for Qualification and Certification of Welding Inspectors*, American Welding Society, Columbus, OH, November 1984, pp. 2 & 20.

[240] Although the problem with welding acceptance criteria cannot be laid at the doorstep of any one utility, the fact remains about five years elapsed before utilities recognized the problem's severity, identified its root cause, and initiated appropriate corrective action.

[241] Whereas the Bonus reactor experienced upwards of 55 scrams/five months, nuclear reactors are now averaging one scram/five months. [Supplement V and NUREG-1350, *Nuclear Regulatory Information Digest*, Volume 2, U.S. Nuclear Regulatory Commission, Washington, DC, March 1990, p. 36.]

[242] Table 4 shows plants licensed after 1970 had an average Lifetime Capacity Factor almost 40% higher than those licensed prior to 1970.

[243] Anita Warren, "Ivan the Elusive," *Nuclear Industry*, Washington, DC, July-September 1992, p. 27. © U.S. Council for Energy Awareness

[244] Plants that have had partial core-melts include EBR-1 on November 29, 1955; WTR on April 3, 1960; SL-1 on January 3, 1961; Fermi 1 on October 5, 1966; and Three Mile Island 2 on March 28, 1979. See Supplements V and VI for further details.

7.2 NEEDED IMPROVEMENTS

7.2.1 General

When issued in 1970, Appendix B was superior to any other QA "standard." Unlike MIL-Q-9858, it recognized the need for material traceability and comprehensive audits. Appendix B learned from NASA's NPC-200-2 which was being revised to incorporate lessons-learned from the Apollo accident. Also, it improved on the ASME Section III, Appendix IX, by greatly strengthening its design control, procurement document control, and status indicator rules. For years, Appendix B was looked on as the world's definitive QA standard and served as a template for many other national and international quality standards including NQA-1, ISO 9001, ISO 9004, and DOE Order 5700.6. However, since about 1980, these and other standards have slowly been improving on Appendix B.

Appendix B has weaknesses that have reduced its effectiveness. The significance of these weaknesses, in terms of impact on plant performance, is summarized in Table 10. The most significant are weak design verification requirements and management QA responsibilities. Also, significant are an absence of deficiency trending requirements, confusing requirements for preparing QA program documents, and weak criteria applicable to plant operation and maintenance. To a lesser extent, weaknesses in Appendix B requirements applicable to configuration management, plant siting, computer programs, and the control of *SARs* have also contributed to poor plant performance.

7.2.2 Design Verification

Section 5.0 reported that errors in original design documents were the second leading reason for reactor scrams. Section 6.0 discussed the consequences of design errors at Trojan, Fort St. Vrain, Three Mile Island, and Zimmer. These findings closely parallel the findings of three professors from the Massachusetts Institute of Technology (MIT). During 1989, they plumbed the annals of our major energy industries to see what lessons could be learned and what, if anything, could be done to stabilize energy prices. Their research included the history of and strategic errors in the nuclear power industry. Their conclusions were as follows:[245]

> *The neglect of the importance of quality by the nuclear industry is not only strategic but also painfully obvious operationally. Although the planning assumption for the capacity factor of nuclear power plants was 70% in most cases, the actual performance in the 1970s was less than 60%. Examining the causes of loss in capacity factor ..., we find that most of the causes were ... not associated with the fission reaction. Failure of "traditional" equipment from inadequate testing of valves, lack of attention to the possibility of stress corrosion cracking, and flow-induced vibration, and under-estimating the importance of water chemistry were responsible for the lion's share of the loss in capacity factor. These are problems related to mature technologies. Their failures cannot be attributed to anything but poor attention to quality.*

The MIT professors found that simple errors in original plant design had significantly affected plant performance. These errors should have been identified and corrected during in-process document reviews and, if overlooked, should have been identified during later design verification. This did not happen because design organizations combined document reviews and design verification into a single "design verification review." This one-step review was inadequate.

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[245] Thomas H. Lee, Ben C. Ball, and Richard D. Tabors, *Energy Aftermath*, Harvard Business School Press, Boston, MA, 1990, pp. 125 & 126. [Excerpt with permission of copyright holder.

Even when performed correctly, design reviews usually fall short of completely "proving" the adequacy of a design. Appendix B and NQA-1 should be amended to explicitly require both in-process document reviews and design verification. The amendment should make it clear that qualification testing is the preferred method of verification. If design reviews are used to verify designs, personnel participating in such reviews should be trained and certified to requirements that are comparable to those in NQA-1 Supplement 2S-3, "Qualification of Quality Assurance Audit Personnel." The design review team leader should be a Registered Professional Engineer. Other team members should be selected based on their expertise in design analysis, materials, construction, plant operation and maintenance, and so forth.

7.2.3 Trending Deficiencies

Section 5.0 reported that the Ford Amendment Study found that the nuclear industry had done a poor job of trending deficiencies, determining the root cause of repetitive deficiencies, and taking appropriate corrective action. Section 6.0 discussed the consequences of recurring deficiencies at Rancho Seco, Zimmer, Marble Hill, and Midland.

The only guidance developed thus far on trending is contained in NQA-1 Appendix 16A-1, "Nonmandatory Guidance on Corrective Action." The guidance is so brief and superficial it is of almost no value. Typically, the nuclear industry evaluates trends in weld defects and deficiencies identified during inspections and surveillances. This type of trending seldom prevents marginal quality problems from becoming full-fledged deficiencies. For example, audit "concerns" and "major" design review comments are indicators of future quality problems. Monitoring these indicators and taking timely preventative action would be far more beneficial than collecting formal deficiency reports and, after enough reports have piled up to show a negative trend, forwarding a recommendation to senior management. Monitoring quality indicators could stop recurring deficiencies.

Appendix B and industry standards should be amended to require establishing and trending *quality indicators*, not just *conditions adverse to quality*. Data should be collected that will provide an early indication of future quality problems. At present, NQA-1 Supplement 16A-1 recommends trending deficiencies by adverse condition, e.g., document control and calibration. It should also recommend trending the "probable" root cause of deficiencies, e.g., inadequate training, unrealistic schedules, or a lack of adequate resources.

7.2.4 Management

Section 5.0 reported that the Ford Amendment Study found that management apathy was the underlying reason for quality problems in the nuclear industry. Section 6.0 discussed the consequences of management-related quality problems at Rancho Seco, Trojan, Fort St. Vrain, Three Mile Island, Shoreham, Zimmer, Marble Hill, and Midland.

Despite the obvious significance of the Study's principal finding, neither NQA-1 nor Appendix B was amended to address the finding. Amendments are needed to require more management participation in establishing and implementing QA programs. At present, management's only responsibility is to regularly assess the QA Program's adequacy and effectiveness. This assessment is normally conducted once a year by an independent consultant. Management's participation is limited to hiring the consultant and reading the assessment report.

NQA-1 should require that management personnel participate in assessments. Others should assist but not replace management. NQA-1 should require that management establish quality policies, objectives, and procedures for handling quality disputes, concerns, and allegations. Management should participate in establishing quality indicators and identify the type and frequency of reports it needs to receive on quality.

7.2.5 QA Program Documents

Section 5.0 discussed the generic nature of problems with procedures at operating nuclear power plants. Section 6.0 mentioned problems with procedures at Zimmer.

The problem is endemic and is not limited to just plant operating procedures. It covers a range of QA Program documents and includes conflicts between Program documents and other documents, within Program documents, and between Program documents. This latter problem is usually due to a failure to establish a sensible QA Program document hierarchy.[246]

Appendix B and NQA-1 should replace reference to "instructions" with "specifications." It should explain the relationship between the two documents: *1)* specifications are design output documents; and *2)* procedures implement requirements in specifications and quality policy documents. A new NQA-1 Appendix 5A-1 is needed that provides guidance on establishing a QA Program document hierarchy, determining appropriate level-of-detail and documentation, incorporating lessons learned and input from affected organizations and subject matter experts, and integrating procedures with other documents and training programs.

7.2.6 Operation and Maintenance

Section 5.0 discussed generic problems that have been experienced applying Appendix B criteria to plant operation and maintenance. Section 6.0 discussed specific problems at Rancho Seco, Fort St. Vrain, and Three Mile Island.

Though the Introduction to Appendix B says it applies to plant operation and maintenance, subsequent criteria make scant reference to plant operation and zero reference to maintenance. Utilities have had chronic problems applying Appendix B to operating plants, especially their maintenance.

Appendix B should be amended to say more about the application of its criteria to plant operation and maintenance. It should mention training of plant personnel, operating procedures, plant security, outages, start-up readiness reviews, emergency planning, and maintenance. The scope of ANS-3.2 should be limited to administrative requirements. Quality assurance requirements in ANS-3.2 should be transferred to NQA-1 Supplements. The scope of NQA-1 Supplements should match that of the amended Regulation. It should require that implementing procedures be developed and apply, in a graded manner, to selected balance-of-plant (BOP) systems.[247] This is especially true of BOP systems that need to function properly to keep the plant operating. Every time the plant has to be shut down, safety-related systems have to be activated and with each challenge to these systems the probability of failure increases.

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246 This paragraph is based on the author's 25 years of experience in the nuclear industry.

247 Graded QA requirements should also be applied to the design and construction of selected BOP systems.

The nuclear industry needs to do a better job applying QA lessons learned from Three Mile Island (TMI) to plant operation and maintenance. TMI lessons learned incorporated in the 1982 amendment to 10CFR50.34 were primarily imposed on the design and construction phases of yet-to-be built plants.[248] If the following 10CFR50.34 requirements apply to design and construction activities, it would appear that they also apply to operation and maintenance activities:[249,250]

a) **Lessons Learned** Paragraph f(3)(i) requires evaluating operating lessons learned and passing them along to design and construction personnel. They should also be passed along, when applicable, to responsible plant operation and maintenance personnel.

b) **QA/QC Staff Location** Paragraph f(3)(iii)(B) requires that, to the extent feasible, QA/QC personnel be located at construction sites. To the extent feasible, they should also be located at operating nuclear power plants versus the utility's corporate headquarters.

c) **Document Review & Approval** Paragraph f(3)(iii)(C) requires that QA personnel review and approve selected design, construction, and installation procedures. They should also review and approve selected operating and maintenance procedures.

d) **Design & Analysis Activities** Paragraph f(3)(iii)(H) requires that QA personnel have a role in design and analysis activities, e.g, verify the adequacy of test and inspection frequencies in a construction specification. They should also have a role in plant operation and maintenance activities, e.g, participate in major schedule decisions and readiness reviews conducted prior to restarting a plant after an extended outage.

7.3 SUMMARY

The publication of 10CFR50, Appendix B, resulted in major improvements in nuclear power plant performance. Though 10CFR50 has been amended to incorporate Three Mile Island and other nuclear industry lessons learned, Appendix B has not changed since January 20, 1975. An amendment is needed to both Appendix B and NQA-1 to correct weaknesses identified in this report.

In addition to correcting weaknesses, the amendments should close the gap with requirements in ISO 9001. Eighteen (18) European countries, Canada, and Mexico are moving toward requiring compliance with ISO 9001. Suppliers are showing a reluctance to implementing both Appendix B and ISO 9001 quality programs without some sort of sign they will receive enough nuclear orders to warrant the expense. Closing the gap with ISO 9001 would reduce plant construction, operating, and maintenance costs and stem the declining number of suppliers qualified to provide materials, spare parts, and specialized technical services needed to keep plants on line.

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[248] All 10 nuclear power plants mentioned in the 1981 amendment to 10CFR50.34 were cancelled during 1982 or 1983. As indicated in Table 9, this includes Allens Creek 1, Black Fox 1&2, Pebble Springs 1&2, Perkins 1, 2 & 3, and Skagit 1&2. Also, none of the eight floating nuclear power plants envisioned by Offshore Power Systems were ever built.

[249] See Supplement IV for exact wording of 10CFR50.34(f)(3).

[250] The QA requirements in 10CFR50.34 add another layer of administrative detail to existing Appendix B requirements. This may be necessary based on TMI lessons learned; however, it may also be an overreaction to one or more limited and unrelated problems. The applicability of 10CFR50.34 requirements should be reevaluated as part of the performance-based initiative discussed in Paragraph 4.5.5.

AEC QA CRITERIA

1. PLANNING[1]

The applicant-licensee should plan and establish, document, and implement a rigorous quality assurance program for each phase or activity affecting quality.[2] This program plan should describe the methods and procedures to be employed to ensure the adequacy of and compliance with the applicable codes, standards, criteria, and requirements in order to provide confidence that the materials, components, and systems of a nuclear power plant are important to safely perform as required.[3]

2. ORGANIZATION[4]

The applicant-licensee should assure that the authority and responsibility of persons and organizations performing quality assurance functions are clearly established and delineated in writing and that they have sufficient organizational freedom to identify problems affecting quality and to ensure that solutions are provided.[5]

3. WORK INSTRUCTIONS[6]

The applicant-licensee should assure that all work affecting quality is prescribed by documented instructions.[7]

4. CONTROL OF INSTRUCTIONS, PROCEDURES, SPECIFICATIONS, AND DRAWINGS[8]

The applicant-licensee should establish a system to assure that instructions, procedures, specifications, and drawings are complete and current and are readily available at the job site.[9]

5. DESIGN REVIEW[10]

An independent, comprehensive, documented assessment of the adequacy of design should be accomplished for major components and systems important to safety to assure compliance with criteria, codes, standards, and requirements.[11]

6. PURCHASE SPECIFICATION REVIEW[12]

The applicant-licensee should assure that all applicable criteria, codes, standards, and requirements which are necessary to assure adequate quality levels and conformance to design characteristics are properly included or referenced in specifications for the procurement of materials, equipment, and services.[13]

7. CONTROL OF PURCHASED MATERIAL, EQUIPMENT, AND SERVICES[14]

The applicant-licensee should assure that all purchased material, equipment, and services conform to the requirements of the purchase specifications.[15]

NOTES

[1] *This title was based on RDT F2-2, Para. 2.2.1.*

[2] *This sentence was based on RDT F2-2, Para. 2.2.*

[3] *This sentence was based on Criterion 1 of Appendix A to 10CFR50.*

[4] *This title was based on MIL-Q-9858A, Para.3.1.*

[5] *This sentence was based on MIL-Q-9858A, Para. 3.1.*

[6] *This title was based on MIL-Q-9858A, Para. 3.3.*

[7] *This sentence was based on MIL-Q-9858A, Para. 3.3.*

[8] *This title was inspired by Para. 5.4(a)3 of Zion's QA Plan.*

[9] *This sentence was based on MIL-Q-9858A, Para. 4.1.*

[10] *This title was based on RDT F2-2, Para. 3.5.*

[11] *This sentence was inspired by RDT F2-2, Para. 3.5*

[12] *This title was influenced by Para. 5.4(c)2 of Zion's QA Plan and Para. 1B502(1) of NHB 4300.4.*

[13] *This sentence was influenced by Para. 5.2 of MIL-Q-9858A and Para. 7.8 of Zion's QA Plan.*

[14] *This title was influenced by Section 5 of MIL-Q-9858A and Para. 1B500 of NHB 5300.4.*

[15] *This sentence was based on MIL-Q-9858A, Para. 5.1.*

8. CONTROL AND IDENTIFICATION OF MATERIALS[16]

The applicant-licensee should establish a system to assure that control and identification of materials are maintained throughout all operations consistent with the intended use of the material.[17]

9. IN-PROCESS AND FINAL INSPECTION[18]

The applicant-licensee should provide a system for planned, documented in-process and final inspection at appropriate stages of fabrication, construction, installation, and test in accordance with documented instructions.[19]

10. CALIBRATION OF MEASUREMENT AND TEST EQUIPMENT[20]

The applicant-licensee should assure that tools, gages, and other measuring and testing devices are calibrated in accordance with recognized standards and procedures.[21]

11. HANDLING, STORAGE, SHIPPING, AND PRESERVATION[22]

The applicant-licensee should assure that a system is established to provide and use adequate work and inspection instructions for handling, storage, shipping, and preservation of materials and equipment to prevent damage or deterioration.[23]

12. NONCONFORMING MATERIAL[24]

The applicant-licensee should establish a system for the control of material, parts, components, and workmanship which do not conform to criteria, codes, standards, and requirements.[25]

13. CORRECTIVE ACTION[26]

The applicant-licensee should assure that conditions adverse to quality are detected and reported, the cause of each condition is determined and corrective action is taken to preclude recurrence.[27]

14. QUALITY CONTROL RECORDS[28]

The applicant-licensee should assure that complete and reliable records are maintained sufficient to furnish documentary evidence of product quality.[29]

15. AUDITS[30]

The applicant-licensee should establish a system of audits to assure compliance with all aspects of the quality assurance program and to determine the effectiveness of the program.[31]

[16] *This title was based on ASME III, Para. IX-226.*

[17] *This sentence was based on ASME III, Para. IX-226.*

[18] *This title was influenced by Para. 7.10 of Zion's QA Plan and Para. 1.1 of RDT F2-2.*

[19] *This sentence was influenced by RDT F2-2, Para. 5.3 and 5.6.1.*

[20] *This title was based on ASME III, Para. IX-230.*

[21] *This sentence was based on MIL-Q-9858A, Para. 4.2.*

[22] *This title was based on Para. 11.1 through 11.4 of Zion's QA Plan.*

[23] *This sentence was based on MIL-Q-9858A, Para. 6.4.*

[24] *This title was based on MIL-Q-9858A, Para. 6.5.*

[25] *This sentence was based on MIL-Q-9858A, Para. 6.5.*

[26] *This title was based on MIL-Q-9858A, Para. 3.5.*

[27] *This sentence was based on MIL-Q-9858A, Para. 3.5.*

[28] *This title was based on ASME III, Para. IX-225.*

[29] *This sentence was based on MIL-Q-9858A, Para. 3.4.*

[30] *This title was based on Section 7.9 of Zion's QA Plan.*

[31] *This sentence was based on Para. 1B205(1) of NHB 4300.4.*

10CFR50, APPENDIX B

INTRODUCTION

Every applicant for a construction permit is required by the provisions of § 50.34 to include in its preliminary safety analysis report a description ~~and evaluation~~[1] of the quality assurance program to be applied to the design, fabrication, construction, and testing of the structures, systems, and components of the facility. Every applicant for an operating license is required to include, in its final safety analysis report, information pertaining to the managerial and administrative controls to be used to assure safe operation. Nuclear power plants and fuel reprocessing plants[2] include structures, systems, and components that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. This appendix establishes quality assurance requirements for the design, construction, and operation of those structures, systems, and components. The~~se~~ pertinent requirements of this appendix apply to all activities affecting the safety-related functions of those structures, systems, and components; these activities include designing, purchasing, fabricating, handling, shipping, storing, cleaning, erecting, installing, inspecting, testing, operating, maintaining, repairing, refueling, and modifying.

As used in this appendix, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service. Quality assurance includes quality control, which comprises those quality assurance actions related to the physical characteristics of a material, structure, component, or system which provide a means to control the quality of the material, structure, component, or system to predetermined requirements.

I. ORGANIZATION

The applicant shall be responsible for the ~~develop~~establishment~~, implementation~~ and execution of the quality assurance program.[3] The applicant may delegate to others ~~organizations~~, such as contractors, agents, or consultants, the work of establishing~~ment~~ and executing~~ment of~~ the quality assurance program, or any part thereof, but shall retain responsibility therefor.[4] The authority and duties of persons and organizations performing ~~quality assurance~~ activities affecting the safety related functions of structures, systems, and components[5] shall be clearly established and delineated in writing.[6] These activities include both the performing functions of attaining quality objectives and the quality assurance functions. The quality assurance functions are those of (a) assuring that an appropriate quality assurance program is established and effectively executed and (b) verifying, such as by checking, auditing, and inspection, that activities affecting the safety-related functions have been correctly performed.[7] ~~Such~~ The persons and organizations performing quality assurance functions shall have sufficient authority and organizational freedom to identify quality problems; to initiate, recommend, or provide solutions; and to verify implementation of solutions.[8] ~~In general, assurance of quality requires management measures which provide that the individual or group assigned the responsibility for checking, auditing or otherwise verifying that an activity has been correctly performed as independent of the individual or group directly responsible for performing the specific activity.~~[9] Such persons and organizations performing quality assurance functions shall report to a management level such that this required authority and organizational freedom, including sufficient independence from cost and schedule when opposed to safety consid-

NOTES

[1] The words "and evaluation" were deleted in response to objections from Westinghouse (06/09/69), Babcock & Wilcox (06/17/69), and General Electric (06/30/69) who believed the applicant's quality assurance program should be evaluated by the AEC rather than the applicant.

[2] The words "and fuel reprocessing plants" were added in a 09/11/71 addendum to Appendix B.

SPECIAL NOTE

Changes shown in the left column are to the original text of Appendix B as it appeared on April 17, 1969. Those changes, unless noted otherwise, occurred during the resolution of public comments and prior to issuance of Appendix B for use on June 27, 1970. Shaded entries are words that were added and strike-outs are words that were deleted from the original text.

[3] This sentence was based on requirements in 10CFR50.34(a)7 as published on 12/17/68.

[4] This sentence was based on Para. 1.4 of RDT F2-2.

[5] This sentence was based on Para. IX-221(b) of ASME III.

[6] On 04/19/74 a proposed change to Appendix B was issued for public comment. Reviewers requested clarifying the phrase "quality assurance functions". This change, which was published 01/20/75, was in response to these comments.

[7] On 01/20/75 this and the previous sentence were added to Appendix B in response to public comments on an proposed amendment issued on 04/19/74. Reviewers asked that requirements of Appendix B be imposed on those responsible for achieving quality and those responsible for verifying attainment of quality.

[8] This sentence was borrowed from Para. 3.1 of MIL-Q-9858A.

[9] This sentence, which came from Para. 2.3.1 of RDT F2-2, was replaced by the next three sentences to resolve a dispute at Midland 1&2 and LaSalle 1&2 where field QC personnel reported to a resident construction superintendent. Twice during 1973, the Atomic Safety and Licensing Appeal Board ruled this arrangement represented a conflict of interest. To clarify requirements, an amendment to Criterion I was issued for public comment on 04/19/74. Following comment resolution, the amendment was published on 01/20/75.

erations, are provided. Because of the many variables involved, such as the number of personnel, the type of activity being performed, and the location or locations where activities are being performed, the organizational structure for executing the quality assurance program may take many forms provided that the persons and organizations assigned the quality assurance functions have this required organizational freedom. Irrespective of the organizational structure, the individual(s) assigned the responsibility for assuring effective execution of any potion of the quality assurance program at any location where activities subject to this Appendix are being performed shall have direct access to such levels of management as may be necessary to perform this function.[10] ~~The applicant shall regularly review the status and adequacy of the quality assurance program. Management of other organizations participating in the quality assurance program shall regularly review the status and adequacy of that part of the quality assurance program which they are executing.~~[11]

II. QUALITY ASSURANCE PROGRAM

The applicant shall establish at the earliest practical time, consistent with the schedule for accomplishing the activities, a quality assurance program which complies with the requirements of this appendix.[12] This program shall be documented by written policies, procedures, ~~and~~ or instructions and shall be carried out throughout plant life~~.~~ in accordance with those policies, procedures or instructions.[13] The applicant shall identify the structures, systems, and components to be covered by the quality assurance program and the major organizations participating in the program, together with ~~their~~ designated functions~~.~~ of these organizations.[14] The quality assurance program shall provide control~~, by means such as design review, verification, inspection, and documentation,~~ over activities affecting the quality of the identified structures, systems, and components, to an extent consistent with their importance to safety.[15] Activities affecting quality shall be accomplished ~~under this program in accordance with instructions, procedures, or drawings of a type appropriate to the circumstances and~~ under suitably controlled conditions. Controlled conditions include the use of appropriate equipment~~,~~; suitable ~~working~~[16] environment~~,~~al conditions of accomplishing the activity, such as adequate cleanliness~~,~~; and assurance that all prerequisites for the given ~~operation~~ activity have been satisfied.[17] The program shall take into account the need for special controls, processes, test equipment, tools, and skills to attain required quality~~;~~, and the need for verification of quality by inspection and test.[18] ~~, and the need~~ The program shall provide for indoctrination and training of personnel ~~to execute the program.~~ performing activities affecting quality as necessary to assure that suitable proficiency is achieved and maintained.[19] The applicant shall regularly review the status and adequacy of the quality assurance program.[20] Management of other organizations participating in the quality assurance program shall regularly review the status and adequacy of that part of the quality assurance program which they are executing.[21]

III. DESIGN CONTROL

Measures shall be established to assure that applicable regulatory requirements and the design basis, as defined in § 50.2 and as specified in the license application, for those systems, structures, and components to which this appendix applies are correctly translated into specifications, drawings, procedures, and instructions.[22] These measures shall include provisions to assure that appropriate quality standards are specified[23] and included in design documents and that deviations from such standards are controlled. Measures shall also be established for the selection and

[10] *This sentence was based on Para. 1B201 of NHB 5300.4.*

[11] *These two sentences were relocated to the end of Criterion II in response to a 06/09/69 letter from Westinghouse that stated the sentences did not belong in Criterion I and should be moved to either Criterion II or XVIII.*

[12] *Westinghouse (06/09/69), Babcock & Wilcox (06/17/69), and the Atomic Industrial Forum (06/18/69) suggested adding "consistent with the scheduled progress of work" or words to this effect. However, the source of this sentence is not known.*

[13] *This sentence was based on Para. 2.4.1 of RDT F2-2 and is very similar to the first sentence of Criterion V to Appendix B. Westinghouse (06/09/69) recommended that the sentence be modified to make it clear that, to be acceptable, a QA program need not contain policies plus procedures plus instructions.*

[14] *This sentence was based on Para. 2.2.2 of RDT F2-2.*

[15] *This sentence was based on Para. 2.2.3 of RDT F2-2.*

[16] *The word "working" was deleted because 06/09/69 comments from Westinghouse said the term "suitable working environment" could be interpreted to mean "comfortable working conditions".*

[17] *This and the previous sentence were based on Para. 6.2 of MIL-Q-9858A.*

[18] *This sentence was based on Para. 3.2 of MIL-Q-9858A.*

[19] *This sentence was loosely based on Para. 2.3.2 of RDT F2-2.*

[20] *This and the next sentence were based on Para. 3.1 of MIL-Q-9858A.*

[21] *Refer to Note 11.*

[22] *This sentence was based on Para. 3.3 of RDT F2-2.*

[23] *The requirement to identify quality standards was borrowed from Criterion I of Appendix A to 10CFR50 which was issued for public comment on 07/11/67. Appendix A was published 02/20/71.*

review of suitability of the application of materials, parts, equipment, and processes that are essential to the safety-related functions of the structures, systems, and components.[24]

Measures shall be established for the identification and control of design interfaces and for coordination among participating design organizations.[25] These measures shall include the establishment of procedures among participating design organizations for the review, approval, release, distribution, and revision of documents involving design interfaces.[26]

The design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculations, or by the performance of a suitable testing program.[27] The verifying or checking process shall be performed ~~These measures shall be provide for the performance of design reviews~~ by individuals or groups other than those who performed the original design, but who may be from the same organization.[28] Where a test program is used to verify the adequacy of a specified design feature in lieu of other verifying or checking processes, it shall include suitable qualification testing of a prototype unit under the most adverse design conditions.[29] ~~In addition to verification of the design, the applicant shall be responsible for assuring that the design is correctly described in the license application and that the contents of the safety analysis reports are accurate.~~[30] ~~Design reviews shall cover~~ Design control measures shall be applied to items such as the following: reactor physics, stress, thermal, hydraulic, and accident analyses; compatibility of materials; accessibility for inservice inspection, maintenance and repair; and delineation of acceptance criteria for inspections and tests.[28] ~~Reports of in process and final design reviews shall be reviewed by management of the responsible design organizations.~~[31]

Design changes, including field changes, shall be subject to design control measures commensurate with those applied to the original design[32] and shall be approved by the organization that performed the original design unless the applicant ~~specifically~~ designates another responsible organization.[33] ~~Procedures shall be established among participating design organizations for the review, approval, release, distribution, and revision of documents involving design interfaces.~~[34]

IV. PROCUREMENT DOCUMENT CONTROL

Measures shall be established to assure that applicable regulatory requirements, design bases, and other requirements which are necessary to assure adequate quality are suitably included or referenced in the documents for procurement of material, equipment, and services, whether purchased by the applicant or by its contractors or subcontractors.[35] To the extent necessary, procurement documents shall require contractors or subcontractors to provide a quality assurance program consistent with the ~~quality assurance requirements~~ pertinent provisions of this appendix.[36]

V. INSTRUCTIONS, PROCEDURES, AND DRAWINGS

Activities affecting quality shall be prescribed by documented instructions, procedures, or drawings of a type appropriate to the circumstances and shall be accomplished in accordance with these instructions, procedures, and drawings.[37] Instructions, procedures, ~~and~~ or drawings shall include appropriate quantitative or qualitative ~~means~~ acceptance criteria for determining that important ~~operations~~ activities have been satisfactorily accomplished.[38]

[24] *This sentence was based on Para. 3.3.4 of RDT F2-2. The decision to create two paragraphs, the first containing design basis requirements and the next design verification rules, was prompted by a 06/16/69, comment from Gilbert Associates.*

[25] *This sentence was based on Para. 3.3.9 of RDT F2-2.*

[26] *This sentence was based on Para. 3.3.10 of RDT F2-2.*

[27] *This sentence was based on Para. 3.5 of RDT F2-2 and expanded to permit use of alternate calculations and testing of prototypes. The change was in response to requests from Westinghouse (06/09/69), Combustion Engineering (06/12/69, and Consolidated Edison to allow verification using more than just design reviews.*

[28] *This sentence was based on Para. 3.5 of RDT F2-2.*

[29] *This sentence was based on Para. 1B704 of NHB 5300.4.*

[30] *This sentence was deleted in response to a 06/17/69 letter from Babcock & Wilcox that noted the sentence was not needed because its requirements already appeared in Criterion VI.*

[31] *This was deleted in the request of Babcock & Wilcox (06/17/69), Combustion Engineering (06/12/69), and Westinghouse (06/09/69).*

[32] *The "commensurate" phrase was added to satisfy 06/11/69 comments from contractors at the AEC's Hanford facility.*

[33] *This sentence, which was based on Para. 3.4.2 of RDT F2-2, became part of a new last paragraph in response to a 06/16/69 letter from Ralph Parsons that recommended rules for design verification be separate from those for design changes.*

[34] *Refer to Note 26.*

[35] *This sentence was based on Para. 5.2 of MIL-Q-9858A.*

[36] *This sentence was based on Para. 1B502.2(a) of NHB 4300.4. The phrase "pertinent provisions" was substituted for "quality assurance requirements" in response to a written suggestion, dated 06/11/69, from United Engineers & Constructors. The change was intended to recognize that all 18 criteria in Appendix B may not apply to all contractors and subcontractors.*

[37] *This sentence was based on Para. 6.2 of MIL-Q-9858A.*

[38] *This sentence was based on Para. 2.4.1 of RDT F2-2. "Means" was replaced with "acceptance criteria" at the request of Stone & Webster (06/09/69), "operations" was replaced with "activities" at the request from Hanford facility contractors (06/11/69), and "and" with "or" at the request of General Electric (06/24/69).*

VI. DOCUMENT CONTROL

Measures shall be established to control the issuance of documents, such as instructions, procedures, and drawings, including changes thereto, which prescribe all activities affecting quality. These measures shall assure that documents, including changes, are reviewed for adequacy and approved for release by authorized personnel and are distributed to and used at the location where the prescribed activity is performed. Changes to documents shall be reviewed and approved by the same organizations that performed the original review and approval unless the applicant ~~specifically~~ designates another responsible organization.[39]

VII. CONTROL OF PURCHASED MATERIAL, EQUIPMENT, AND SERVICES

Measures shall be established to assure that ~~all~~[40] purchased material, equipment, and services, whether purchased directly or through contractors and subcontractors, conform to the procurement documents.[41] These measures shall include provisions, as appropriate, for source evaluation and selection, objective evidence of quality furnished by the contractor or subcontractor, inspection at the contractor or subcontractor source, and examination of products upon delivery.[41] Documentary evidence that material and equipment conform to the procurement requirements shall be available at the nuclear power plant or fuel reprocessing plant[42] site prior to installation or use of such material or equipment. This documentary evidence shall be retained at the nuclear power plant or fuel reprocessing plant[42] site and shall be sufficient to identify the specific requirements such as codes, standards, or specifications, met by the purchased material and equipment.[43] The effectiveness of the control of quality by contractors and subcontractors shall be assessed by the applicant or designee at intervals consistent with the importance, complexity, and quality of the product or services.[41] ~~Test reports, inspection records, audit reports, certificates, and other evidence of quality shall be used in this assessment, and corrective action shall be taken where indicated.~~[44]

VIII. IDENTIFICATION AND CONTROL OF MATERIALS, PARTS, AND COMPONENTS

Measures shall be established for the identification and control of materials, parts and components, including partially fabricated assemblies.[45] These measures shall assure that identification of the item is maintained by heat number, part number, serial number, or by other means, either on the item or records traceable to the item, as required throughout fabrication, erection, installation, ~~repair, or modification~~ and use of the item.[46] These identification and control measures shall be designed to prevent the use of incorrect or defective material, parts, and components ~~items, and items which have not received the required inspections and tests.~~[47]

IX. CONTROL OF SPECIAL PROCESSES

Measures shall be established to assure that special processes, including welding, heat treating, and nondestructive testing, are controlled ~~in accordance with applicable codes, standards, specifications, criteria, and other special requirements,~~ and ~~are~~ accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements.[48]

[39] *This paragraph was based on Para. 3.4.2 of RDT F2-2.*

[40] *"All" was deleted in response to a 06/09/70 Westinghouse letter which expressed concern that "all" could be interpreted to include procurement of nonsafety-related items and services.*

[41] *Requirements in this and the previous sentence were based on Para. 5.1 of MIL-Q-9858A.*

[42] *The words "or fuel processing plant" were added in a 09/11/71 addendum to Appendix B. The addendum was issued for public comment on 04/10/71.*

[43] *This and the previous sentence were added in response to: 1) a 06/11/69 request from Hanford facility contractors; and 2) lessons learned at Oyster Creek.*

[44] *This sentence was deleted in response to letters from General Electric (06/30/69) and Westinghouse (06/09/69) which argued that its requirements were redundant with Criteria XVI and XVIII.*

[45] *This sentence was based on Para. 5.4 of RDT F2-2.*

[46] *This sentence was modified in response to letters from Hanford facility contractors (06/11/69), Combustion Engineering (06/12/69), and Gilbert Associates (06/16/69) which expressed concern it could be interpreted to require that each bolt (versus keg of bolts) have a unique identification number.*

[47] *This and the previous sentence were based on Para. IX-226(a) of ASME III.*

[48] *Criterion IX was primarily based on Para. 6.2 of MIL-Q-9858A but was also influenced by Para. IX-222(a) of ASME III and Para. 5.5 of RDT F2-2.*

X. INSPECTION

A program for ~~in-process and final~~[49] inspection of activities affecting quality shall be established and executed by or for the organization performing the activity to verify ~~assure~~ conformance with documented instructions, procedures, and drawings for accomplishing the activity.[50] Such inspection shall be performed by individuals other than those who performed the activity being inspected.[51] Examinations, measurements, or tests of materials or products processed shall be performed for each work operation where necessary to assure quality. If inspection of processed material or products is impossible or disadvantageous, indirect control by monitoring processing methods, equipment, and personnel shall be provided when control is inadequate without both.[52] If ~~M~~mandatory inspection hold points, which require witnessing or inspecting by the applicant's designated representative and beyond which work may not proceed without the consent of the designated representative are required, the specific hold points shall be indicated in appropriate documents.[53]

[49] "In-process and final" was deleted in response to a 06/09/69 Westinghouse letter that questioned requiring in-process inspection, regardless of need and applicability.

[50] This sentence was based on Para. 5.3 and 5.6.1 of RDT F2-2.

[51] This and the end of the previous sentence were moved from the seventh sentence of Criterion I in response to a 06/11/69 United Engineers & Constructors letter that suggested, regardless of the utility's inspection program, each organization should be required to inspect its own work.

[52] This and the previous sentence were borrowed from Para. 6.2 of MIL-Q-9858A.

[53] This sentence was based on Para. 9.0 of Zion's QA Plan. The need for mandatory hold points was relaxed in response to requests from Stone & Webster (06/09/69), Westinghouse (06/09/69), Combustion Engineering (06/12/69, and the Atomic Industrial Forum (06/18/69).

XI. TEST CONTROL

A test program shall be established to assure that all ~~required~~[54] testing required to demonstrate that structures, systems, and components will perform satisfactorily in service~~, including proof testing, acceptance testing, and operational testing,~~ is identified and performed in accordance with written test procedures which incorporate the requirements and acceptance limits contained in applicable design documents.[55] The test program shall include, as applicable, proof tests prior to installation, preoperational tests, and operational tests during nuclear power plant or fuel reprocessing plant[56] operation, of structures, systems, and components.[57] ~~The t~~Test procedures shall include provisions for assuring that all prerequisites for a given test have been met, that adequate test instrumentation is available and used, and that the test is performed under suitable environmental conditions.[58] Test results shall be documented and evaluated to assure that test requirements have been satisfied.[59]

[54] "Required" was relocated to the other side of "testing" in response to a 06/09/69, letter from Stone & Webster that asked what was meant by "required testing".

[55] This sentence was loosely based on Para. 6.3 of MIL-Q-9858A.

[56] The words "or fuel reprocessing plant" were added in a 09/11/71 addendum to Appendix B. The addendum was issued for public comment on 04/10/71.

[57] This sentence was added and "operational testing" deleted from the previous sentence in response to requests from General Electric (06/30/69) and Ralph Parsons (06/16/69) to clarify the meaning of "operational testing".

[58] This sentence was based on Para. 5.6.1 of RDT F2-2.

[59] This sentence was loosely based on Para. IX-240 of ASME III.

XII. ~~CALIBRATION~~ CONTROL OF MEASUREMENT AND TEST EQUIPMENT

Measures shall be established to assure that tools, gages, instruments, and other measuring and testing devices used in activities affecting quality are properly controlled, calibrated and ~~properly~~ adjusted at specified periods to maintain accuracy within necessary limits.[60] ~~Calibration shall be against certified measurement standards which have known valid relationships to national standards.~~[61]

[60] This and the next sentence were based on Para. 4.2 of MIL-Q-9858A. The words "properly controlled" were added in response to a 06/11/69 request from Hanford facility contractors.

[61] This sentence was deleted in response to a 06/12/69 letter from Combustion Engineering that noted in some cases national standards may not exist.

XIII. HANDLING, STORAGE, AND SHIPPING ~~AND PRESERVATION~~

Measures shall be established to ~~provide work and inspection instructions for~~ control the handling, storage, shipping, cleaning, and preservation of material and equipment in accordance with work and inspection instructions to prevent damage or deterioration. When necessary for particular products, special environments, such as inert gas atmosphere, specific moisture content levels, and high temperature levels, shall be specified and provided ~~and their existence verified.~~[62]

[62] Requirements in this and the previous sentence were borrowed from Para. 6.4 of MIL-Q-9858A.

XIV. INSPECTION, TEST, AND OPERATING STATUS

Measures shall be established to indicate, by the use of markings such a stamps, tags, labels, routing cards, or other suitable means, the status of inspections and tests performed upon individual items of the nuclear power plant or fuel reprocessing plant[63] ~~and the status of plant operating equipment.~~[64] These measures shall provide for identification of ~~these~~ items which ~~conform to~~ have satisfactorily passed required inspections and tests ~~requirements,~~ where necessary to prevent inadvertent bypassing of such inspections and tests ~~nonconforming item shall be clearly marked for subsequent disposition.~~[65] ~~Procedures shall be provided for~~ Measures shall also be established for indicating the operating status of structures, systems, and components of the nuclear power plant or fuel reprocessing plant[63] such as by tagging ~~equipment such as~~ valves and switches, ~~when necessary~~ to prevent inadvertent operation.[66]

XV. NONCONFORMING MATERIALS, PARTS, OR COMPONENTS

Measures shall be established to control materials, parts, or components which do not conform to requirements in order to prevent their inadvertent use or installation.[67] These measures shall include, as appropriate,[68] procedures for identification, documentation, segregation, disposition, and notification to affected organizations.[69] Nonconforming items shall be reviewed and accepted, rejected, repaired, or reworked in accordance with documented procedures. ~~Ultimate disposition of nonconforming items shall be documented.~~[70]

XVI. CORRECTIVE ACTION

Measures shall be established to assure that ~~all~~ conditions adverse to quality, such as failures, malfunctions, deficiencies, deviations, defective material and equipment, and nonconformances~~,~~ are promptly identified and corrected[71] ~~reported to appropriate levels of management.~~[72] In the case of significant conditions adverse to quality, ~~T~~the measures shall ~~also~~ assure that the cause of the conditions ~~adverse to quality be~~ is determined and correct~~ed~~ive action taken to preclude repetition.[73] ~~The corrective action measures shall extend to the performance of all contractors and subcontractors as necessary.~~[74] The identification of the significant[73] conditions adverse to quality, the cause of the condition, and the corrective action taken shall be documented and reported to appropriate levels of management.[72]

XVII. QUALITY ASSURANCE RECORDS

Sufficient ~~R~~records shall be maintained to furnish evidence of activities affecting quality ~~for use in the management of the program.~~[75] The records shall include, ~~but not be limited to,~~ at least the following: ~~construction and o~~Operating logs~~,~~ and the results of reviews, inspections, tests, audits, monitoring of work, performance, and material analyses. The records shall also include closely-related data such as the qualifications of personnel, procedures, and equipment.[76] Inspection and test records, shall, as a minimum, identify the inspector or data recorder, the type of observation, the results, the acceptability, and the action taken in connection with any deficiencies noted.[75] Records shall be identifiable and retrievable. Consistent with applicable regulatory requirements, the applicant shall establish requirements concerning record retention, such as duration, location, and assigned responsibility.[77]

[63] The words "or fuel reprocessing plants" were added in a 09/11/71 addendum to Appendix B.

[64] This sentence was based on Para. 6.3 of MIL-Q-9858A. The last seven words were deleted in response to a 06/30/69 letter from General Electric that noted "plant" could mean a nuclear power plant, manufacturing plant, or both.

[65] This sentence was based on Para. 5.6.4 of RDT F2-2. The phrase about marking nonconforming items was deleted because it duplicated a similar requirement in Criterion XV.

[66] The source of this sentence is unknown. It was revised to indicate tagging is but one way of identifying operating status. So. Calif. Edison (06/24/69) and Westinghouse (06/09/69) noted the sentence excluded use of other satisfactory methods.

[67] This sentence was inspired by Para. 5.10 of RDT F2-2.

[68] "As appropriate" was added after a 06/09/69 Stone & Webster letter noted all these requirements may not apply to everyone.

[69] This and the next sentence were based on Para. 6.5 of MIL-Q-9858A.

[70] This sentence was based on Para. 1B804(3) of NHB 4300.4. It was deleted after a 06/09/69 letter from Westinghouse said it was more closely related to controlling cost than quality.

[71] This sentence was based on Para. 6.2 of MIL-Q-9858A.

[72] The requirement to report adverse conditions to management, which is based on Para. 2.6 of RDT F2-2, was moved to the last sentence of Criterion XV to indicate that only significant adverse conditions need be reported to management.

[73] This sentence was based on Para. 3.5 of MIL-Q-9858A. At the request of General Electric (06/30/69), So. Calif. Edison (06/24/69), and Westinghouse (06/09/69), it was revised to require only the cause of significant deficiencies be determined.

[74] This sentence, borrowed from Para. 6.2 of MIL-Q-9858A, was deleted in response to letters from Ralph Parsons (06/16/69) and Stone & Webster (06/09/69) which expressed concern that preventive action could take months and, to verify its completion, purchasers would have to audit work being done for others.

[75] Requirements within this sentence were borrowed from Para. 3.4 of MIL-Q-9858A.

[76] This and the previous sentence were based on Para. 7.11 of RDT F2-2.

[77] Requirements in this and the next sentence were based on Para. IX-225 of ASME III.

XVIII. AUDITS

A comprehensive system of planned and periodic audits shall be carried out to ~~assure~~ verify compliance with all aspects of the quality assurance program and to determine the effectiveness of the program.[78] The audits shall be performed in accordance with the written procedures or check lists by appropriately ~~qualified~~ trained personnel not having direct responsibility in the areas being audited.[79] Audit results shall be documented and reviewed by management having responsibility in the area audited. Follow-up action, including reaudit of deficient areas, shall be taken where indicated.[80]

[78] *This sentence was based on Para. 1B205(1) of NHB 4300.4.*

[79] *This sentence was based on Para. 8.2 and 8.3 of RDT F2-2. "Trained" was substituted for "qualified" in response to a 06/09/69 Westinghouse request to clarify the term "appropriately qualified".*

[80] *This and the previous sentence were based on Para. 1B205(3) of NHB 4300.4.*

1. *WEST VALLEY (Western New York Nuclear Service Center)*

General Data

Owner Nuclear Fuel Services (NFS), a W.R. Grace subsidiary. During 1969, the facility was sold to Getty Oil Company. [*Nuclear Witnesses*, pp. xx & xxi]

Location West Valley, NY [*AEC Fact Book*, p. IX-3]

Capacity 300 metric tons of spent fuel per year [*Nuclear Industry*, 07/00/74, p. 9]

Began Operation 06/00/66. [*Forevermore*, p. 78]

Date Closed 03/00/72 [*NFS Environmental Report No. 24*, p. 1]

Designer Not known

Builder Bechtel. Construction began during 06/00/63. [*Power*, 07/00/66, p.78; and *Forevermore*, p. 76]

Cost to Build $32.5 million [*Engineering News-Record*, 11/30/78, p. 19; and *Nuclear Stakes*, p. 112]

Licensing Data

- CP received 04/30/63; OL received 04/19/66 [*AEC Fact Book*, p. IX-3]
- The AEC assigned a resident inspector to the plant beginning 00/00/67. [*Power*, 07/00/67, p. 87]
- West Valley currently holds a OL to store, but not process, 26.8 metric tons of spent fuel. [SR/CNEAF/92-01, p. 34; and *1978 Annual NRC Report*, p. 73]
- On 09/30/81, the NRC transferred the plant's license to the U.S. Department of Energy (DOE) in order to allow DOE to begin cleaning up the plant. [*Nuclear News*, 10/00/83, p. 88]

Operating Data

- The plant ran, on average, at about one-third capacity because of chronic equipment breakdowns and accidents involving radioactive contamination. [*Forevermore*, p. 79]
- There were 180 full-time and 1,400 part-time workers at the plant. Part-time workers were used to clean up spills and repair contaminated equipment. [*Nuclear Witnesses*, p. 217]
- At the time it was closed, 600,000 gallons of liquid radioactive waste and 640.5 metric tons of spent fuel was being stored at the plant. [Ibid, pp. 239 & 243]
- After Getty bought the plant, NFS continued running it. [*Engineering News-Record*, 03/24/77, p. 46]
- The plant reprocessed about 630 tons of spent fuel. [*Nuclear News*, 01/00/76, p. 68]

Decommissioning Data As of 12/00/89, about fifty (50) percent of the plant's liquid waste had been "pre-treated" to reduce its volume. Following pretreatment, the waste will be vitrified, sealed in glass. Vitrification will begin during 1995 and be completed in 18 months. Decommissioning will cost about $1.1 billion. [*Engineering News-Record*, 11/30/78, p. 19; DOE/S-0078, pp. 145 & 392; and *Nuclear News*, 10/00/80, p. 23]

Historical Summary

0?/00/65 During plant construction, water collected in excavations holding concrete radioactive waste tanks. The tanks popped free of the ground and stresses on the floating tanks cracked their floors and roofs. [*Nuclear News*, 05/00/77, p. 82; and EMD-77-27, pp. 9 & 10]

02/00/68 The AEC investigated allegations that radioactive liquids had been discharged into a nearby creek. Releases were found to have been within limits. [*AEC Fact Book*, p. E-20]

03/00/72 The plant was shut down for modernization and to expand its capacity to 750 metric tons of spent fuel per year. [*Nuclear News*, 01/00/76, p. 68; and *NFS Environmental Report No. 24*, p. 1]

10/00/73 NFS submitted, for the AEC's acceptance, a Safety Analysis Report, describing its plans for modifying the plant. [EMS-77-27, p. 2]

07/15/76 NFS decided not to modify or reopen the plant because of new NRC licensing criteria. It was most concerned with the NRC's new waste solidification and seismic requirements. NFS estimated it would cost $615 million to meet these requirements. [*Nuclear Industry*, 10/00/76, p. 25; and EMD-77-27, p. 2]

10/29/76 Ownership of West Valley was transferred to New York State in accordance with an agreement signed during the 1960s. [*Nuclear News*, 08/00/76, p. 128]

01/04/78 Leaks were found in waste storage tanks. [*Nuclear Witnesses*, p. xxiv]

02/25/78 President Carter signed Public Law 95-238 which directed the U.S. Department of Energy to determine what should be done to clean up West Valley site. [*1978 Annual NRC Report*, p. 75]

09/15/80 Congress passed the West Valley Demonstration Project Act (Public Law 96-368) which assigned the U.S. Department of Energy responsibility for cleaning up the West Valley site. [DOE/S-0078, p. 392; and *Nuclear News*, 10/00/80, p. 23]

07/00/83 A Federal judge ordered that 740 spent fuel assemblies, stored at the plant, be removed and returned to the utilities that shipped the assemblies to the plant. [*Nuclear News*, 10/00/83, p. 88]

12/00/83 A trailer returning spent fuel from West Valley to Dresden broke loose from its truck. The driver backed the truck up, reconnected it to the trailer, and continued the trip without further incident. [*Nuclear News*, 01/00/84, p. 117; and *Nuclear News*, 02/00/84, p. 95]

2. MORRIS (Midwest Fuel Recovery Plant)

General Data

Owner General Electric [*AEC Fact Book*, p. E-19]

Location Morris, IL [Ibid]

Capacity 500 metric tons of spent fuel per year [*Nuclear Industry*, 07/00/74, pp. 9-10]

Began Operation Began start-up testing during late 1972; never began commercial operation. [Ibid, p. 8; and *Nuclear News*, 01/00/76, p. 68]

Date Closed Never opened as a spent fuel reprocessing facility. [*1977 Annual NRC Report*, p. 50]

Designer Not known

Builder Not known

Cost to Build $64 million [*Nuclear Industry*, 07/00/74, p. 8]

Licensing Data CP received 12/28/67. Never received an OL. [*AEC Fact Book*, p. E-19]

Operating Data

- During 1976, the plant was converted to a spent fuel storage facility and received an OL to store 700 metric tons of spent fuel. [*Nuclear News*, 01/00/76, p. 68; and *Nuclear Industry*, 09/00/76, p. 7]
- The plant's current licensed storage capacity is 1660 PWR and 3775 BWR spent fuel assemblies. [SR/CNEAF/92-01, pp. 34 & 164]

Historical Summary

04/00/74 General Electric announced the plant was not operable. Pulverized spent fuel clogged piping and machinery as it made its way through the reprocessing systems. Equipment could not easily be cleaned and restarted because of high radiation fields. The longest the plant ever operated was 26 hours. General Electric estimated that redesigning and modifying the plant would take four years and cost another $90 to 130 million. [*Nuclear Industry*, 07/00/74, pp. 8-9; and *Unacceptable Risk*, p. 156]

07/00/76 General Electric was sued for $300 million. Two utilities claimed General Electric had mislead them about the plant's troubles and now they had no place to store the spent fuel that General Electric had contractually agreed to reprocess. [*Nuclear News*, 08/00/76, pp. 56 & 57]

3. BARNWELL (Barnwell Nuclear Fuel Plant)

General Data

Owner Allied General Nuclear Services (AGNS), a partnership between Allied Chemical and General Atomic Company [*Nuclear News*, 01/00/76, p. 69]

Location Barnwell, SC [*Nuclear Industry*, 07/00/74, p. 9]

Capacity 1500 metric tons per year of spent fuel [Ibid]

Began Operation The facility was never completed nor opened. [*1978 Annual NRC Report*, pp. 72-73]

Date Closed Not applicable

Designer Bechtel [*AEC Reports*, Vol. 4, p. 484]

Builder Daniel Construction. Work began during 03/00/71. [*Nuclear Industry*, 07/00/74, p. 9; and *Forevermore*, p. 85]

Cost to Build $362 million was spent before stopping work. [*The New York Times*, 12/01/81, p. D4]

Licensing Data CP received 12/18/70. Never received an OL. [*Nuclear News*, 01/00/76, p. 69; and *AEC Reports*, Vol. 4, p. 523]

Operating Data Not applicable

Historical Summary

11/00/76 President Ford told private industry it should not count on always being allowed to reprocess spent nuclear fuel. [*Engineering News-Record*, 11/04/76, p. 7]

04/07/77 To curb access by developing nations to material needed to manufacture nuclear weapons, President Carter called a halt to reprocessing spent fuel. Work on the partially completed plant stopped. At the time, AGNS estimated the facility was about half finished and would have required another $500 million to complete. [Ibid; *Engineering News-Record*, 04/14/77, p. 7, and *1978 Annual NRC Report*, pp. 72-73]

12/23/77 In keeping with President Carter's nonproliferation policies, the NRC decided to stop licensing spent fuel reprocessing facilities. [*1978 Annual NRC Report*, p. 72]

01/00/78 To maintain plant staffing levels, the Department of Energy awarded Barnwell a $13 million fuel cycle research contract. Also, Congress tentatively agreed to provide the Department of Energy with another $13-18 million during 1979 to continue the research. [EMD-78-97, p.4]

10/15/81 Allied Chemical terminated its involvement in the plant by turning over its 50% ownership to General Atomic at no cost to General Atomic. [*Nuclear News*, 11/00/81, p. 21]

01/00/82 An Argonne National Laboratory study reported, "Because of fundamental philosophical, dimensional and fabrication details for the design, full scale operation of [Barnwell] would be accompanied... by inordinately high operation and maintenance risks. [Design] and construction is unfortunately no better than that of the Nuclear Fuel Services plant..." [*Nuclear News*, 04/00/82, pp. 54 & 56; and *Forevermore*, p. 87]

03/16/83 AGNS filed suit against the Federal Government for more than $500 million in damages. AGNS claimed the Government induced it to build the plant then passed legislation that barred it from ever operating. [*Nuclear News*, 04/00/83, p. 25]

07/31/83 The plant received its last Federally-funded research project. [*Forevermore*, p. 88]

03/28/84 A Government Accounting Office study estimated it would take another ten years and cost an additional $700 million to complete the plant. [*Nuclear News*, 06/00/84, pp. 87-88]

12/31/84 The last Federally-funded research project was completed and, with staffing reduced to three employees, the plant was permanently closed. [Ibid, p. 87; and *Forevermore*, p. 89]

10CFR50.34, CONTENTS OF APPLICATIONS: TECHNICAL INFORMATION

10CFR50.34(f) ADDITIONAL TMI-RELATED REQUIREMENTS

(3) To satisfy the following requirements, the application shall provide sufficient information to demonstrate that the requirement has been met. This information is of the type customarily required to satisfy ~~10CFR50.34~~ paragraph (a)(1) ~~of this section~~ or to address the applicant's technical qualifications and management structure and competence.[1]

(i) Provide administrative procedures for evaluating operating, design and construction experience and for ensuring that applicable important industry experiences will be provided in a timely manner to those designing and constructing the plant.[2] [I.C.5][3]

(ii) Ensure that the quality assurance (QA) list required by Criterion II, App. B, 10CFR50 includes all structures, systems and components important to safety.[4] [I.F.1]

(iii) Establish a quality assurance (QA) program based on consideration of: (A) Ensuring independence of the organization performing checking functions from the organization responsible for performing the functions;[5] (B) performing ~~the entire~~ quality assurance/quality control functions at construction sites to the maximum feasible extent;[6] (C) including QA personnel in the documented review of and concurrence in quality-related procedures associated with design, construction and installation;[7] (D) establishing criteria for determining QA programmatic requirements for specific classes of equipment;[8] (E) establishing ~~minimum~~ qualification requirements for QA and QC personnel;[9] (F) sizing the QA staff commensurate with its duties~~,~~ and responsibilities~~, and important to safety~~;[10] (G) establishing procedures for maintenance of "as-built" documentation;[11] and (H) providing a QA role in design and analysis activities.[12] [I.F.2]

SPECIAL NOTE

Changes shown in the left column are to the propose draft of 10CFR50.34(f)3 as it appeared in the *Federal Register* on March 23, 1981. The changes occurred during resolution of public comments and prior to issuance of the final Regulation on January 15, 1982. Shaded entries are words that were added and strike-outs are words that were deleted.

NOTES

[1] *10CFR50.34(a)(1) contains requirements for describing in PSARs the relevant surface and subsurface features of a proposed nuclear power plant site.*

[2] *This requirement expands on Criterion III.*

[3] *These numbers correspond to action plan items in NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident," dated June 1980, and NUREG-0718, "Licensing Requirements for Pending Applications for Construction Permits and Manufacturing Licenses," dated March 1981. This is discussed in a footnote in 10CFR50.34(f)1.*

[4] *This requirement directly references Criterion II.*

[5] *This requirement expands on Criterion I. It was added because of NRC concerns about a "lack of sufficient independence of the organization responsible for performing checks, verifications, and inspections."*

[6] *This requirement expands on Criterion II. It was modified in response to ASME cost-benefit concerns.*

[7] *This requirement expands on Criterion VI. It was clarified in response to ASME and Bechtel concerns about its intent.*

[8] *This requirement expands on Criterion II. It was clarified in response to an ASME request to clarify the term "QA requirements."*

[9] *This requirement expands on Criterion II. According to the NRC, "minimum" was deleted "to be consistent with Appendix B to 10CFR Part 50."*

[10] *This requirement expands on Criterion I. In response to ASME concerns about its relevance to staff size, the phrase "importance to safety" was deleted.*

[11] *This requirement expands on Criterion VI. The NRC noted that Criterion VI mentions drawings, but not "as-built" drawings or equivalent documentation.*

[12] *This requirement expands on Criterion III. It was added because of NRC concerns about the QA/QC knowledge of individuals assigned to verify the adequacy of test, inspection, and related requirements in design documents.*

CONTENTS

NOTES

1. Documents referenced in this Supplement are listed in Supplement IX.
2. Plants are listed by the date they started producing electricity with the oldest being listed first.
3. Problems followed by a check (✓) are "Major Problems" as defined in Paragraph 6.2.1(c) of the main body of this report.

1. ***EBR-I (Experimental Breeder Reactor - 1) [12/20/51]***

General Data

Owner AEC [*Nuclear Age*, p. 126]

Location Idaho Falls, ID [*Friends in High Places*, p. 103]

Reactor 0.15 MWe sodium-potassium cooled fast breeder [Ibid]

First Electricity 12/20/51; first electricity produced in U.S. using nuclear energy. [DOE/NE-0068, p. 51]

Designer Austin Company [*Ninth Semiannual AEC Report*, p. 8]

Builder Bechtel. Construction began 12/00/49 and was completed in 04/00/51. [*Friends in High Places*, p. 103; and GPO Publication 794-218]

Cost to Build $3.3 million [*The New York Times*, 05/31/51, p. 39]

Licensing Not licensed.

Operating Data

- The initial reactor core was refitted with a plutonium-bearing core and the plant restarted and operated from 11/00/62 through 12/00/63. [DOE/OSTI-8200, p. III-4]
- The plant (Cores 1 and 2) generated 579 MW-hrs of electricity. [WASH-1203-71, p. 10]
- The plant's Lifetime Capacity Factor, estimated from the above data, was 3.7%.

Decommissioning The reactor was dismantled and the plant decommissioned in 04/00/64. On 08/26/66, the facility was dedicated as a national historic landmark. [DOE/OSTI-8200, p. III-4; and *AEC Fact Book*, p. D-4]

Problems

00/00/51 Radiation levels around the reactor were too high. An extra 2.5 feet of concrete shielding was added to protect plant personnel. [*Nuclear Safety*, 12/00/61, p. 69] ✓

06/00/52 The plant was shut down for repairs when sodium-potassium coolant began leaking out of the reactor's primary heat exchanger. [Ibid] ✓

11/29/55 Tests were being conducted on the reactor's power characteristics. It was supposed to be scrammed when power started doubling every tenth second. The operator hit the wrong button, one used for a slow shutdown. Core temperatures reached 2000 °F before the scram button was hit. The top third of core completely melted and middle third was partially melted. Pressure calculations indicated the reactor was a half-second from rupturing. [*Nuclear Age*, p. 126; *Cover Up*, p. 47; and *The Careless Atom*, pp. 155-156] ✓

12/00/63 The AEC permanently shut the plant down. The reason is not known. [DOE/OSTI-8200, p. III-4; and *AEC Fact Book*, p. D-3]

2. ***SHIPPINGPORT [12/18/57]***

General Data

Owner AEC and Duquesne Light Company [DOE/MA-0152, p.38]

Location Shippingport, PA [DOE/OSTI-8200, p. III-2]

Reactor 60.0 MWe PWR ordered 07/00/53 [WASH-1208, p.1]

First Electricity 12/18/57 [Ibid]

Designer Stone & Webster [*Power*, 10/00/68, p. S-9; and WASH-1208, p. 1]

Builder Dravo Corp. and Burns & Roe. "Real" construction began 03/00/55; however, on 09/06/54, President Eisenhower broke ground with bulldozers started by remote control from Denver. [*Rickover and the Nuclear Navy*, pp. 2 & 199; and *Forum*, 12/00/57, p. 28]

Cost to Build $74 million [*Atomic Energy Deskbook*, p. 502; and *Forum*, 04/00/58, p. 9]

Licensing Not licensed.

Operating Data

- The reactor's first core, rated at 60.0 MWe, operated to 02/09/64 and generated 1,798,554 MW-hrs of electricity. [WASH-1203-71, p. 9; DOE/OSTI-8200, p. III-2; and *Rickover and the Nuclear Navy*, p. 223]
- The reactor's second core, rated at 90 MWe, operated from 09/25/65 to 02/04/74 and generated 3,476,620 MW-hrs of electricity. [*Nucleonics Week*, 04/25/74, p. 10; DOE/OSTI-8200, p. III-2; and *Rickover and the Nuclear Navy*, p. 224]
- The reactor's third core, rated at 60 MWe, operated from 08/26/77 on and produced 2,114,039 MW-hrs of electricity. These core replacements were part of the plant's original design. [*Nucleonics Week*, 12/23/82, p. 14; DOE/OSTI-8200, p. III-2; and *Rickover and the Nuclear Navy*, p. 227]

• The plant's Lifetime Capacity Factor, calculated using the above data, was 47.9%.

Decommissioning Decommissioning began during 09/00/85 and was completed in 12/00/89. The reactor was removed on 12/14/88 and barged to DOE's Hanford facilities where it arrived 04/13/89. It was buried in a 40-foot deep low-level waste pit. The total cost of decommissioning the plant was $91.3 million [*DOE News Release* R-88-159; *The New York Times*, 11/25/86, pp. C1 & C3; GAO/RCED-90-208, p. 17; and *The Bulletin of the Atomic Scientists*, 10/00/89, p. 17]

Problems

12/16/57 Initial start-up was delayed for two days to correct procedural and hardware deficiencies identified by Navy inspection personnel. [*Rickover and the Nuclear Navy*, pp. 203-204]

03/15/58 The plant was shut down because a Navy inspector thought the reactor was being cooled too fast. [Ibid, p. 228]

06/10/58 The plant was shut down because a Navy inspector wanted deficiencies in nuclear instrumentation promptly corrected. [Ibid]

08/00/61 A second replacement reactor coolant pump failed. The original and a first replacement were of a different design. Also, problems with steam generators shut the plant down often enough that they were eventually replaced. [Ibid, p. 205; and WASH-1203-73, p. 19] ✓

12/00/64 Work had just been completed on installing four new, heavier steam generators. As the plant was being readied for start-up, the steam generator supports buckled. *The Accident Hazards of Nuclear Power Plants*, p. 192; *Nuclear Industry*, 01/00/65, p. 5; and WASH-1203-73, p. 20] ✓

01/00/73 Plant site soil samples, collected by NUS Corporation between 01/00/71 and 03/00/72 had radiation levels 50 to 100 times normal. Levels decreased the further the samples were from the plant. Airborne radiation levels rose and fell with the plant's power output. Dr. Sternglass, a local college professor, announced his findings during 01/00/73 and claimed these and earlier releases had resulted in about 200 deaths. NUS and the scientific community accused Dr. Sternglass of misinterpreting field radiation data. [*Saga*, 10/00/73, pp. 60 & 62; *The War Against the Atom*, pp. 125 & 126; *Before Its Too Late*, p. 258; *The Nation*, 08/03/74, p. 78; and *Nucleonics Week*, 01/11/73, pp. 2 & 3] ✓

02/04/74 The plant was shut down to replace its vibration-damaged turbine. [*Rickover and the Nuclear Navy*, p. 224] ✓

10/01/82 The plant was permanently shut down due to high operating costs and Federal budget restrictions. [*DOE News Release* R-88-159; and *Rickover and the Nuclear Navy*, p. 227] ✓

3. SL-1 (Stationary Low Power Reactor - 1) [10/24/58]

General Data

Owner AEC [*Reactor Accidents*, p. 37]

Location Idaho Falls, ID [Ibid, p. 31]

Reactor 0.30 MWe BWR prototype reactor designed to meet the electrical needs of remote U.S. military installations. [DOE/OSTI-8200, p. III-22; and *Reactor Accidents*, p. 31]

First Electricity 10/24/58 [*Reactor Accidents*, p. 41]

Designer Pioneer Service & Engineering [*Atomic Energy Deskbook*, p. 503]

Builder Fegles Construction [*AEC SL-1 Report*, p. 4]

Cost to Build $2.59 million [*Nucleonics Week*, 01/05/61, p. 2]

Licensing Not licensed.

Operating Data

• The plant produced 1937 MW-hrs of electricity over its 1.11 yr operating life. [WASH-1203-71, p. 11]

• The plant's Lifetime Capacity Factor, calculated using the above data, was 66.4%.

Decommissioning Plant cleanup began on 01/08/61. The reactor was shipped from the site on 12/01/61. Decommissioning was completed during 07/00/62. [*Nucleonics Week*, 12/07/61, p. 1; *Nuclear Age*, p. 139; and *Reactor Accidents*, pp. 39-40]

Problems

11/11/60 Cadmium strips were added to the reactor's control rods to temporarily replace missing boron moderator strips. With control rods fully inserted, only a 2% safety margin existed. [*Reactor Accidents*, p. 38]

01/03/61 The reactor had been shut down for maintenance on 12/23/60 and was being restarted. A control rod jammed and, in pulling it free, it was withdrawn 3.3 inches beyond the point needed to achieve criticality. It and four other control rods blew out of the reactor, impaling a plant operator, and embedded themselves and the operator in the ceiling. The blast lifted the reactor nine feet off its foundation. Two plant personnel were killed instantly and another died two hours later. Twenty percent (20%) of the reactor core structure and 47% of its fuel was destroyed. Radiation was contained within the reactor building. Damage was estimated at $4.35 million. [Ibid, pp. 37-41; *AEC SL-1 Report*, pp. 25-27; and *Cover Up*, p. 35] ✓

4. WTR (Westinghouse Testing Reactor) [08/01/59]

General Data

Owner Westinghouse [DOE/OSTI-8200, p. III-9]

Location Waltz Mill, PA [Ibid]

Reactor 60.0 MWt, water cooled and moderated, low pressure and temperature irradiation test reactor. The reactor was 8'-0" dia. and 32'-6" long. [Ibid and *AEC Reports*, Vol. 1, pp. 109-110]

Initial Criticality 08/01/59 [Author's estimate and DOE/OSTI-8200, p. III-9]

Designer/Builder Westinghouse [*AEC Reports*, Vol. 1, p. 108-110]

Cost to Build $20 million [*Forum*, 04/00/62, p. 23]

Licensing CP received 07/03/57; OL received 06/19/59 [*AEC Reports*, Vol. 1, p. 108; and *1960 Annual AEC Report*, p. 407]

Operating Data No information

Decommissioning On 03/22/62, Westinghouse announced a two-phase decommissioning plan. The first phase involved removing the reactor's fuel, selective decontamination, and restricting access to the site. [*1962 Annual AEC Report*, p. 423]

Problems

06/19/59 Westinghouse received an OL with the provision that operation of the reactor would begin no later than 07/07/59. The AEC threatened to revoke the OL when, for unknown reasons, Westinghouse was unable to meet this deadline. [*AEC Reports*, Vol. 1, pp. 186-188]

04/03/60 During a planned increase in power, cladding separated, blocking the transfer of heat to the reactor's coolant, and a fuel element melted. Some reactivity was released to the atmosphere and significant quantities were discharged into the Youghiogheny River. Pittsburgh's water supply, 29 miles downstream from the plant, was partially contaminated. Studies by Dr. Sternglass, a local professor, claimed infant mortality rates increased sharply in those Pittsburgh neighborhoods that used the suspect water. The AEC and others in the scientific community sharply disagreed with his mortality findings. [*Nuclear Age*, p. 173; *Saga*, 10/00/73, p. 60; *Nuclear Witnesses*, p. 74; *Containing the Atom*, p. 335; and *Before Its Too Late*, p. 258] ✓

04/13/60 The plant was shut down and never restarted. [*NRC Inspection Report 50-22/91-01*, p. 1]

06/30/60 Westinghouse was ordered not to restart the plant without specific approval from the AEC . [*AEC Correspondence Log*; and *1960 Annual AEC Report*, p. 407]

03/00/62 Westinghouse said it could not afford the cost of restarting and operating the plant based on future business prospects. One major program that Westinghouse was counting on that did not materialize was the AEC's nuclear aircraft program. [*Forum*, 04/00/62, p. 23]

5. DRESDEN I [04/15/60]

General Data

Owner Commonwealth Edison [DOE/OSTI-8200, p. III-1]

Location Morris, IL [Ibid]

Reactor 200.0 MWe BWR ordered 07/00/55 [WASH-1208, p. 1]

First Electricity 04/15/60 [Ibid]

Designer/Constructor Bechtel [NUREG-0020, 01/00/79, p. D-4]

Cost to Build $51 million. [*Science News Letter*, 10/22/60, p. 265; and *Atomic Energy Handbook*, p. 129]

Licensing CP received 05/04/56; OL received 09/28/59 [*AEC Reports*, Vol. 1, pp. 219 & 224]

Operating Data The plant had a Lifetime Capacity Factor of 50.56% over the 18.54 yrs it operated. At the time the national average was 53.69%. [*The Silent Bomb*, p. 108; and NUREG-0020, 03/00/90, p. 3-6]

Decommissioning Half the plant's spent fuel was reprocessed at West Valley; the other half remains at Dresden 1. Chemical cleaning of piping and mothballing began in 1984. Dismantling will begin when Unit 2 is permanently shut down. [SR/CNEAF/92-01, pp. 23 & 112; and *Nuclear News*, 10/00/84, p. 48] ✓

Problems

12/12/59 A control rod was found in the reactor core, separated from its drive. The first time this happened was on 11/03/59. A subsequent investigation found the cause of the problem to be control rod drive pins that were shearing off. [*AEC Reports*, Vol. 1, pp. 355-356] ✓

05/16/60 50 reactor scrams occurred during the first six months of operation. Due to extensive cracks, all of the reactor's zircaloy fuel rods were replaced with stainless steel. However, the stainless rods also cracked and powdered boron moderator leached into the reactor coolant. Thus, all of the stainless rods were re-replaced with zircaloy rods. [Ibid, pp. 355-361; *The Silent Bomb*, p. 288; and *The Careless Atom*, p. 125] ✓

11/15/60 The plant shut down until 06/00/61 to modify all 80 control rod drives. The reactor was drained, defuelled and the control rod drives shipped to California for modification. [*Forum*, 01/00/61, p. 6] ✓

00/00/63 The plant was shut down for 36 days to reline the reactor canal. [*Power*, 05/00/68, p. 73] ✓

11/12/65 Tornados destroyed all five incoming power lines, knocking the plant out of commission until off-site power could be restored the next day. [*Power*, 02/00/66, p. 92; and *1965 Annual AEC Report*, p. 317]

00/00/66 Cracks were found in several sections of small-diameter piping. Tests were unable to determine the reason for the cracks. [*1966 Annual AEC Report*, p. 413]

00/00/67 The plant was down for 21 days to overhaul the reactor's control rod drive mechanisms. [Ibid]

09/23/68 Water from a plugged roof drain seeped into a control room electrical panel, knocking out part of the plant's power supply system. [*Nugget File*, p. 9]

06/19/71 The AEC ordered the utility to modify the plant's emergency core cooling piping system or greatly increase its in-service inspection of the system. [*Nucleonics Week*, 06/24/71, pp. 1-3] ✓

08/00/71 Incomplete grounding of filters in an off-gas system resulted in a gas explosion. [*Nuclear News*, 03/00/77, p. 41]

11/00/73 Leaking heat exchangers, faulty valves, turbine problems, and bent and warped control rods drove the cost of operating the plant beyond that of an equivalent fossil plant. A $700,000 study found extensive contamination throughout the facility. The study estimated decontamination would cost $30 million. [*Friends in High Places*, pp. 111, 201 & 202; *Nuclear Witnesses*, p. 258; and WASH-1203-73, pp. 22-24] ✓

08/09/74 1130 gallons of liquid radioactive waste was accidently discharged into the Des Plaines River. [*Time Bomb*, p. 176; and *Nuclear Witnesses*, p. xxii] ✓

09/21/74 Because of cracks in Dresden 2 reactor coolant piping, the AEC ordered Dresden 1 to shut down until the utility inspected for similar cracks in its piping. [*The New York Times*, 09/22/74, pp. 1 & 34]

01/29/75 Due to cracks in Dresden 2 emergency core cooling piping, the NRC ordered Dresden 1 shut down until the utility inspected for similar cracks in its piping. [*The New York Times*, 01/30/75, pp. 1 & 11]

10/31/78 The plant was shut down to clean contamination that had built up in the plant's piping systems and was not restarted. Because of the plant's size and age, the utility was not willing to meet the NRC's demands and spend $300 million upgrading its emergency core cooling system. [NUREG-0020, 01/00/79, pp. D-4 & 5; NUREG-0020, 01/00/81, pp. D-4 & 5; and *Nuclear News*, 10/00/84, p. 48]

6. YANKEE ROWE [11/10/60]

General Data

Owner Yankee Atomic Electric Company [DOE/OSTI-8200, p. I-3]

Location Rowe, MA [Ibid]

Reactor 167.0 MWe PWR ordered 06/00/56 [Ibid and WASH-1208, p. 1]

First Electricity 11/10/60 [WASH-1208, p. 1]

Designer/Builder Stone & Webster [NUREG-0020, 03/00/90, p. 2-488]

Cost to Build $52.4 million [DOE/EIA-0473, p. 15]

Licensing

- CP received 11/04/57; OL received 12/24/63 [NUREG-1350, p. 86]
- During 1955, the AEC named Yankee Rowe one of three new nuclear power plants eligible for special U.S. Government financing and other assistance. [DOE/MA-0152, p. 39]

Operating Data

- During 1987-89, plant operating and maintenance costs averaged $190.93/kW, the second highest of the nation's operating nuclear power plants. [*Nuclear Lemons*, 05/00/89, p. 25, and 04/25/91, p. 10]
- As of 06/30/90, the plant had a Cumulative SALP Rating of 1.36, the best of the eight oldest operating plants. It has never received a Category 3 Finding. [NUREG-1214, p. 2-21]
- As of 02/28/90, the plant's Lifetime Capacity Factor was 71.5%, well above the national average of 61.9%. Forced outages totalled 9432 hrs (1.1 yrs) and the plant was on-line a total of 202,904 hrs (23.2 yrs), the most of any operating nuclear plant. [NUREG-0020, 03/00/90, p. 2-486]

Decommissioning The plant's spent fuel storage pool holds 533 assemblies. A decommissioning plan is scheduled to be sent to the NRC during 1994 and decommissioning begin during 1995. Costs are expected to total $247 million. [SR/CNEAF/92-01, p. 163; *Nuclear News*, 07/00/92, p. 27; and *Nuclear Waste News*, 1992 Sample Edition, pp. 1 & 5]

Problems

12/30/60 During its first 15 weeks of operation, the plant experienced: a) leakage at reactor coolant pump flanges, b) misaligned parts in the reactor head, c) low boron concentrations in cooling water, d) poorly located radiation monitors, e) inadequate shielding, and f) valves installed in the wrong place; valves had to be switched around. [*AEC Reports*, Vol. 1, pp. 608-611] ✓

00/00/65 During refueling, two holes were discovered in the reactor's cladding and several bolts were found to have failed that were supporting the reactor's thermal shield. [*1965 Annual AEC Report*, p. 316] ✓

06/19/71 The AEC ordered the utility to modify the plant's emergency core cooling piping system or greatly increase its in-service inspection of the system. [*Nucleonics Week*, 06/24/71, pp. 1-3] ✓

04/00/73 The utility spent $6 million and 6 months to reexamine and repair defective bolts in the reactor core. [*The Wall Street Journal*, 05/03/73, p. 1; and WASH-1203-73, p. 27] ✓

08/27/76 Because actual reactor temperatures were higher than assumed in original design calculations, the NRC ordered a 2% reduction in power to ensure required safety margins. [*Nuclear News*, 10/00/76, p. 34]

02/14/80 A severe crack in a blade caused a turbine failure and an NRC order to 18 utilities to inspect their turbine blades. [*Nuclear News*, 04/00/80, p. 123] ✓

12/00/85 The reactor scrammed twice; initially because the main control board was accidently bumped into and, later, because maintenance personnel initiated a false test signal. [*Not Worth the Risk*, p. 11]

12/31/86 During 1985 and 1986, Yankee Rowe personnel scored the lowest in the nation on NRC tests. In 1985 only 22% passed the tests and in the next year only 50% passed. [*USA Today*, 03/21/89, p. 5A] ✓

12/31/87 The NRC changed its rules, it decided to require that key plant personnel pass a special proficiency test. Thirty-three percent (33%) of Yankee Rowe personnel failed the test. The industry average was 14%. [Ibid; and *Not Worth the Risk*, p. 21]

10/01/91 The reactor was permanently shut down in the wake of concerns by the NRC and Union of Concerned Scientists that years of operation had so embrittled the reactor it no longer met regulations and could rupture at any time. The utility estimated it would have cost $23 million to prove the reactor met regulations. [*Nuclear News*, 07/00/91, p. 26; *The Nuclear Monitor*, 10/07/91, pp. 1-2; *The Washington Post*, 02/27/92, p. A3; *Nuclear Safety*, 04/00/92-06/00/92, p. 277; and *Nuclear Waste News*, 1992 Sample Edition, p. 1]

7. *INDIAN POINT 1 [09/16/62]*

General Data

Owner Consolidated Edison [DOE/OSTI-8200, p. III-1]

Location Buchanan, NY [Ibid]

Reactor 265.0 MWe PWR ordered 02/00/55 [WASH-1208, p. 1]

First Electricity 09/16/62 [Ibid]

Designer Vitro Engineering [*Atomic Energy Deskbook*, p. 237]

Builder Owner [NUREG-0020, 01/00/77, p. 2-50]

Cost to Build $263 million. [*AEC Reports*, Vol. 1, p. 793]

Licensing CP received 05/04/56; OL received 03/26/62 [WASH-1208, p. 1; *AEC Reports*, Vol. 1, p. 789; and *Nuclear Safety*, 01/00/71-02/00/71, p. 65]

Operating Data The plant's Lifetime Capacity Factor was 37.79% over the 12.12 yrs it operated. At the time, the national average was 51.7%. [*The Silent Bomb*, pp. 107-108; NUREG-0020, 03/00/90, p. 3-6]

Decommissioning The reactor was defuelled on 12/30/76. The plant's spent fuel storage pool current holds and will continue holding 30.6 metric tons of the spent fuel, because of the disruptive affect further decommissioning would have on Indian Point 2&3. [NUREG-0020, 01/00/77, p. 2-50; *Nuclear Power in Crisis*, p. 212; and SR/CNEAF/92-01, p. 28]

Problems

11/00/62 The plant was down for 6 weeks to install a new type of reactor control rod drive system. WASH-1203-73, p. 28]

02/00/64 The plant was down 6 months to install a stainless steel liner in its fuel transfer canal. [Ibid] ✓

10/00/65 The plant was down 7 months to refuel and repair broken reactor control rod drives. [Ibid] ✓

05/20/70 The plant had been shut down since 03/20/70 for refueling. During start-up on 05/20/70, pieces of broken thermal sleeve were spotted in the reactor. The reactor was shut-down to retrieve the material. Closer examination revealed that, after the sleeve failed, another larger pipe cracked that the sleeve was designed to protect from overheating [refer to similar problem at Nine Mile Point 1]. To complete required repairs, the utility brought in 700 people to work for a few minutes each prior to receiving their maximum three- to six-month radiation dose. The plant was not restarted until 02/00/71. [*The New York Times*, 06/30/70, pp. 1 & 34; *The Silent Bomb*, p. 354; *The New York Times Magazine*, 02/07/71, p. 16; *Engineering News-Record*, 07/16/70, p. 22; and WASH-1203-73, p. 29] ✓

06/19/71 The AEC ordered the utility to modify the plant's emergency core cooling piping system or greatly increase its in-service inspection of the system. [*Nucleonics Week*, 06/24/71, pp. 1-3] ✓

01/22/74 The plant was restarted after being out of service since 12/00/72 to repair leaks in its steam generator feedwater system. Because of high radiation fields, about 1500 persons were sent in for a few minutes each to repair the system. The cost was $2 million. [*The Wall Street Journal*, 01/22/74, p. 18; *Nuclear News*, 09/00/75, pp. 54 & 56; and WASH-1203-73, p. 29] ✓

10/31/74 The plant was permanently shut down. The utility decided not to spend $20 million to install the emergency core cooling piping system required by the AEC. Also, eddy current testing of steam generators found problems that would have required additional expenditures. [*Nucleonics Week*, 11/14/74, p. 8; and NUREG-1350, p. 90]

8. SAXTON [11/16/62]

General Data

Owner Saxton Nuclear Experimental Corporation, a subsidiary of GPU Nuclear [*Forum*, 04/00/62, p. 23; and DOE/OSTI-8200, p. III-5]

Location Saxton, PA [DOE/OSTI-8200, p. III-5]

Reactor 3.2 MWe BWR [Ibid and WASH-1203-71, p. 7]

First Electricity 11/16/62 [WASH-1203-71, p. 7]

Designer/Builder Gilbert Associates [*Forum*, 08/00/61, p. 31]

Cost to Build $6.25 million [*AEC Reports*, Vol. 1, p. 289]

Licensing CP received 02/11/60; OL received 10/03/62 [*AEC Reports*, Vol. 2, p. 158; and *Nuclear Safety*, 01/00/71-02/00/71, p. 66]

Operating Data The plant's Lifetime Capacity Factor was 26.5%. [WASH-1203-71, p. 14; and WASH-1203-72, p.10]

Decommissioning Phase 1, which included removal of 99% or more of the facility's contaminated items, was completed during 1973 at a cost of $500,000. Spent fuel and other high-level waste were shipped to Savannah River. [*Decommissioning of Nuclear Power Facilities*, p. 27; *The Menace of Atomic Energy*, p. 140; and *NRC Report 50-146/86-01*, p. 8]

Problems

12/01/63 The plant's reactor scrammed 19 times during its first year of operation. [*Nuclear Safety*, Spring 1964, p. 273] ✓

11/00/68 The plant was shut down until 12/00/69 for repairs, maintenance, modifications, and refueling. [WASH-1203-71, p. 52] ✓

03/00/71 The plant was shut down until 11/00/71 for plant modifications. [Ibid] ✓

05/01/72 The plant was closed permanently; the reason is not known. [*NRC Report 50-146/86-01*, p. 8]

9. BIG ROCK POINT [12/08/62]

General Data

Owner Consumers Power [DOE/OSTI-8200, p. II-1]

Location Charlevoix, MI [NUREG-1350, p. 69]

Reactor 69.0 MWe BWR ordered 12/00/59 [Ibid and WASH-1208, p. 1]

First Electricity 12/08/62 [WASH-1208, p. 1]

Designer/Builder Bechtel [NUREG-0020, 03/00/90, p. 2-024]

Cost to Build $26.2 million [COO-284, p. 17]

Licensing

- CP received 05/31/60; OL received 05/01/64 [NUREG-1350, p. 69]
- During 1957, the AEC named Big Rock Point one of five new nuclear power plants eligible for special U.S. Government financing and other assistance. [DOE/MA-0152, p. 39]
- During 05/00/68, Big Rock Point became the first plant to be subjected to an AEC compliance inspection (Division of Nuclear Material Safeguards). [*AEC Fact Book*, p. E-21]

Operating Data

- On 07/22/77, the plant broke the world record for continuous power generation, 343 consecutive days. [*Nuclear News*, 09/00/77, p. 40]
- As of 06/30/90, the plant had a Cumulative SALP Rating of 1.69. Three Category 3 Findings have been reported since its first SALP inspection during 02/00/81. One Finding pertained to management of outages; the other two pertained to radiation controls. [NUREG-1214, p. 2-40]
- As of 02/28/90, the plant had a Lifetime Capacity Factor of 56.3%, below the national average of 61.9%. Forced outages totalled 12,831 hrs (1.5 yrs) and on-line hrs totalled 167,706 (19.1 yrs). [NUREG-0020, 03/00/90, p. 2-022; NUREG-1350, p. 31; and *Nuclear News*, 05/00/91, pp. 44-49]
- During 1987-89, the plant had the highest operating and maintenance costs of the nation's operating nuclear power plants. [*Nuclear Lemons*, 05/00/89, p. 25, and 04/25/91, p. 10] ✓
- During 1987-89, the plant released 84,021 curies of radioactive gas, steam, and water to the environment. This was the second highest release of the nation's operating nuclear power plants. The national average was 2995 curies/yr. [*Nuclear Lemons*, 05/00/89, p. 19, and 04/25/91, p. 7] ✓
- During 1989-90, the plant experienced no safety system actuations or significant operating events, the best record of the nation's 111 operating nuclear power plants. [*Nuclear Lemons*, 04/25/91, p. A48]

Problems

05/00/63 The plant was shut down to repair the following problems: a) loose screws that had fallen into and jammed key moving parts, b) seven broken studs that had been supporting thermal shielding in the reactor, c) stuck control rod drive mechanisms, d) a valve that had been malfunctioning for what was determined to be 12 different reasons, e) debris lodged between reactor control rods, and f) cracked welds on two different critical components. [*Nuclear Lessons*, p. 72; and COO-284, pp. 37-40] ✓

09/18/64 The core shroud and reactor thermal shield seal was damaged as a result of flow-induced vibration. Repairs necessitated a one-year outage. [COO-284, pp. 26, 38, & 39; and *The Silent Bomb*, p. 282] ✓

10/00/67 After suffering with stress corrosion cracking of stainless steel fuel elements for more than a year, the plant switched over to zircaloy elements. [*The Careless Atom*, pp. 125-126; and WASH-1203-73, p. 30] ✓

01/00/71 A Strategic Air Command B-52 bomber, heading toward the plant during a routine training flight, crashed about 20 seconds short of the reactor building. All nine crew members were killed. [*Normal Accidents*, p. 41; and *The New York Times*, 08/14/71, p. 21]

06/19/71 The AEC ordered the utility to modify the plant's emergency core cooling piping system or greatly increase its in-service inspection of the system. [*Nucleonics Week*, 06/24/71, pp. 1-3] ✓

09/21/74 The plant was ordered shut down by the AEC until its reactor coolant (RC) piping could be reexamined. Cracks had been found in Dresden 2 RC piping. [*The New York Times*, 09/22/74, pp. 1 & 34]

01/17/75 The plant was shut down for repairs when inspections and tests found its emergency core cooling (ECC) system switches did not always work properly. The ECC system is supposed to flood the reactor core in the event regular cooling systems fail. [*The Wall Street Journal*, 01/17/75, p. 21]

01/29/75 The plant was ordered shut down by the NRC until its ECC piping could be reexamined. Cracks had been found in Dresden 2 ECC piping. [*The New York Times*, 01/30/75, pp. 1 & 11]

02/22/84 Three of four containment isolation valves failed during routine in-service testing. [*1984-1985 Nuclear Power Safety Report*, pp. 25-26] ✓

10. HUMBOLDT BAY [04/18/63]

General Data

Owner Pacific Gas & Electric [DOE/OSTI-8200, p. III-1]

Location Eureka, CA [Ibid]

Reactor 65.0 MWe BWR ordered 02/00/56 [WASH-1208, p. 1]

First Electricity 04/18/63 [Ibid]

Designer/Builder Bechtel [*Power*, 10/00/68, p. S-9, and *AEC Reports*, Vol. 1, p. 530]

Cost to Build $24.2 million [COO-284, p. 17]

Licensing CP received 11/09/60; OL received 08/28/62 [*AEC Reports*, Vol. 2, p. 144; and NUREG-1350, p. 90]

Operating Data The plant's Lifetime Capacity Factor was 60.6% over the 13.21 yrs it operated. At the time, the U.S. average was 53.7%. [*The Silent Bomb*, p. 108; and NUREG-0020, 01/00/77, p. 2-49]

Decommissioning 270 fuel assemblies were sent to West Valley where they were reprocessed. 389 assemblies are still in Humboldt Bay's spent fuel storage pool. The reactor is in "dry storage". The plant will be decommissioned at an estimated cost of $58 million once a Federal high level waste repository is available to receive its remaining spent fuel. [SR/CNEAF/92-01, pp. 23 & 30; and *Nucleonics Week*, 07/30/87, p. 15]

Problems

10/26/63 The plant was down for a month to repair a leaky reactor head. [COO-284, p. 180; and WASH-1203-73, p. 32]

09/14/65 The plant was shut down and 25% of its stainless fuel rods were replaced with zircaloy rods. During 06/00/65, radioactivity in stack gases began to increase and, by 09/00/65, exceeded by 35 curies/second the AEC's upper limit of 50 curies/second. [*The Careless Atom*, pp. 111-116] ✓

12/29/66 The plant achieved full-power for the first time since initial operation. It was shut down from 11/21/66 through 12/20/66 for refueling and to replace another 50% of its stainless rods with zircaloy rods. [Ibid and *Nucleonics Week*, 01/05/67, p. 4]

06/00/70 A fired plant employee, Robert Rowan, went to the AEC with a list of 49 alleged safety violations at the plant. The AEC found two of the allegations to be true. [*The Wall Street Journal*, 12/27/71, p. 9; and *USCEA Report*, p. 1] ✓

07/17/70 An operator error resulted in an electrical "fireball" that destroyed the plant's 60,000 volt bus and scrammed the reactor. Valves stuck that should have closed, the wrong valves opened, internal reactor pressure rose rapidly, and several piping connections started to leak. During the confusion, 250 gallons of untreated (raw) water were introduced into the reactor to prevent uncovering the core. [*Nugget File*, p. 24; and *Normal Accidents*, p. 47] ✓

09/21/74 The plant was ordered shut down by the AEC until its reactor coolant (RC) piping could be reexamined. Cracks had been found in Dresden 2 RC piping. [*The New York Times*, 09/22/74, pp. 1 & 34]

01/29/75 The NRC ordered the plant shut down until its emergency core cooling (ECC) piping could be reexamined. Cracks had been found in Dresden 2 ECC piping. [*The New York Times*, 01/30/75, pp. 1 & 11]

03/17/76 A one-inch long crack was discovered in a two-inch diameter pipe in the plant's reactor coolant water clean-up system. [*Nuclear News*, 05/00/76, p. 41]

05/00/76 Plant personnel received excessive radiation exposures. Within the next 12 months, additional personnel received excessive exposures and the utility was fined $7500. [*Nuclear News*, 07/00/77, p. 38] ✓

07/02/76 The plant was shut down to refuel, repair four stuck control rods, and replace a reactor feedwater sparger and thermal sleeve. Though $21 million had been spent on geologic studies and seismic supports, the NRC required about $500 million in further seismic upgrades before restarting the plant. The utility decided to permanently close the plant. [*Engineering News-Record*, 12/15/77, pp. 20-21; *1976 NRC Annual Report*, p. 31; *Nuclear News*, 08/00/83, p. 57; and NUREG-0020, 01/00/77, p. 2-48] ✓

06/0(77 The utility was fined $7500 for permitting employees to receive excessive radiation exposures. Three separate violatio s were identified over a 12 month period. [*Nuclear News*, 07/00/77, p. 38]

11. HALLAM [05/29/63]

__General Data__

Owner AEC and Consumers Public Power District [DOE/OSTI-8200, p. III-1]

Location Hallam, NE [Ibid]

Reactor 75.0 MWe sodium-cooled,graphite-moderated reactor ordered 09/00/57 [Ibid; *AEC Reports*, Vol. 1, p. 368; and WASH-1208, p. 1]

First Electricity 05/29/63 [WASH-1208, p. 1]

Designer Bechtel [COO-284, p. 13]

Builder Peter Kiewit & Sons [COO-284, p. 148, and *AEC Reports*, Vol. 1, pp. 375-377]

Cost to Build $60.3 million [COO-284, p. 17]

Licensing

- CP received 06/06/60; OL received 01/02/62. OL terminated 07/20/71 [WASH-1208, p. 1; *AEC Fact Book*, p. IX-4; *AEC Reports*, Vol. 2, p. 94; and NUREG-1350, p. 90]
- During 1955, the AEC named Hallam one of three new nuclear power plants eligible for special U.S. Government financing and other assistance. [DOE/MA-0152, p. 39]

Operating Data

- The plant produced 192,458 MW-hrs of electricity over the 1.26 years it was in operation. [NUREG-0020, 03/00/90, p. 3-6; and WASH-1203-71, p. 9]
- The plant's Lifetime Capacity Factor, calculated using the above data, was 23.25%.

Decommissioning Work began 11/03/67. The reactor was entombed during 1968. [DOE/OSTI-8200, p. III-1; *AEC Fact Book*, p. E-18]

__Problems__

06/22/60 The reactor vessel slipped off the vehicle transporting it to the plant site. It rolled down a hill and 150 feet into a field. Damage to the reactor was minor. [*1960 Annual AEC Report*, pp. 46-47] ✓

08/03/63 The plant shut down for three months to investigate and repair excessive leakage of helium from control rod thimbles. [COO-284, p. 151]

04/24/64 The plant was shut down to repair a sodium pump seal and investigate why four graphite moderator elements had failed. [Ibid, p. 152] ✓

09/27/64 The reactor was shut down after it was determined that sodium coolant was attacking the graphite core. [Ibid, p. 142; and NUREG-1350, p. 90] ✓

08/09/65 The AEC rejected the utility's plans to repair the reactor and, citing unresolvable technical problems with the reactor, terminated its operating contract with the utility. [COO-284, p. 142; *Nucleonics Week*, 12/23/65, p. 3; and *AEC Fact Book*, p. D-5]

12. ELK RIVER [08/24/63]

__General Data__

Owner AEC and Rural Cooperative Power Association [DOE/OSTI-8200, p. III-1]

Location Elk River, MN [WASH-1208, p. 1]

Reactor 22.0 MWe BWR, with superheater, ordered 06/00/58 [WASH-1208, p. 1; and *1968 Annual AEC Report*, p. 9]

First Electricity 08/24/63 [Ibid]

Designer Sargent & Lundy [Ibid]

Builder Maxon Construction [*Nuclear Industry*, 02/00/77, p. 8]

Cost to Build $14.4 million [COO-284, p. 17]

Licensing

- CP received 12/18/59; OL received 11/06/62. During June 1970, OL was changed to "possession only". [NUREG-1350, p. 90; *AEC Fact Book*, p. E-31; and *AEC Reports*, Vol. 2, p. 215]

- During 1956, the AEC named Elk River one of four new nuclear power plants eligible for special U.S. Government financing and other assistance. [DOE/MA-0152, p. 39]

Operating Data

- The plant produced 510,598 MW-hrs of electricity over 4.44 yrs that it was in operation. [NUREG-0020, 03/00/90, p. 3-6; and WASH-1203-71, p. 9]
- The plant's Lifetime Capacity Factor, calculated using the above data, was 59.67%.

Decommissioning During 03/00/71, the AEC and utility reached an agreement to dismantle the reactor. Work began in 1972 and took two years and $6.2 million to complete. [*AEC Fact Book*, p. D-9; EMD-77-46, p. 9; and *Nuclear Industry*, 02/00/77, pp. 8-9]

Problems

00/00/60 Cracks were discovered in four 17-inch reactor nozzles. Repairs took 6 weeks and delayed plant start-up. [*1960 Annual AEC Report*, pp. 30-31]

00/00/61 Plant construction personnel chipped and drilled grout out of a thermal expansion gap below the reactor. Stress analyses were conducted to verify that the reactor, which had been heated to 425°F, had not been damaged when it expanded into the filled-in space. [COO-284, pp. 118 & 127] ✓

04/00/62 The reactor's stainless steel cladding was tested and found acceptable after being removed and replaced, and reexamined. The reactor had been built in California between 10/00/58 and 01/00/60. Cracks were found in the cladding's welds during 03/00/61, after it had been shipped to the power plant. [*AEC Reports*, Vol. 2, pp. 226-237; and COO-284, pp. 129-130] ✓

06/05/62 The Advisory Committee on Reactor Safeguards limited operation of the repaired reactor to five years or 250 thermal cycles, whichever occurred first. [CCO-284, p. 129] ✓

03/25/64 The plant was down until 07/06/64 to modify feedwater piping. The piping had been vibrating. [Ibid, p. 130] ✓

02/01/68 The plant was permanently shut down because of leakage in the reactor coolant piping system and other unspecified "technical problems". [*AEC Fact Book*, p. E-31; DOE/OSTI-8200, p. III-1; and NUREG-1350, p. 90]

13. PIQUA [11/04/63]

General Data

Owner AEC and City of Piqua [DOE/OSTI-8200, p. III-2]

Location Piqua, OH [Ibid]

Reactor 11.4 MWe organically cooled and moderated reactor ordered 06/00/59. Capable of using low-enrichment uranium. The reactor was 6'-6" dia. and 29'-0" long. [Ibid; *The New York Times*, 09/28/56, p. 40; and WASH-1208, p. 1]

First Electricity 11/04/63 [WASH-1208, p. 1]

Designer Holmes & Narver [Ibid]

Builder Atomics International [*AEC Reports*, Vol. 2, pp. 74-76]

Cost to Build $8.2 million [COO-284, p. 17]

Licensing

- CP received 01/28/60; OL received 08/63/62 and terminated 04/24/69. [*AEC Reports*, Vol. 2, p. 74; *AEC Fact Book*, p. E-27; and NUREG-1350, p. 90]
- During 1956, the AEC named Piqua one of four new nuclear power plants eligible for special U.S. Government financing and other assistance. [DOE/MA-0152, p. 39]

Operating Data

- The plant produced 70,601 MW-hrs of electricity, 20% of Piqua's needs, over the 2.16 yrs it was in operation. [NUREG-0020, 03/00/90, p. 3-6; WASH-1203-71, p. 9; and *Nucleonics Week*, 12/23/65, p. 3]
- The plant's Lifetime Capacity Factor, calculated using the above data, was 32.73%.

Decommissioning Work on entombing the reactor in sand was completed in 02/00/69. The reactor building was converted to a warehouse. [DOE/OSTI-8200, p. III-2; EMD-77-46, p. 9; *Decommissioning of Nuclear Power Facilities*, p. 27; and *The Decommissioning of Nuclear Plants*, p. 8]

Problems

05/25/63 Defects were found in HVAC equipment during start-up. Because the original builder was no longer on site, repairs took longer than expected. Due to this and a fire, instead of the one month scheduled, preoperational testing took sixteen months. [COO-284, pp. 253-254; and *1962 Annual AEC Report*, p. 147]

12/00/65 From 01/00/64 to 12/00/65, the plant was shut down three times for repairs and modifications to control rod drive systems. [COO-284, p. 258] ✓

01/01/66 The plant was shut down to repair malfunctioning control rods and was never restarted. During repairs, extensive carbon deposits on fuel elements, and core damage was identified. [Ibid, pp. 259-260; WASH-1208, p. 1; *1966 Annual AEC Report*, p. 415; and NUREG-1350, p. 90] ✓

12/13/67 The AEC terminated its operating contract with the City of Piqua, presumably because of the plant's relatively high operating costs. [WASH-1208, p. 1; and *1967 Annual AEC Report*, p. 327] ✓

14. CVTR (Carolinas-Virginia Tube Reactor) [12/18/63]

General Data

Owner Carolinas Virginia Nuclear Power Associates, a consortium of four utilities. [DOE/OSTI-8200, p. III-1; and *AEC Reports*, Vol. 1, p. 304]

Location Parr, SC [WASH-1208, p. 1]

Reactor 17.0 MWe heavy water reactor ordered 01/00/59. The reactor had 42 U-tubes and was 10"-3" dia. and 11"-0" high. [Ibid; DOE/OSTI-8200, p. III-1; and *AEC Reports*, Vol. 2, pp. 306-307]

First electricity 12/18/63 [WASH-1208, p. 1]

Designer Stone & Webster [Ibid; and *AEC Reports*, Vol. 1. p. 311]

Builder Daniel Construction [COO-284, p. 103]

Cost to Build $19.3 million [Ibid, p. 17]

Licensing

- CP received 05/04/60. OL received 11/27/62, converted to a "possess only" OL on 07/14/67, and terminated on 06/25/68. [*AEC Reports*, Vol. 2, p. 183; *AEC Fact Book*, p. E-24; NUREG-1350, p. 90; and DOE/OSTI-8200, p. III-1]
- During 1957, the AEC named CVTR one of five new nuclear power plants eligible for special U.S. Government financing and other assistance. DOE/MA-0152, p. 39]

Operating Data

- The plant produced 212,216 MW-hrs of electricity over the 3.04 yrs it was in operation. [NUREG-0020, 03/00/90, p. 3-6; and WASH-1203-71, p. 9]
- The plant's Lifetime Capacity Factor, calculated using the above data, was 46.88%.

Decommissioning Decontamination was completed in 1970. About 3.5 metric tons of CVTR spent fuel were shipped to West Valley. [*The Decommissioning of Nuclear Plants*, p. 8, and *Nuclear Witnesses*, p. 239]

Problems

12/16/63 Numerous problems were experienced during plant start-up. The problems were due to manufacturing defects in off-the-shelf equipment or wear and leakage at locations where tight tolerances were not met during field installation. [COO-284, p. 103] ✓

03/08/66 Stress corrosion cracks were detected in stainless steel piping and mechanical equipment. While the plant was shut down for repairs, defective fuel elements were found inside the reactor, removed, and replaced. [*1966 Annual AEC Report*, p. 416] ✓

01/24/67 The plant was shut down and never restarted. The AEC told Congress the reactor's zircaloy fuel rods had been failing and, earlier, fuel cladding failures had also been experienced using both stainless and Incaloy rods. [*The Careless Atom*, pp. 126-127; and DOE/OSTI-8200, p. III-1] ✓

06/00/67 The utility formally decided to deactivate the reactor; supposedly because it was unable to find a suitable solution to its fuel rod problems. [*AEC Fact Book*, p. D-6]

15. BONUS (BOiling Water NUclear Superheater Reactor) [08/14/64]

General Data

Owner AEC and Puerto Rico Water Resources Authority [DOE/OSTI-8200, p. III-1]

Location Punta Higuera, PR [Ibid]

Reactor 16.5 MWe BWR with integral superheater. Ordered 12/00/59. [Ibid; and WASH-1208, p. 1]
First electricity 08/14/64 [WASH-1208, p. 1]
Designer Jackson & Moreland [Ibid]
Builder Maxon Construction. [*AEC Reports*, Vol. 1, pp. 421-422]
Cost to Build $18.0 million [COO-284, p. 17]
Licensing

- CP received 12/23/59; OL issued 04/02/64. The plant's OL was terminated 06/05/72. [Ibid, p. 54; *AEC Fact Book*, p. IX-4; and NUREG-1350, p. 90]
- During 1956, the AEC named Bonus one of four new nuclear power plants eligible for special U.S. Government financing and other assistance. [DOE/MA-0152, p. 39]

Operating Data

- The plant produced 68,297 MW-hrs of electricity during the 3.80 yrs it was in operation. [WASH-1203-73, p. 9; and NUREG-0020, 03/00/90, p. 3-6]
- The plant's Lifetime Capacity Factor, calculated using the above data, was 12.43%.

Decommissioning On 08/11/69, the AEC ordered the utility to begin dismantling the plant. The reactor was entombed and Phase 2 decommissioning completed during 1970. About 5.1 metric tons of spent fuel was shipped to West Valley. [WASH-1208, p. 1; *The Decommissioning of Nuclear Plants*, p. 8; EMD-77-46, p. 9; and *Nuclear Witnesses*, p. 239]

Problems

00/00/60 The stainless steel cladding on superheater fuel elements failed during tests. Additional tests were started to find a suitable alternate material. [*1962 Annual AEC Report*, p. 150] ✓

02/00/63 Fabrication of the reactor vessel was completed in 29 months, severely delaying plant start-up. The reactor was originally scheduled to be completed in 12 months. [COO-284, p. 65]

10/00/64 The reactor scrammed 55 times in five months, mostly because of operator errors, voltage dips during thunderstorms, and instrument failures. [Ibid, pp. 70 & 78] ✓

11/11/64 Plant operators closed the wrong valve, causing a jump in reactor power and pressure. Instead of scramming the reactor, power was gradually reduced, a procedural violation that could have resulted in a serious accident. Five fuel rods failed during the incident. An investigation attributed their failure to a variety of factors including weld defects. [*Nuclear Lessons*, p. 180; and *Nuclear Safety*, Fall 1965, pp. 113-118] ✓

03/11/65 A valve in the reactor containment spray system failed, flooding the reactor with 3100 gallons of untreated water. The reactor had to be cleaned and flushed prior to being restarted. [COO-284, p. 73] ✓

04/10/66 Due to hydrogen build-up in the reactor's control rod drive housings, the reactor was shut down and a ventilation system installed in the housings. [*1966 Annual AEC Report*, p. 417] ✓

08/00/67 The plant was shut down because of core flow restrictions caused by crud build-up in the reactor. [*1967 Annual AEC Report*, pp. 95 & 327] ✓

06/01/68 The reactor was permanently shut down because the NRC was not willing to continue funding major repairs and modifications. Chloride stress corrosion would have required replacing superheater piping. The reactor's core and control rod drives would have also required major repairs or modifications. [NUREG-1350, p. 90; *Nuclear News*, 07/00/77, p. 105; *1967 Annual AEC Report*, p. 95; and *Power*, 09/00/68, p. 116]

16. HANFORD-N [04/08/66]

General Data

Owner DOE [DOE/OSTI-8200, p. II-8]

Location Richland, WA [Ibid]

Reactor 860.0 MWe water-cooled, graphite-moderated reactor ordered 04/00/63 This was a dual purpose reactor, producing both steam for electricity and plutonium for nuclear weapons [Ibid; and WASH-1208, p. 2]

First Electricity 04/08/66; initial criticality, required for plutonium production, was achieved 12/31/63. [WASH-1208, p. 2; and *AEC Fact Book*, p. C-7]

Designer Burns & Roe [Ibid]

Builder Kaiser Engineers. Construction began 05/01/59. [*AEC Fact Book*, p. C-5; and *The New York Times*, 05/21/59, p. 5]

Cost to Build $145 million. [*The New York Times*, 05/21/59, p. 5]

Licensing Not licensed

Operational Data

- The plant was out of service for a total of seven months during 1966 and 1967 because of trade council strikes. It was shut down on 01/28/71 and restarted 07/12/71 under a three-year agreement with WPPSS (Washington Public Power Supply System). It was shut down again 05/12/73 after fulfilling its electrical commitments to WPPSS. It resumed operation a few weeks later; however, its operating history after 1974 is rather sketchy. [*AEC Fact Book*, pp. C-5, 14, 16, & 19; and WASH-1203-73, p. 36]
- The plant generated 67,979,085 MW-hrs of electricity over its life. Based on this, its Lifetime Capacity Factor was 43.7%. [*Nucleonics Week*, 03/05/87, p. 18]
- During the early 1980s, Hanford-N reactor scrams were 10 times more frequent than that of a typical licensed reactor. [*The New York Times*, 05/03/86, p. A5] ✓

Decommissioning On 08/14/91, DOE announced the plant would be decommissioned. [*DOE News Release* R-91-172]

Problems

00/00/68 Work began on retubing 10 of the plant's 12 steam generators. About 20 miles of stainless steel tubes were removed and replaced with Inconel tubes. [*1968 Annual AEC Report*, p. 36] ✓

09/30/70 Both the primary and back-up control rod drive systems failed. A secondary scram system was activated that dumped a hopper full of graphite balls into the reactor. It took months to clean the graphite out of the reactor. [*Decline and Fall*, p. 101] ✓

02/04/71 Dismantling of the reactor was stopped by the White House. The reactor was shut down on 01/28/71 due to a lack of funds and because the reactor was "unreliable and a possible safety hazard". One Government official said the plant was subject to frequent breakdowns because of "a sloppy engineering job" and it would cost millions to bring it up to "acceptable standards". [*The Washington Post*, 02/05/71, p. A05; and *The New York Times*, 02/07/71, p. 61] ✓

07/08/79 The reactor tripped 3 times in 12 days. Once each when the wrong valve closed, fuel cladding broke off into the reactor's coolant, and offsite power was lost. [*Nuclear News*, 08/00/77, p. 40] ✓

01/06/86 The plant was placed in standby condition in response to Congressional concerns about the capability of its emergency core cooling system. [*NAS Study*, p. viii]

04/26/86 Because of the Chernobyl accident, Congress asked the National Academy of Sciences (NAS) to study the possibility of a similar accident at Hanford-N. The NAS found that swelling of graphite blocks in the reactor's moderator stack had bent: a) horizontal control rod channels, b) vertical channels for the boron carbide-ball scram system, and c) process and cooling water tubes running through the stack. Also, years of irradiation had embrittled tubing materials embedded in the graphite blocks. [Ibid, pp. vii & 20-22] ✓

05/00/86 Six fuel rod failures occurred within three months, partially because of damage from scaling inside the reactor. [*The New York Times*, 05/03/86, p. A5] ✓

01/07/87 The plant was shut down in order to begin work on a $110 million safety systems modernization program. [*Nuclear Age*, p. 302] ✓

10/00/89 DOE decided to defuel and drain the reactor. However, work continued on safety enhancements should it be necessary to restart the plant. [*DOE News Release* R-91-172]

17. *PATHFINDER [07/25/66]*

General Data

Owner Northern States Power [DOE/OSTI-8200, p. III-2]

Location Sioux Falls, SD [COO-284, p. 207]

Reactor 58.5 MWe BWR with integral superheater; ordered 05/00/57 [Ibid and WASH-1208, p. 1]

First Electricity 07/25/66 [Ibid]

Designer Pioneer Service & Engineering [Ibid]

Builder Fegles Construction [COO-284, p. 207]

Cost to Build $25.8 million [Ibid, p. 17]

Licensing

- CP received 05/12/60. An OL was received 03/12/64, modified to a "possess only" OL on 05/14/69, and terminated on 03/05/73. [Ibid, p. 210; WASH-1208, p. 1; and *AEC Fact Book*, pp. IX-4 & E-28]

- During 1957, the AEC named Pathfinder one of five new nuclear power plants eligible for special U.S. Government financing and other assistance. [DOE/MA-0152, p. 39]

Operating Data

- The plant produced 96,450 MW-hrs of electricity during the 1.19 yrs it was in operation. [NUREG-0020, 03/00/90, p. 3-6; and WASH-1203-71, p. 9]
- The plant's Lifetime Capacity Factor, calculated using the above data, was 15.82%.
- On 09/09/68, the utility announced it would convert Pathfinder to a gas-fired plant. Work was completed 05/00/69 and the plant is still operating. [*Nuclear News*, 07/00/91, p. 31; and WASH-1208, p. 1]

Decommissioning Partial decommissioning, which included filling the reactor with gravel and sending 9.6 metric tons of spent fuel to West Valley, was completed 11/00/71. On 08/08/91, the reactor was shipped to DOE's Hanford facility. As of 01/00/92, 1000 tons of low-level radioactive waste had been shipped from the plant to Hanford. Final decommissioning costs are expected to total $20 million. [GAO/RCED-90-208, p. 22; *Nuclear News*, 07/00/91, p. 31; *The Nuclear Monitor*, 01/27/92, p. 8; and *Nuclear Witnesses*, p. 239]

Problems

03/24/66 Major delays occurred during construction because of: a) design changes to resolve concerns expressed by the Advisory Committee on Reactor Safeguards, b) manufacturing quality control problems delayed shipment of the reactor and reactor fuel, and c) heat-treatment records could not be found for the control rod drives. As a precaution, they were heat-treated a "second" time. [COO-284, pp. 221, 224, & 225] ✓

09/00/67 The reactor was shut down due to serious problems with steam separators inside the reactor and was never re-started. [GAO/RCED-90-208, p. 22; *Nuclear News*, 07/00/91, p. 31; and COO-284, p. 230] ✓

18. FERMI 1 [08/05/66]

General Data

Owner Power Reactor Development Company, a consortium of 21 utilities and equipment manufacturers. [DOE/OSTI-8200, p. III-1; and *Reactor Accidents*, p. 45]

Location Lagoona Beach, MI [DOE/OSTI-8200, p. III-1]

Reactor 60.9 MWe sodium-cooled fast-breeder reactor ordered 03/00/57 [Ibid; and WASH-1208, p. 1]

First electricity 08/05/66 [WASH-1208, p. 1]

Designer Commonwealth Associates [Ibid]

Builder United Engineers & Constructors [*Fermi 1*, p. 167]

Cost to Build $48.8 million [Ibid, p. 91]

Licensing

- CP received 08/04/56; OL received 05/10/63. The OL was modified on 05/10/68 to restrict operation to activities required to support investigation of the cause of the 10/05/66 accident. On 02/10/70, restrictions were partially lifted to allow reloading fuel. During 07/00/70, they were further relaxed to allow operating the reactor, assessing damage, and completing repairs. [*AEC Fact Book*, pp. E-29, D-8, & E-21; *AEC Reports*, Vol. 1, p. 129; and NUREG-1350, p. 90]
- During 1955, the AEC named Fermi 1 one of three new nuclear power plants eligible for special U. S. Government financing and other assistance. [DOE/MA-0152, p. 39]

Operating Data

- The plant was in operation 6.32 yrs. As of 12/31/71, it had produced 33,430 MW-hrs of electricity. [NUREG-0020, 03/00/90, p. 3-6; and WASH-1203-71, p. 9]
- Using the above data, as of 12/31/71 the plant's Lifetime Capacity Factor was 0 12%. There is no reason to believe it changed much before it was permanently shut down. The plant only operated about 30 days and never more than five days in succession. [*Unacceptable Risk*, p. 64]
- To compensate for its poor reliability, a $23 million oil-fired power plant was built alongside Fermi 1. The plant came on line and produced electricity whenever the reactor was down. [Ibid]

Decommissioning A decision to decommission the plant was announced 11/29/72. Phase 1 work was completed on 10/31/75 at a cost of $7.2 million. About 77,000 gallons of contaminated sodium were drained from the reactor and stored in drums at the plant. [WASH-1208, p. 1; *Unacceptable Risk*, p. 64; *Decommissioning of Nuclear Power Facilities*, p. 27; and *Fermi 1*, pp. 293 & 427]

Problems

08/00/59 Six people were seriously injured when a sodium coolant mixture, planned for the Fermi 1 reactor, exploded during tests at a gravel pit near the proposed plant. [*Nuclear Age*, p. 156] ✓

12/00/59 Lab tests found that sodium coolant eroded fuel rods and, in the process, reduced their life expectancy by 75%. Additional tests, a few months later, found that sodium caused the fuel rods to swell, reducing the flow of coolant between the rods. This required increasing the space between rods and accepting a 50% reduction in the reactor's efficiency. [Ibid] ✓

01/04/63 During start-up tests, sodium leaked out of a faulty valve. The leak went unnoticed until the volatile sodium burst into flames. [Ibid, p. 157]

09/00/66 High temperatures were noticed in 2 of 91 fuel assemblies; these same high temperatures had been detected 3 months earlier. The assemblies were moved to a "cooler" region of the core. Nothing else was done because, the temperatures were within specifications. [*Reactor Accidents*, pp. 46-47]

10/04/66 The plant was restarted after an extended outage during which time its steam generators were repaired. [*Power*, 12/00/66, p. 100]

10/05/66 Part of two fuel assemblies melted and two others buckled when two of six metal sheets broke loose inside the reactor, partially blocking the flow of coolant (liquid sodium). The metal sheets were not identified on as-built drawings. The cause of the accident was verified a year later when periscopes were lowered into the reactor. The second sheet was found wedged on the underside of the reactor core support structure during 10/00/68. [*Reactor Accidents*, pp. 45 & 49; and *The Careless Atom*, pp. 156-165] ✓

05/00/70 As the reactor coolant system was being refilled with sodium, about 200 pounds of sodium leaked out of a crack, came into contact with water, and exploded. Though there were no serious injuries to workers or AEC observers, the building was contaminated. [*Nuclear Age*, p. 158] ✓

00/00/71 Shut downs occurred throughout the year due to steam generator repairs, pump seal and lubrication failures, shielding problems, and bowing of reactor core subassemblies. [WASH-1203-71, p. 30] ✓

09/22/72 The plant was closed because it could not be operated economically. [*Fermi 1*, p. 266] ✓

19. PEACH BOTTOM 1 [01/27/67]

General Data

Owner Philadelphia Electric [DOE/OSTI-8200, p. III-2]

Location Peach Bottom, PA [Ibid]

Reactor 40.0 MWe HTGR ordered 11/00/58 [WASH-1208, p. 1]

First electricity 01/27/67 [Ibid]

Designer/Builder Bechtel [*AEC Reports*, Vol. 2, p. 23]

Cost to Build $28.1 million [COO-284, p. 17]

Licensing

- CP received 02/02/62; OL received 01/27/67 [*AEC Reports*, Vol. 2, p. 25; and NUREG-1350, p. 90]
- During 1957, the AEC named Peach Bottom 1 as one of five new nuclear power plants eligible for special U.S. Government financing and other assistance. [DOE/MA-0152, p. 39]

Operating Data The plant's Lifetime Capacity Factor, over the 7.76 yrs it was in operation, was 44.5%. At the time the national average was about 54%. [*The Silent Bomb*, p. 108; *World Nuclear Power Plant Directory*, p. 739; and WASH-1203-73, p. 8]

Decommissioning Removal of spent fuel and "mothballing" the plant was completed during 02/00/78 at a cost of $3.5 million. Dismantling the plant may not begin for another 20 years because of the disruptive affect it would have on Peach Bottom 2&3. [*Decommissioning of Nuclear Power Facilities*, p. 27; *Nuclear Power in Crisis*, p. 212; and GAO/RCED-90-208, p. 24]

Problems

02/03/65 A construction fire in the reactor building destroyed about 1100 electrical cables and a control board. A heavy layer of soot was deposited over the inside of the building. Completion of construction was delayed until specially fabricated cables could be replaced. [COO-284, p. 239] ✓

12/00/65 Cracks were discovered in several steam generator tubes. [*1965 Annual AEC Report*, p. 311]

02/00/66 Retubing began of the reactor's superheater which failed as a result of chloride-stress corrosion. [*Power*, 02/00/66, p. 93] ✓

02/00/67 The plant was shut down until 06/00/67 for steam generator repairs. [WASH-1203-73, p. 34] ✓

10/00/68 The plant was down until 02/00/69 to remove and replace eleven damaged fuel rods and examine the reactor core and steam generators. [Ibid; and *1968 Annual AEC Report*, p. 93] ✓

09/00/69 The plant was down until 07/00/70 to remove 78 damaged fuel rods and place a new core in the reactor. [WASH-1203-73, p. 34; and *1969 Annual AEC Report*, p. 98] ✓

01/00/72 The plant was down for six months to investigate problems with reactor cooling system instrumentation. [Ibid, p. 35] ✓

10/31/74 The plant was permanently closed because it was too small to be operated economically. [*World Nuclear Power Plant Directory*, p. 739; DOE/OSTI-8200, p. III-2; and *Unacceptable Risk*, pp. 19 & 22] ✓

20. SAN ONOFRE 1 [07/16/67]

General Data

Owner Southern California Edison [DOE/OSTI-8200, p. II-5]

Location San Clemente, CA [Ibid]

Reactor 436.0 MWe PWR ordered 01/00/63 [WASH-1208, p. 2]

First Electricity 07/16/67 [Ibid]

Designer/Builder Bechtel [NUREG-0020, 03/00/90, p. 2-380]

Cost to Build $98.5 million [DOE/EIA-0473, p. 15]

Licensing

- CP received 03/02/64; OL received 03/27/67 [NUREG-1350, p. 82]
- During 1962, the AEC named San Onofre 1 as one of three new nuclear power plants eligible for special U.S. Government financing and other assistance. [DOE/MA-0152, p.39]

Operating Data

- As of 02/28/90, the plant's Lifetime Capacity Factor was 51.0%, the worst of the nation's eight oldest nuclear units. The plant's 1989-90 Capacity Factor was the eighth worst among operating nuclear power plants and its 1984 Capacity Factor was the seventh worst. To date, forced outages have totalled 14,509 hrs (1.7 yrs) and on-line hrs totalled 111,099 (12.7 yrs). [NUREG-0020, 03/00/90, p. 2-378; *1984-1985 Nuclear Power Safety Report*, p. D3; and *Nuclear Lemons*, 04/25/91, p. 9]
- As of 06/30/90, the plant had a Cumulative SALP Rating of 1.81. Three Category 3 Findings have been identified since its first SALP inspection during 08/00/81. The Findings pertained to inadequacies in radiological controls, maintenance, and security. [NUREG-1214, p. 2-11]
- During 1989-90, the plant had the fourth highest operating and maintenance costs of the nation's 111 operating nuclear power plants. [*Nuclear Lemons*, 04/25/91, p. 10] ✓

Decommissioning Final decommissioning will not begin until San Onofre 2&3 are ready to permanently shut down because of the disruptive affect it would have on these two units. [*Nuclear Power in Crisis*, p. 212]

Problems

09/08/68 The plant restarted after being down since 03/12/68 due to a major switchgear fire. Faulty wiring caused the fire. A few months earlier, on 02/07/68, wiring problems resulted in a smaller fire that shut the plant down for several days. [*Nugget File*, pp. 7&8; *AEC Fact Book*, p. E-25; *Power*, 10/00/68, p. S-8; *1968 Annual AEC Report*, p. 92; and WASH-1203, p. 38.] ✓

06/19/71 The AEC ordered the utility to modify the plant's emergency core cooling piping system or greatly increase its in-service inspection of the system. [*Nucleonics Week*, 06/24/71, p. 1-3] ✓

00/00/73 Work began on replacing the turbine condenser's tubes. High velocities and turbulence had eroded the inlet side of the tubes to the point they were beginning to leak. [*Nuclear News*, 01/00/78, p. 48]

06/00/74 During excavation, geological faults were found under planned foundations for San Onofre 2&3, raising questions about the adequacy of the San Onofre 1 site. [*AEC Fact Book*, p. E-56]

07/00/74 Several hundred gallons of water leaked past a bad gasket onto the reactor head and shorted out its neutron detection system. [*Nugget File*, p. 48]

06/00/79 While repairing leaks in a steam generator, cracks were found in three feedwater nozzles. Similar problems were subsequently found with feedwater nozzles at ten other nuclear plants. [*Nuclear News*, 07/00/79, p. 36; and *Nuclear News*, 08/00/79, p. 28] ✓

11/00/79 Poor housekeeping and a nest of mice led to an electrical fire and $2 million in damage. [*Normal Accidents*, p. 58] ✓

03/00/80 For one hour, the plant experienced a total loss of cooling water due to inoperable valves. Desiccants had abraded holes through seals in the valve solenoids. [*Nuclear News*, 01/00/88, p. 51] ✓

04/09/80 The plant was down until 06/00/81 for refueling, and resleeving steam generator tubes. During the outage, 66 workers received excessive radiation doses due to improperly placed film badges, and two others received excessive exposures due to inadequate training. The utility was fined $150,000, and 50 truckloads of contaminated sand was hauled from the plant. [*Normal Accidents*, p. 59; *Engineering News-Record*, 07/31/80, p. 17; *Nuclear News*, 10/00/80, pp. 35-36; 11/00/80, pp. 61-62; 03/00/81, p. 38; and 12/00/82, p. 49; and NUREG-0523, pp. 14, 15, 23, 37, & 38] ✓

06/09/81 Barnacle build-up in a heat exchanger caused a reduction in flow of reactor coolant water. This, in turn, caused a valve to malfunction which automatically shut down the reactor. [*Nuclear Age*, p. 312]

07/00/81 An explosion in a radioactive gas holding tank resulted in damage to the tank and a small unplanned release. [*Nuclear News*, 10/00/81, pp. 40 & 42]

02/00/82 The utility was fined $60,000 for security violations. [*Nuclear News*, 08/00/82, pp. 50 & 51] ✓

11/09/82 A power cable was accidently knocked loose causing the plant to shut down. Once reconnected, reactor coolant levels rose too fast, "shocking" the reactor's temperature-sensitive materials. [*Nuclear Age*, p. 316] ✓

03/31/83 The utility filed a $ 250 million suit against Westinghouse to cover the cost of resleeving tubes in three of the plant's steam generators. The suit claimed the tubes should have been good for the life of the plant. [*Nuclear News*, 05/00/83, p. 38] ✓

11/28/84 The plant went back on line after being out of service for two years while $150 million in seismic modifications were being completed. [*Nuclear Safety*, 03/00/85-04/00/85, p. 238] ✓

11/21/85 All plant power was lost for four minutes causing severe water hammer in piping systems. Some systems overheated and others cooled down too fast. The water hammer caused leaks in piping systems and damaged plant equipment. [*1984-1985 Nuclear Power Safety Report*, p. 29] ✓

12/31/87 San Onofre 1 spent $141.17/kw on major repairs and backfits during 1983-1987, more than any other U.S. nuclear power plant. The average was $30.39/kw. [*Nuclear Lemons*, 05/00/89, pp. 26-27] ✓

02/28/90 The plant cut back to 90% of full power because of steam generator tube corrosion problems. [NUREG-0020, 03/00/90, p. 2-378] ✓

10/16/90 The Government Accounting Office issued a report on counterfeit hardware in nuclear plants. It stated San Onofre had counterfeit fasteners, pipe fittings, and circuit breakers. [GAO/RCED-91-6, p. 16]

09/00/91 The Ratepayers Advocate Division of the California PUC advised against adding over $100 million to the rate base to bring it into compliance with current licensing requirements. [*The Nuclear Monitor*, 10/07/91, p. 3; and *Nuclear News*, 02/00/92, pp. 99-100]

01/00/92 Bowing from pressure from the PUC, the utility decided to close San Onofre 1 by mid-1993. The PUC considered the plant too old and inefficient to spend $125 million to upgrade. [*The Washington Post*, 02/27/92, p. A3; *The Nuclear Monitor*, 01/27/92, pp. 1-2; and *Nuclear News*, 02/00/92, pp. 99-100]

11/30/92 The plant was permanently shut down. [*The Nuclear Monitor*, 12/14/92, p. 8; and *Nuclear News*, 01/00/93, p. 23]

21. HADDAM NECK (also called CONNECTICUT YANKEE) [08/07/67]

General Data

Owner Connecticut Yankee Atomic Power Company [DOE/OSTI-8200, p. II-3]
Location Haddam Neck, CT [Ibid]
Reactor 569.0 MWe PWR ordered 12/00/62 [Ibid; and WASH-1208, p. 2]
First Electricity 08/07/67 [WASH-1208, p. 2]
Designer/Builder Stone & Webster [NUREG-0020, 03/00/90, p. 2-178]
Cost to Build $109.3 million [DOE/EIA-0473, p. 15]
Licensing

- CP received 05/26/64; OL received 12/27/74. [NUREG-1350, p. 75]
- During 1962, the AEC named Haddam Neck one of three new nuclear power plants eligible for special U.S. Government financing and other assistance. [DOE/MA-0152, p. 39]

Operating Data

- On 08/20/77, the plant broke the world's record for continuous power generation, 344 days. During 09/00/89, it set another new record with a run of 461 continuous days. [*Nuclear News*, 09/00/77, p. 104; and *Nuclear News*, 12/00/89, p. 28]
- As of 06/30/90, the plant had a Cumulative SALP Rating of 1.46, the second best of the nation's eight oldest nuclear units. Only one Category 3 Finding was identified since its first SALP inspection during 10/00/80. The Finding pertained to the plant's fire protection systems. [NUREG-1214, p. 2-5]
- As of 02/28/90, the plant's Lifetime Capacity Factor was 72.4%, the second best among the nation's eight oldest nuclear units. Forced outages totalled 2,433 hrs (0.3 yrs) the lowest of the oldest nuclear units. On-line hrs totalled 152,100 (17.4 yrs). [NUREG-0020, 03/00/90, pp. 2-176 & 178]
- During 1987, the operating and maintenance costs were $164.87/kW, the sixth highest of all U.S. nuclear power plants. The industry average was $72.47. [*Nuclear Lemons*, 05/00/89, p. 25] ✓
- During 1988-89, the plant was holding 314.7 metric tons of spent fuel in its spent fuel pool. Only four other operating nuclear plants were holding more spent fuel. The industry average was 177.8 metric tons. [*Nuclear Lemons*, 04/25/91, p. 10]

Problems

07/00/73 A turbine failure shut the plant down for five months. Its Capacity Factor for 1973 was 48.3%. [*Engineering News-Record*, 01/10/74, p. 11; and WASH-1203-73, pp. 42-43] ✓

05/00/75 A wiring error caused an alarm system to fail that had been installed on the plant's steam generator support bolts. As a consequence, for years, two broken bolts went undetected. [*Nugget File*, p. 55]

12/00/81 The utility was fined $22,500 for deficiencies associated with radiation surveys, posting radiation precautions/warnings, and maintaining records of exposures. [*Nuclear News*, 01/00/80, p. 30]

08/21/84 A refueling pool seal failed, emptying 200,000 gallons of contaminated water onto the reactor building floor. The NRC fined the utility $80,000. [*1984-1985 Nuclear Power Safety Report*, p. 27; *Nuclear News*, 10/00/84, p. 46; and *Nuclear News*, 02/00/85, p. 54] ✓

03/03/86 During refueling, a fuel assembly fell and lodged among other assemblies in the reactor. Retrieval of the assembly extended refueling by three months. [*Nuclear News*, 04/00/86, p. 32, and 05/00/91, p. 47] ✓

07/23/86 A contract employee exceeded his maximum quarterly radiation exposure while repairing a steam generator. The utility was fined $50,000. [*The New York Times*, 12/13/86, p. 33]

00/00/87 A surveillance found thermal shield bolts had sheared off. Repairs kept the plant out of service until the spring of 1988. [*Nuclear News*, 05/00/91, p. 47]

09/00/90 The reactor was restarted after being out of service since 09/00/89 for refueling and additional repairs to thermal shielding. [*Nuclear News*, 05/00/91, p. 47; and NUREG-0020, 03/00/90, p. 2-177] ✓

12/31/90 During 1989-90, the plant's safety systems failed 27 times, more than any other operating U.S. nuclear power plant. [*Nuclear Lemons*, 04/25/91, p. 8] ✓

08/12/91 Maintenance workers left a reactor coolant system valve open. Twenty (20) minutes later it was closed but not before 400 gallons of contaminated water had leaked into the reactor building. [*The Nuclear Monitor*, 08/26/91, p. 7]

22. LA CROSSE (also called DAIRYLAND or GENOA) [04/26/68]

General Data

Owner Dairyland Power Cooperative [DOE/OSTI-8200, p. III-2]
Location La Crosse, WI [Ibid]
Reactor 48.0 MWe BWR ordered during 06/00/62 [Ibid; and WASH-1208, p. 2]
First Electricity 04/26/68 [WASH-1208, p. 2]
Designer Sargent & Lundy [Ibid]
Builder Maxon Construction [NUREG-0020, 01/00/77, p. 2-58]
Cost to Build $19.1 million [COO-284, p. 17]

Licensing

- CP received 03/29/63; OL received 07/03/67 [NUREG-1305, p. 90; and COO-284, p. 201]
- During 1956, the AEC named La Crosse one of four new nuclear power plants to receive special U.S. Government financing and other assistance. [DOE/MA-0152, p. 39]

Operating Data

- As of 06/30/90, the plant had a Cumulative SALP Rating of 2.03. Category 3 Findings were identified during four of the eight SALP inspections performed since 01/00/81. The most frequent Findings pertained to plant operations and emergency preparedness. [NUREG-1214, p. 2-51]
- The plant had a Lifetime Capacity Factor of 49.0% over the 19.01 yrs it was in operation; at the time the national average was 61.6%. Forced outages totalled 10,806 hrs (1.23 yrs) and the plant was on-line a total of 96,275 hrs (10.99 yrs). [NUREG-0020, 05/00/87, p. 2-200; and NUREG-0020, 03/00/90, p. 3-6]

Decommissioning After shut down, the reactor's fuel was moved to the unit's spent fuel storage pool, raising its inventory to 38 metric tons of spent fuel. Decommissioning will begin as soon as a Federal repository is built to hold the spent fuel. [*Nucleonics Week*, 04/30/87, pp. 1 & 8; and SR/CNEAF/92-01, p. 27]

Problems

00/00/64 Welding problems were found with the reactor during fabrication. Pitting defects resulted in rejection of 40% of the reactor containment's liner plate. [*1964 Annual AEC Report*, p. 92] ✓

04/26/68 The plant was down virtually all of the first two years it was in operation due to the following problems: a) construction debris left in piping systems, b) equipment and piping system seal failures, c) control rod drive repairs, d) turbine-condenser repairs, e) malfunctioning containment isolation valves, and (f) cracks in steam generator feedwater nozzles. [WASH-1203-73, pp. 44 & 46; *Nuclear Industry*, 05/00/68, p. 20; *Nuclear Industry*, 09/00/68, p. 45; and *Nucleonics Week*, 05/14/70, pp. 1-2] ✓

09/00/71 The plant was down until 01/00/72 to repair and replace fuel rods and reactor head studs. [WASH-1203-73, pp. 44 & 46] ✓

07/00/72 The plant was down for three months to repair pump seals, replace damaged fuel rod assemblies, and perform other unscheduled maintenance. [Ibid] ✓

09/21/74 After finding cracks in Dresden 2 reactor coolant (RC) piping, the AEC ordered La Crosse shut down until its RC piping could be reexamined. [*The New York Times*, 09/22/74, pp. 1 & 34]

01/29/75 After finding cracks in Dresden 2 emergency core cooling (ECC) piping, the NRC ordered La Crosse shut down until its ECC piping could be reexamined. [*The New York Times*, 01/30/75, pp. 1 & 11]

08/00/75 Repairs were completed on intergranular stress-corrosion cracks in furnace-sensitized stainless steel used in critical areas of the reactor. [*Poisoned Power*, p. 168; *World Nuclear Power Plant Directory*, p. 716; and *The Silent Bomb*, p. 304] ✓

10/25/79 La Crosse was briefly shut down after a caller alleged a bomb had been left at the plant. A subsequent investigation traced the call to a mental patient. [*Nuclear News*, 12/00/79, p. 35]

04/01/81 Emergency core cooling system equipment was removed from service in violation of plant Technical Specifications. The utility was fined $38,000. [*Nuclear News*, 12/00/81, pp. 76 & 79]

04/30/87 The plant was permanently closed because the cost of operating La Crosse was expected to continue increasing and the utility had just negotiated an attractive long-term contract with coal companies. [NUREG-0020, 05/00/87, p. 2-201; NUREG-1305, p. 90; and *Nucleonics Week*, 04/30/87, pp. 7-8] ✓

23. OYSTER CREEK [09/23/69]

General Data

Owner GPU Nuclear [DOE/OSTI-8200, p. II-4]

Location Toms River, NJ [Ibid]

Reactor 620.0 MWe BWR ordered 12/00/63 [Ibid; and WASH-1208, p. 2]

First Electricity 09/23/69 [WASH-1208, p. 2]

Designer/Builder Burns & Roe as a subcontractor. General Electric had a "turnkey contract" with the utility. [*Containing the Atom*, p. 30; and NUREG-0020, 03/00/90, p. 2-288]

Cost to Build $91.4 million [DOE/EIA-0473, p. 15]

Licensing CP received 12/15/64; OL received 08/01/69. The utility received a "provisional" OL on 04/09/69 [*AEC Fact Book*, p. E-27; and NUREG-1350, p. 79]

Operating Data

- During 1986, radioactive discharges to the environment were the highest of any U.S. nuclear power plant. During 1988-89, plant workers received exposures totalling 1207 rem, the highest any U.S. power plant. The U.S. average was 382 rem. [*Nuclear Lemons*, 05/00/89, p. 19; and 04/25/91, p. 7] ✓

- During 1987-89 the plant had the third highest and eighth highest maintenance and operating costs of the nation's operating nuclear power plants. [*Nuclear Lemons*, 05/00/89, p. 25; and 04/25/91, p. 10] ✓
- During 1987-88 and 1989-90, the Public Citizen, an organization founded by Ralph Nader, labelled Oyster Creek the nation's fifth worst nuclear plant. [*Nuclear Lemons*, 05/00/89, p. 4; and 04/25/91, p. 5] ✓
- As of 06/30/90, the plant's Cumulative SALP Rating was 2.01, the worst of the nation's eight oldest operating nuclear units. As of 02/00/91, the plant's SALP Rating was 2.14. Category 3 Findings were identified during seven of last ten SALP inspections. Most pertained to problems with radiological controls and plant operating procedures. [NUREG-1214, p. 2-12; and *Nuclear Lemons*, 04/25/91, p. 8]
- As of 02/28/90, the plant's Lifetime Capacity Factor was 51.6%, the second worst of the nation's eight oldest nuclear plants. Forced outages totalled 19,040 hrs (2.2 yrs) and on-line hrs totalled 109,337 (12.5 yrs). [NUREG-0020, 03/00/90, p. 2-286]

Problems

09/29/67 Defects were discovered in the reactor's control rod drive housing welds and base material. [*The New York Times*, 11/10/67, p. 71; *Containing the Atom*, pp. 214 & 215; and *AEC Fact Book*, p. E-18] ✓

05/00/68 Stress corrosion cracks were detected in the reactor core shroud's support structure and steam separator assemblies. [*Poisoned Power*, p. 168; *Containing the Atom*, p. 219; and *AEC Fact Book*, p. E-22] ✓

06/00/68 The AEC refused to give the utility a provisional OL until "evidence that the [weld] repair work can and will be carried out successfully and that verification of the integrity of the repairs can be achieved". Two years later the utility received a provisional OL. [*Power*, 07/00/68, p. 104; and *AEC Fact Book*, p. E-27]

11/00/68 Cracks were found in reactor vessel's nozzle welds. Repairs and tests took months and resulted in costly delays. [*Forbes*, 11/15/68, p. 58] ✓

02/00/69 The NRC received allegations that substandard piping and valves had been installed in the plant. A subsequent investigation found some of the allegations to be true. [*Containing the Atom*, pp. 217 & 218] ✓

07/22/71 The utility sued General Electric (GE) for $62.8 million in damages caused by a 27 month start-up delay that GE allegedly could have prevented. GE settled for $5 million. [*Forbes*, 02/15/70, p. 34; *The New York Times*, 07/23/71, p. 41, and 10/25/73, p. 72; and *Engineering News-Record*, 08/12/71, p. 21] ✓

01/00/73 50,000 gallons of radioactive water were dumped into the basement of the reactor building due to an operator error. [*Unacceptable Risk*, p. 258; and *The New York Times*, 01/27/73, p. 64] ✓

08/24/73 Power was reduced by 9% until a solution could be found to fuel densification problems first identified at Ginna during 05/00/72. Full power operation resumed 01/03/74. [*Nucleonics Week*, 08/30/73, p. 1; and *AEC Fact Book*, pp. E-49 & 52] ✓

09/00/73 The utility found that improper settings on both of its emergency generators would have prevented the generators from starting in the event of a loss of off-site power. [*Nugget File*, pp. 42&43] ✓

09/21/74 Because of cracks found in Dresden 2 reactor coolant (RC) piping, the AEC ordered Oyster Creek shut down to reexamine its RC piping. [*The New York Times*, 09/22/74, pp. 1 & 34]

01/29/75 Because of cracks found in Dresden 2 emergency core cooling (ECC) piping, the NRC ordered Oyster Creek shut down to reexamine its ECC piping. No cracks were found. [*The Wall Street Journal*, 02/11/75, p. 18; and *The New York Times*, 01/30/75, pp. 1 & 11]

04/00/75 The design of the containment drywell was questioned after testing of a scale model found that accident loads were much larger than used in original calculations. [*The Silent Bomb*, pp. 292-298]

01/00/76 The plant was shut down for $8.5 million in repairs to condenser tubing which was damaged when seawater leaked into the system. [*Engineering News-Record*, 01/08/76, p. 3] ✓

06/00/76 The utility was fined $8000 for allowing an unauthorized individual to pass through the main plant gate without being challenged. [*Nuclear News*, 08/00/76, p. 36]

01/00/79 The utility was fined $26,000 for 90 violations of plant procedures over a 3-year period. Violations included unlocked security doors, failure to monitor airborne releases, and unmarked high-radiation work areas. [*Nuclear News*, 02/00/79, p. 109] ✓

05/02/79 A faulty electrical system shut down the plant's recirculating cooling water and feedwater pumps, preventing the removal of decay heat from the reactor. The core had to be cooled using the plant's isolation condensers. Reactor coolant dropped one foot below the top of the core before malfunctioning valves could be re-opened. [*Cover Up*, p. 53; *Nuclear News*, 06/00/79, p. 148; and *Nuclear Age*, p. 243] ✓

07/00/80 The utility was fined $21,000 for inadequately protecting employees from radiation while cleaning and examining contaminated tools. [*Nuclear News*, 09/00/80, p. 35]

04/00/81 The utility was fined $80,000 for blocking the movement of two suppression pool vacuum breakers with scaffolding. [*Nuclear News*, 10/00/81, p. 39] ✓

12/21/86 The plant was restarted after being down since 04/00/86 to refuel and investigate corrosion found behind the plant's main containment liner. Measurements found that corrosion had reduced the thickness of the 1.15 inch thick liner by up to 0.25 inches. The corrosion was attributed to moisture and impurities in sand backing the liner. [*The New York Times*, 12/22/86, p. B6; and *NRC Information Notice 86-99*, p. 1] ✓

04/24/87 While the reactor was at 23% power, two vents to the suppression pool were intentionally blocked open thereby exposing the containment to the possibility of over-pressurization in the event of an accident. The utility was fined $205,000. The fine took into consideration similar incidents that occurred during 1977 and 1981. [*Nuclear News*, 09/15/87, p. 84A] ✓

09/10/87 The plant was shut down until 11/06/87 to allow the NRC to complete an investigation of missing records. In order to isolate a pipeline leak, a valve was closed that was supposed to remain open and to hide the misdeed, the five involved personnel destroyed all associated documentation. The NRC permanently banned the five from working at Oyster Creek. [*Nuclear News*, 10/00/87, pp. 11 & 12, and 12/00/87, p. 109] ✓

12/31/87 During 1983-87, Oyster Creek spent $121.17/kW on major repairs and backfits. This was the second worst record of the nation's operating nuclear power plants. [*Nuclear Lemons*, 05/00/89, p. 27] ✓

10/16/90 A Government Accounting Office report identified use of counterfeit fasteners at Oyster Creek. Some of the fasteners were considered a significant safety hazard. [GAO/RCED-91-6, pp. 16-19] ✓

01/23/93 During refueling, reactor water temperatures rose 14°F above the maximum permitted by plant Technical Specifications. The utility was fined $50,000. [*The Nuclear Monitor*, 06/07/93, p. 3; and *NRC Information Notice 93-45*, p. 1]

03/29/93 The utility announced that, because its spent fuel pool was near capacity, beginning in 1996, fuel removed from the reactor would be placed in dry storage casks. [*The Nuclear Monitor*, 04/12/93, p. 8]

24. NINE MILE POINT 1 [11/09/69]

__**General Data**__

Owner Niagara Mohawk Power [DOE/OSTI-8200, p. II-3]

Location Scriba, NY [Ibid]

Reactor 610.0 MWe BWR ordered 10/00/63 [Ibid; and WASH-1208, p. 2]

First Electricity 11/09/69 [WASH-1208, p. 2]

Designer Niagara Mohawk Power [NUREG-0020, 03/00/90, p. 2-254]

Builder Stone & Webster [Ibid]

Cost to Build $150.5 million [DOE/EIA-0473, p. 15]

Licensing CP received 04/12/65; OL received 12/26/74. A "provisional" OL was received 08/22/69. [NUREG-1350, p. 78; and *AEC Fact Book*, p. E-28]

__**Operating Data**__

- As of 06/30/90, the plant's Cumulative SALP Rating was 1.81. Category 3 Findings were identified during seven of the nine SALP inspections performed since 05/00/81. As of 02/00/91, its SALP Rating was the fourth worst of America's operating nuclear power plants. Most of the Findings pertained to plant operations, maintenance, and QA verification. [NUREG-1214, p. 2-11; and *Nuclear Lemons*, 04/25/91, p. 8]
- As of 02/28/90, the plant had a Lifetime Capacity Factor of 54.7%, below the national average of 61.9%. Forced outages totalled 31,464 hrs (3.6 yrs) and on-line hrs totalled 112,103 (12.8 yrs). Forced outages were the worst of the eight oldest operating nuclear plants and, during 1989-1990, the fourth highest nationally. [NUREG-0020, 03/00/90, p. 2-252; and *Nuclear Lemons*, 04/25/91, p. 9]
- The Public Citizen, an organization founded by Ralph Nader, identified the plant as the sixth worst of 111 nuclear power plants operating in the U.S. during 1989-90. [*Nuclear Lemons*, 04/25/91, p. 5] ✓

__**Problems**__

02/00/70 The plant was down until 07/00/70 to repair the generator and cracks in core spray safe end nozzles. While the repairs were taking place, cracks were found in a thermal sleeve in the reactor. [*The New York Times*, 06/30/70, p. 34; *Nucleonics Week*, 05/14/70, p. 1; and WASH-1203-73, p. 47] ✓

03/00/72 The plant was down for two months to replace the reactor control rods and overhaul other plant equipment. [WASH-1203-73, p. 47]

08/24/73 Power was reduced by 10% until a solution could be found to fuel densification problems first noticed at Ginna during 05/00/72. Full power operation resumed 01/03/74. [*Nucleonics Week*, 08/30/73, p. 1; and *AEC Fact Book*, pp. E-49 & 52] ✓

09/21/74 Because of cracks found in Dresden 2 reactor coolant (RC) piping, the AEC ordered Nine Mile Point 1 shut down until its RC piping could be reexamined. [*The New York Times*, 09/22/74, pp. 1 & 34]

01/29/75 Because of cracks in Dresden 2 emergency core cooling (ECC) piping, the NRC ordered Nine Mile Point 1 shut down until its ECC piping could be reexamined. [*The New York Times*, 01/30/75, pp. 1 & 11]

04/00/75 The design of the containment drywell was questioned after testing of a scale model found that accident loads were much larger than used in original calculations. [*The Silent Bomb*, pp. 292-298]

03/22/76 Cracks and leaks were found in a six-inch pipe in the plant's reactor coolant water clean-up system. [*Nuclear News*, 05/00/76, p. 41]

00/00/79 Cracks were found in the steam generator's feedwater nozzles. [*Nuclear News*, 08/00/79, p. 28]

03/00/81 A reactor coolant pump failed and plant operators dumped tens of thousands of gallons of contaminated water into a room holding 150 barrels of high-level radioactive waste. Repairs to all five reactor coolant pumps took about one year. The barrels banged into each other and split open. The room was cleaned up during 1990 at a cost of $2.5 million. [*The New York Times*, 02/23/90, pp. B1 & B4; *The New York Times*, 02/24/90, p. A28; and *Nuclear News*, 05/00/82, p. 42] ✓

09/00/81 The utility was fined $50,000 for removing safety equipment from service on three occasions and, each time, violating plant Technical Specifications. [*Nuclear News*, 10/00/81, p. 39]

03/03/82 Cracks in reactor coolant (RC) pipe resulted in replacing all RC pipe and an NRC order to recheck RC pipe at nine other plants. [*1983 Nuclear Power Safety Report*, p. 1; and *Nuclear News*, 12/00/82, p. 43]

06/04/86 A robot, used to conduct surveillances in high-radiation areas of the plant, exploded injuring nine workers. [*Nuclear News*, 07/00/86, p. 34] ✓

04/29/87 After investigating a plant worker's allegations, the NRC fined the utility $50,000 for recurring QA violations that it attributed to a complacent management attitude. [*Nuclear Safety*, 10/00/87-12/00/87, p. 565]

12/00/87 During 1983-87, the plant spent $82.64/kW on major repairs and backfitting, the fifth most of any of the nation's operating nuclear power plants. Unfortunately, it was not enough. Beginning 12/00/87, the plant was shut down for three years. Initially the problem was excessive vibration in its feedwater system; however, once shut down, other technical and management problems came to light. [*Nuclear Lemons*, 05/00/89, p. 27; NUREG-0020, 03/00/90, pp. 2-252 & 253; *Nuclear News*, 09/00/90, pp. 33 & 34; and *The New York Times*, 02/23/90, p. B1] ✓

03/00/88 The utility was fined $100,000 for failing to detect weld defects during inservice inspection of piping. [*Nuclear News*, 05/00/88, p. 38] ✓

09/00/88 The plant was placed on the NRC's list of problem units because utility management was so concerned with bringing Nine Mile Point 2 on line, it neglected Unit 1. The plant was removed from the NRC's list during 06/00/91. [*Nuclear News*, 02/00/89, p. 29; and *USA Today*, 08/14/91, p. A3] ✓

10/16/90 The Government Accounting Office issued a report identifying use of counterfeit fasteners, pipe fittings, circuit breakers, and fuses at Nine Mile Point. Some of the fasteners were considered a significant safety hazard. [GAO/RCED-91-6, pp. 16-18] ✓

05/22/92 The utility was fined $200,000 for recklessly overriding automatic controls and inadequate maintenance of safety systems. [*Nuclear News*, 07/00/92, p. 28; and *Nuclear Safety*, 10/00/92-12/00/92, p. 608] ✓

11/20/92 The utility announced it may close the plant in early 1995 because of high operating and maintenance costs. [*The Nuclear Monitor*, 12/14/92, pp. 4 & 7; and *Nuclear News*, 01/00/93, p. 21] ✓

25. GINNA (also called BROOKWOOD) [12/02/69]

General Data

Owner Rochester Gas & Electric [DOE/OSTI-8200, p. II-5]
Location Ontario, NY [Ibid]
Reactor 470.0 MWe BWR ordered 08/00/65 [Ibid and WASH-1208, p. 2]
First Electricity 12/02/69 [WASH-1208, p. 2]
Designer Gilbert Associates [NUREG-0020, 03/00/90, p. 170]

Builder Bechtel [Ibid]

Cost to Build $64.9 million [DOE/EIA-0473, p. 15]

Licensing CP received 04/25/66; OL received 12/10/84. A "provisional" OL was received 09/19/69. [*AEC Fact Book*, p. E-29; and NUREG-1350, p. 74]

Operating Data

- As of 06/30/90, the plant's Cumulative SALP Rating was 1.62. Only one Category 3 Finding, pertaining to administrative controls, was identified during a 07/00/80 SALP inspection. [NUREG-1214, p. 2-4]
- As of 02/28/90, the plant's Lifetime Capacity Factor was 73.8%, the best of the nation's eight oldest operating nuclear power plants. Forced outages totalled 5,074 hrs (0.6 yrs) and on-line hrs totalled 137,229 (15.7 yrs). Forced outages were the second best of the nation's eight oldest operating nuclear power plants. [NUREG-0020, 03/00/90, p. 2-168]

Problems

05/00/68 Pressure grouting sections of the reactor containment shell resulted in cracking and buckling steel frames around both the personnel access and equipment hatch openings. Six months was spent redesigning and replacing the frames. [*AEC Fact Book*, p. E-22; and *AEC Speech*, 07/00/69, p. 15] ✓

00/00/71 The reactor core suffered flow-induced vibration damage. [*The Silent Bomb*, pp. 282-283] ✓

05/00/72 During reactor refueling, technicians noticed dozens of fuel rods were partially crushed, bent, or cracked. An investigation found that heat and radiation compressed fuel pellets. As the pellet compressed, they slipped down in the fuel rod leaving gaps of several inches between adjacent sections of pellets. [*Popular Science*, 09/00/73, p. 80; and *AEC Fact Book*, p. E-40] ✓

08/24/73 Because of fuel densification problems at Ginna, the AEC placed operating limits on 10 General Electric reactors including Dresden 2, Millstone 1, Nine Mile Point 1, and Oyster Creek. [*AEC Fact Book*, p. E49; and *Nucleonics Week*, 08/30/73, pp. 1 & 2] ✓

05/00/78 The NRC imposed a $24,000 fine for 68 instances of noncompliance with nuclear health safety procedures and regulations. [*Nuclear News*, 06/00/78, p. 56; and 12/00/78, pp. 31-32] ✓

07/00/79 Cracks were found in the steam generator's nozzles. [*Nuclear News*, 08/00/79, pp. 28 & 30]

01/25/82 The plant was down for 4 months and $10 million in repairs after a debris, left inside a steam generator during maintenance, severed one of its tubes. Five days later, a plant emergency was declared when a relief valve failed to close and some radioactive steam and 5000 gallons of contaminated water leaked out into the reactor building. This incident is generally considered the most serious at a U.S. nuclear power plant since the accident at Three Mile Island 2 in 03/00/79. [*The Wall Street Journal*, 05/25/82, p. 21; *Nuclear Age*, pp. 265 & 266; *1983 Nuclear Power Safety Report*, p. 6, and *The Truth About Chernobyl*, p. 71] ✓

10/16/90 A Government Accounting Office report identified counterfeit fasteners, pipe fittings, and circuit breakers at Ginna. Some of the fittings represented significant safety hazards. [GAO/RCED-91-6, p. 1] ✓

12/31/90 During 1989-90, the reactor scrammed eight times and other safety systems were activated seven times. Nationally, the plant had the seventh poorest record on reactor scrams (two/yr was average) and fourth poorest record on safety system actuations (1.35/yr was average). [*Nuclear Lemons*, 04/25/91, pp. 6 & 7] ✓

26. DRESDEN 2 [04/13/70]

General Data

Owner Commonwealth Edison [DOE/OSTI-8200, p. II-2]

Location Morris, IL [Ibid]

Reactor 772.0 MWe BWR ordered during 02/00/65. [Ibid and WASH-1208, p. 2]

First Electricity 04/13/70 [WASH-1208, p. 2]

Designer Sargent & Lundy [NUREG-0020, 03/00/90, p. 2-132]

Builder United Engineers & Constructors [Ibid]

Cost to Build $101.3 million [DOE/EIA-0473, p. 15]

Licensing CP issued 01/10/66; OL received 12/22/69. [NUREG-1350, p. 73]

Operating Data

- During 1989-1990, the plant was eleventh on the Public Citizen's list of worst U.S. operating nuclear power plants. The Public Citizen is an organization founded by Ralph Nader. [*USA Today*, 08/14/91, p. A3] ✓

- As of 12/31/89, Dresden 2 had more spent fuel in its storage pool than any other of the nation's 111 operating nuclear power plants. [*Nuclear Lemons*, 04/25/91, p. 10]
- As of 02/28/90, the plant's Lifetime Capacity Factor was 57.2% whereas the national average was 61.9%. Forced outages totalled 7,658 hrs (0.9 yrs) and on-line hrs totalled 126,171 (14.4 yrs). [NUREG-0020, 03/00/90, p. 2-130]
- As of 06/30/90, the plant's Cumulative SALP Rating was 1.89. Category 3 Findings were identified during six of the nine SALP inspections performed since 11/00/80. Most Findings pertained to problems with radiological controls and plant operations. [NUREG-1214, p. 2-47]
- In 1992, Dresden 2 was placed on the NRC's list of "problem plants." [*USA Today*, 12/02/92, p. 8A] ✓

Problems

06/05/70 Designers placed a safety valve in the wrong location. When a defective voltage meter sent out a bad signal, valves opened that should have closed; instrument cables buckled in overcrowded ducts; and a water level indicator gave a false reading. Operators allowed the reactor's water level to exceed safety margins and twice violated operating procedures, once putting ten times as much pressure on a vent as it was designed for. The emergency core cooling system was called on, however it was down for repairs. For several minutes, operators lost control of the reactor's cooling water system. Some damage occurred to the reactor core and contaminated water spilled into the reactor building; however, no radiation escaped the building. Three months was spent repairing the damage, revising operating procedures, and cleaning up contamination. [*Reader's Digest*, 06/00/72, pp. 97 & 98; *Popular Science*, 09/00/73, p. 81; and *The Silent Bomb*, p. 151] ✓

09/00/70 The plant was shut down until 12/00/70 to repair condenser tubes, feedwater pumps, the main transformer, and control rod drives. [WASH-1203-71, p. 52]

00/00/71 A defective water-level gauge resulted in over-filling the reactor and blow-down into the drywell. The resulting transient destroyed most of the core's monitoring cables and may have damaged the reactor support structure. [*The Silent Bomb*, pp. 196, 291, & 292; and *Chemtech*, 05/00/76, p. 309] ✓

00/00/72 Paint inside the plant's pressure-suppression pool failed and had to be removed and replaced with an inorganic zinc coating. [*Power Engineering*, 06/00/74, p. 46] ✓

08/24/73 Power was reduced by 8% until fuel densification problems similar to those at the Ginna plant during 05/00/72 could be solved. Full power operation resumed 01/03/74. [*Nucleonics Week*, 08/30/73, p. 1; and *AEC Fact Book*, pp. E-49 & 52] ✓

09/21/74 Hairline cracks were found in 4-inch bypass lines in the reactor coolant (RC) piping system. Coolant was dripping from the cracks at 5 gallons/minute. Similar cracks had been found in RC bypass lines at Quad Cities 2 and Millstone 1. The AEC ordered 20 other plants shut down to determine whether they also had cracked bypass lines. Initially, no cracks were detected; however, in 12/00/74, cracks were found in RC bypass lines at Dresden 2, Quad Cites 1&2, and Monticello. [*The New York Times*, 09/22/74, pp. 1 and 34; *1975 Annual NRC Report*, pp. 75-76; and *The Silent Bomb*, p. 151] ✓

01/25/75 The wrong control rods were removed from the reactor. [*1975 Annual NRC Report*, p. 96] ✓

01/28/75 Small cracks were found in two 10-inch emergency core cooling (ECC) system lines. Similar cracks had been found in ECC lines at Quad Cities 2 and Peach Bottom 3. The NRC ordered 23 plants shut down to determine whether they also had cracked ECC lines. No new cracks were found. The shutdown cost utilities $30 million. [*The New York Times*, 01/30/75, pp. 1 & 11; *The Washington Post*, 03/07/75, p. C6; *1975 Annual NRC Report*, p. 97; *Nucleonics Week*, 02/27/75, p. 3; and *The Silent Bomb*, p. 151] ✓

04/00/75 The design of the containment drywell was questioned after testing of a scale model found that accident loads were much larger than used in original calculations. [*The Silent Bomb*, pp. 292-298]

05/00/75 A containment isolation valve failed to close because of metal filings and missing insulation in its electrical components. [*Nugget File*, p. 55]

03/25/76 A leak and crack was found in a 14-inch diameter pipe in the plant's high-pressure reactor coolant system. [*Nuclear News*, 05/00/76, p. 41]

08/00/77 Makeup demineralizer tanks overflowed and acid fumes were drawn into the main control room's ventilation ducts. Operators remained in the control room by donning respirators. The tanks were moved and ventilation system modified to prevent the possibility of future recurrences. [*Nuclear News*, 11/00/78, p. 39] ✓

10/07/80 The utility was fined $40,000 after, on 08/08/80, the NRC found two control room operators asleep while on duty. [*Nuclear News*, 10/00/80, p. 38; and *Nuclear News*, 11/00/80, pp. 29-30] ✓

05/05/81 A plant worker received about 21 rems during removal of concrete shielding over the reactor - the second largest dose ever received at a commercial plant. The utility was fined $75,000. [*Nuclear News*, 04/00/81, pp. 52 & 53; 10/00/81, p. 39; and 08/00/82, p. 51] ✓

12/03/82 Floodwaters, exceeding the "Maximum Probable Flood", brought the Illinois River into the plant's fire protection water pumphouse. The waters receded without damaging electrical equipment needed to remove residual heat from the reactor after it is shut down. [*1983 Nuclear Power Safety Report*, p. 3] ✓

12/18/83 The NRC fined the utility $50,000 for quality assurance deficiencies in vacuum breaker seal testing and installation. [*Nuclear News*, 12/00/83, p. 129]

06/07/84 The utility was fined $140,000 for violating security regulations including an incident involving a guard who turned of the plant's security system in order to climb a fence. [*Nuclear News*, 06/00/84, p. 188] ✓

02/00/87 Six loose bolts were found on an emergency diesel generator, one on 02/17/87, four on 02/24/87, and one on 02/25/87. The NRC and FBI were notified of possible sabotage. [*Nuclear News*, 05/00/87, p. 26]

05/00/87 The utility was fined $50,000 for an unsecured path through a security fence. It had been in use for seven years. [*Nuclear News*, 07/00/87, p. 30; and *Nuclear Safety*, 10/00/87-12/00/87, pp. 566-567] ✓

12/31/90 During 1989-90, Dresden 2 had five significant operating events, more than any other operating nuclear power plant. "Significant events" are those that are capable of damaging safety equipment. [*Nuclear Lemons*, 04/25/91, p. 8] ✓

05/17/91 The utility was fined $100,000 for, over a two year period, failing to check, identify, and repair a defective containment leak test valve. [*Nuclear News*, 06/00/91, p. 36] ✓

27. ROBINSON 2 [09/26/70]

General Data

Owner Carolina Power & Light [DOE/OSTI-8200, p. II-3]
Location Hartsville, SC [Ibid]
Reactor 569.0 MWe PWR ordered 01/00/66 [Ibid and WASH-1208, p. 2]
First Electricity 09/26/70 [WASH-1208, p. 2]
Designer/Builder Ebasco [NUREG-0020, 03/00/90, p. 368]
Cost to Build $76.4 million [DOE/EIA-0473, p. 15]
Licensing CP received 04/13/67; OL received 09/23/70 [NUREG-1305, p. 82]

Operating Data

- As of 06/30/90, the plant's Cumulative SALP Rating was 1.81. Only one Category 3 Finding was identified since its first SALP inspection during 01/00/81. The Finding pertained to radiological controls. [NUREG-1214, p. 2-33]
- As of 02/28/90, the plant's Lifetime Capacity Factor was 60.6%. Forced outages totalled 15,384 hours (1.8 yrs) and the plant was on-line a total of 114,262 hours (13.0 yrs). During 1989-90, the plant was down 23.2% of the time due to forced outages. This was the ninth highest forced outage rate in the nation. [NUREG-0020, p. 366; and *Nuclear Lemons*, 04/25/91, p. 10]

Problems

06/19/71 The utility was ordered to reduce the reactor's temperature to 2300°F to meet new AEC criteria for emergency core cooling systems. [*Nucleonics Week*, 06/24/71, pp. 1-3]

08/00/71 The plant was restarted after major turbine repairs. During 03/00/71, a bearing failed that was replaced. After restarting, the turbine suffered vibration damage. [WASH-1203-73, p. 49] ✓

07/00/74 A worker ingested considerable radioactive dust when he opened a vacuum cleaner that had been used to remove dirt from inside the plant's steam generators. [*Nugget File*, pp. 48&49] ✓

05/02/75 132,500 gallons of contaminated water leaked into the reactor building when seals failed on a reactor coolant pump. The leak occurred because plant operators activated a pump that was still out of service for repairs. [*1975 Annual NRC Report*, pp. 94-95] ✓

00/00/79 Cracks were found in the steam generator's feedwater nozzles. [*Nuclear News*, 08/00/79, p. 28]

05/12/81 The utility was fined $40,000 after three workers receiving excessive radiation exposures due to the improper placement of film badges. [*Nuclear News*, 07/00/81, p. 42]

08/15/81 The utility was fined $50,000 after an employee received an excessive radiation exposure. The fine considered previous excessive exposures during 1981. [*Nuclear News*, 01/00/82, p. 132]

12/03/81 About 1070 (11%) of the plant's steam generator tubes were plugged to prevent leaking. While restarting the plant, a pump gasket failed and 1500 gallons of water spilled into the plant's auxiliary building. [NUREG-0886, p. 19; and *Nuclear News*, 01/00/82, p. 54] ✓

10/01/83 The plant was shut down until 04/09/84 to replace, at a cost of $86.8 million, its steam generators and stainless steel piping suffering from microbiologically induced corrosion. [*Nuclear Age*, p. 312; and *Nuclear News*, 06/00/83, p. 50] ✓

11/00/87 The utility was fined $50,000 after the NRC found no evidence of procedures for safely shutting the reactor down in the event of a fire. [*Nuclear News*, 01/00/88, p. 30] ✓

12/31/87 During 1983-87, $80.31/kW was spent on major repairs and backfitting, the sixth most of U.S. operating nuclear power plants. [*Nuclear Lemons*, 05/00/89, p. 27] ✓

06/16/88 The NRC fined the utility $450,000 for extensive failures in documentation and procedures for qualifying plant electrical equipment. The fine was one of the largest ever by the NRC. [NUREG-0940, p. 3; and *Nuclear News*, 08/00/88, pp. 36 & 38] ✓

10/16/90 A Government Accounting Office report identified use of counterfeit fasteners at the plant. Some of the fasteners were considered to pose a significant safety hazard. [GAO/RCED-91-6, pp. 16-18] ✓

12/17/91 The utility was fined $37,500 because of multiple design control deficiencies including errors in calculations. [*Nuclear Safety*, 04/00/92-06/00/92, p. 289]

08/24/92 The plant was briefly shut down to remove pieces of plastic accidently left in safety injection piping following completion of modifications two months earlier. The problem was discovered when the plastic blocked the flow of water during safety injection pump tests. [*NRC Information Notice 92-85*, pp. 1 & 2]

28. POINT BEACH 1 [11/06/70]

General Data

Owner Wisconsin Electric Power [DOE/OSTI-8200, p. II-4]
Location Two Creeks, WI [Ibid]
Reactor 485.0 MWe PWR ordered 02/00/66 [Ibid and WASH-1208, p. 2]
First Electricity 11/06/70 [WASH-1208, p. 2]
Designer/Builder Bechtel [NUREG-0020, 03/00/90, p. 330]
Cost to Build $60.6 million [DOE/EIA-0473, p. 15]
Licensing CP received 07/19/67; OL received 10/05/70 [NUREG-1350, p. 81]

Operating Data

- As of 06/30/90, the Cumulative SALP Rating was 1.60, one of the best in the nation. Only one Category 3 Finding was identified during six SALP inspections performed since 09/00/82. The Finding pertained to the plant's fire protection systems. [NUREG-1214, p. 2-56]
- As of 02/28/90, the plant's Lifetime Capacity Factor was 72.8%, well above the national average. Forced outages totalled 2,464 hours (0.3 yrs) and the plant was on-line a total of 136,955 hours (15.6 yrs). [NUREG-0020, 03/00/90, p. 2-328]

Problems

03/00/69 The reactor vessel rolled over on its transporter as it was being moved into the reactor building. Two of its nozzles were damaged. [*Nucleonics Week*, 03/06/69, p. 3] ✓

03/00/70 A pipe bomb, filled with dynamite, was found at the plant. [*CEP Report*, p. 35; and *Nuclear News*, 05/00/76, p. 38]

04/00/71 Valves in both containment sumps were installed horizontally instead of vertically. Tests found the valves would not operate. [*Nugget File*, p. 30] ✓

10/24/72 Seventy (70) collapsed fuel rods were found in the reactor during refueling. [*Nucleonics Week*, 10/26/72, p. 1] ✓

05/03/73 Refueling turned into a five month outage for turbine and steam generator repairs. [*The Wall Street Journal*, 05/03/73, p. 1] ✓

02/26/75 The plant was shut down for several weeks after a steam generator tube ruptured. Contaminated water leaked into the steam generator at up to 125 gpm for 45 minutes. [*1975 Annual NRC Report*, pp. 91-92]

10/09/82 The plant shut down for three months to install sleeves in leaking steam generator tubes. [*Nuclear News*, 01/00/82, p. 54] ✓

05/00/90 The utility was fined $50,000 because, during steam generator repairs, the reactor coolant temperature dropped 140°F in one hour, 40°F more than permitted. [*Nuclear News*, 10/00/92, p. 29] ✓

10/16/90 The Government Accounting Office issued a report identifying counterfeit fasteners at Point Beach. Some of the fasteners were considered a significant safety hazard. [GAO/RCED-91-6, pp. 16-18] ✓

29. MILLSTONE 1 [11/29/70]

General Data

Owner Northeast Nuclear Energy [DOE/OSTI-8200, p. II-3]
Location Waterford, CT [Ibid]
Reactor 654.0 MWe BWR ordered 09/00/65 [WASH-1208, p. 2]
First Electricity 11/29/70 [Ibid]
Designer/Builder Ebasco [NUREG-0020, 03/00/90, p. 2-238]
Cost to Build $92.0 million [DOE/EIA-0473, p. 15]
Licensing CP received 05/19/66; OL received 10/31/70 [NUREG-1350, p. 77]

Operating Data

- On 08/13/85, the plant set a U.S. record for continuous operation, 374 consecutive days. [*Nuclear News*, 09/00/85, p. 114]
- During 1989-90, the plant had more significant operating events than any operating nuclear power plant except Dresden 2. [*Nuclear Lemons*, 04/25/91, p. 8] ✓
- During 1984-88, the plant shipped off-site more low-level waste than any other operating nuclear power plant. [Ibid, p. 10]
- As of 12/31/89, the plant was holding 340.6 metric tons of spent fuel, the third most of the nation's operating nuclear power plants. [Ibid]
- As of 02/28/90, the plant's Lifetime Capacity Factor was 70.6%. Forced outages totalled 6,704 hours (0.8 yrs) and the plant was on-line a total of 130,493 hours (14.9 yrs). [NUREG-0020, 03/00/90, p. 2-236]
- As of 06/30/90, the plant's Cumulative SALP Rating was 1.37, one of the best in the nation. Three Category 3 Findings were identified during two of eight SALP inspections performed since 10/00/80. Two Findings pertained to radiological controls and one to security. [NUREG-1214, p. 2-10]

Problems

12/00/70 A wiring error prevented inserting control rods in the reactor. [*Nugget File*, p. 27] ✓

08/25/72 A plane crashed 1000 yards short of the reactor, knocking out lines supplying power to the plant's safety systems. [*Nuclear Witnesses*, p. xxii; *Nugget File*, p. 39; and *The New York Times*, 08/26/72, p. 28]

09/01/72 The plant shut down until 03/00/73 due to corrosion from seawater that seeped into the reactor, primary coolant system, and condenser. [*Nuclear Age*, p. 233; and *Chemtech*, 05/00/76, p. 309] ✓

08/24/73 The AEC ordered the plant to keep its reactor temperature below 2300°F in response to fuel densification problems at Ginna. Power did not need to be reduced. [*Nucleonics Week*, 08/30/73, p. 1]

09/17/74 Cracks were found in a 4-inch bypass line in the reactor coolant (RC) piping system. Cracks were also found in RC bypass lines at Dresden 2 and one other plant. This resulted in the AEC ordering 20 other nuclear power plants to re-examine their RC bypass lines. [*The New York Times*, 09/22/74, pp. 1 & 34; and *1975 NRC Annual Report*, p. 97] ✓

01/29/75 Because of cracks found in Dresden 2 emergency core cooling (ECC) piping, the NRC ordered Millstone 1 shut down until its ECC piping could be re-examined. [*The New York Times*, 01/30/75, pp. 1 & 11]

03/27/75 1200 personnel working on Millstone 2&3 construction were briefly evacuated from the plant when Millstone 1 operators accidently mixed contaminated water with clean water. [*Unacceptable Risk*, p. 39]

02/00/76 The plant's fire water system was accidently activated. Water shorted out the plant's power, tripping the reactor. Defective residual heat removal piping cracked and radioactive steam escaped into the reactor building and over an acre of land adjacent to the building. [*Nugget File*, p. 67] ✓

11/12/76 The wrong control rods were withdrawn from the reactor while it was being refuelled. Twice the reactor started up and then scrammed. The plant was shut down until 12/03/76, the utility was fined $15,000, and a plant operator temporarily suspended. [*1977 Annual NRC Report*, p. 99; *Nuclear News*, 01/00/77, p. 38; *Nuclear Stakes*, p. 77; and *Nuclear News*, 02/00/77, p. 32] ✓

07/14/77 The NRC ordered the plant shut down to reinforce electrical cable splices to withstand a loss-of-coolant accident. The work was completed in five days. [*Nuclear News*, 08/00/78, pp. 20 & 135]

10/27/77 Dr. Sternglass, a Pittsburgh college professor, told Congress that, during 1974-75, the plant released 2,970,000 curies of radioactive gas, more radioactivity than ever before released in the history of nuclear energy. His statistics greatly alarmed the NRC and Congress. A subsequent investigation found the high readings were due to weapons testing fallout. Nevertheless, the utility installed a new $15 million gas treatment system which became operational on 05/23/78. [*Nuclear Witnesses*, p. 75; *Nuclear News*, 02/00/78, p. 34; and *Nuclear News*, 07/00/78, p. 38] ✓

12/13/77 Two off-gas explosions occurred within three hours of each other. One employee required hospitalization after being thrown 40 feet by the blast. Plant repairs took a month. [*Nuclear News*, 01/00/78, p. 22; and *Nuclear Stakes*, p. 77] ✓

03/30/90 The utility was fined $3,750 for failing to adequately package contaminated tools before shipping the tools to another utility. [NUREG-0940, pp. 6-7]

10/04/90 Operator error and heavy seas caused three of five circulating water intake screens to collapse and cavitation damage to two intake pumps. [*NRC Information Notice 92-49*, p. 3] ✓

10/16/90 The General Accounting Office issued a report identifying use of counterfeit fasteners, pipe fittings, and fuses at Millstone. [GAO/RCED-91-6, p 16]

09/31/91 The plant began shutting down after 8 of 20 plant operators failed their NRC requalification exams. [*The Nuclear Monitor*, 10/21/91, p. 6; and *Nuclear Safety*, 04/00/92-06/00/92, p. 284] ✓

04/01/92 NRC inspectors found gaskets and seals missing from barriers that protected electrical switchgear from nearby steam pipes. [*NRC Information Notice 92-52*, p. 1]

05/00/93 The utility was fined $100,000 for harassing Paul Blanch, a supervisor who raised concerns about the reliability of a reactor vessel water indicator. Subsequent tests found readings could be distorted by as much as 27 feet. [*Nuclear News*, 06/00/93, p. 31; and *The Nuclear Monitor*, 06/07/93] ✓

30. MONTICELLO [03/05/71]

General Data

Owner Northern States Power [DOE/OSTI-8200, p. II-3]
Location Monticello, MN [Ibid]
Reactor 536.0 MWe BWR ordered 04/00/66 [WASH-1208, p. 2]
First Electricity 03/05/71 [Ibid]
Designer/Builder Bechtel [NUREG-0020, 03/00/90, p. 2-250]
Cost to Build $88.8 million [DOE/EIA-0473, p. 15]
Licensing CP received 06/19/67; OL received 09/08/70 [WASH-1208, p. 2; and *AEC Fact Book*, p. E-31]

Operating Data

- As of 06/30/90, the plant had a Cumulative SALP Rating of 1.52. Three Category 3 Findings were identified during eight SALP inspections conducted since 01/00/81. The Findings pertained to security, radiological controls, and emergency preparedness. [NUREG-1214, p. 2-53]
- As of 02/28/90, the plant had a Lifetime Capacity Factor of 69.9%. Forced outages totalled 1,651 hrs (0.2 yrs) and the plant was on-line a total of 126,768 hrs (14.5 yrs). [NUREG-0020, 03/00/90, pp. 2-248]
- On 03/31/86, the NRC announced a reduction in oversight of Monticello because of the plant's "continuing record of superior regulatory performance." [*Nuclear News*, 04/15/86, p. 22A]

Problems

11/19/71 A radioactive waste storage tank overflowed and 53,000 gallons of contaminated water spilled into the Mississippi River. Of this, 10,000 gallons entered the City of Minneapolis drinking water system. [*The Truth About Chernobyl*, p. 17; and *Nucleonics Week*, 11/27/71, p. 3] ✓

08/24/73 The AEC ordered the plant to keep its reactor temperature below 2300°F in response to fuel densification problems at Ginna. Power did not need to be reduced. [*Nucleonics Week*, 08/30/73, p. 1]

07/00/74 The plant experienced its third hydrogen recombiner gas explosion in as many months. The explosions were attributed to migration of the recombiner's catalyst and sparks from a faulty inlet flow control valve. [*Nuclear News*, 03/00/77, p. 41] ✓

09/21/74 After finding cracks in Dresden 2 reactor coolant piping, the AEC ordered Monticello shut down until its RC piping could be re-examined. No cracks were found. [*The New York Times*, 09/22/74, pp. 1 & 34; and *1975 Annual NRC Report*, p. 97]

01/29/75 The NRC ordered Monticello and 22 other plants shut down to look for cracks in emergency core cooling (ECC) piping. During 12/00/74, cracks had been found in ECC piping at Monticello, Dresden 2, and two other plants. No new cracks were found during the mandated re-examination. [*The New York Times*, 01/30/75, pp. 1 & 11; and *1975 Annual NRC Report*, pp. 90 & 97] ✓

07/30/81 About 1,500 gallons of contaminated water leaked from radioactive waste storage tanks and some of the waste drained into the Mississippi River. [*Nuclear News*, 09/00/81, p. 85] ✓

12/00/81 The utility was fined $20,000 for storing 28 drums of low-level radioactive waste at a truck rental facility. [*Nuclear News*, 01/00/82, p. 132]

12/31/87 During 1983-87, $86.95/kW was spent on major repairs and backfitting, the third most of operating nuclear power plants. [*Nuclear Lemons*, 05/00/89, p. 27] ✓

CONTENTS

NOTES

1. Documents referenced in this Supplement are listed in Supplement IX.
2. Plants are listed by the date they started producing electricity with the oldest being listed first.
3. Problems followed by a check (✓) are "Major Problems" as defined in Paragraph 6.2.1(c) of the main body of this report.

1. *RANCHO SECO [10/13/74]*

General Data

Owner Sacramento Municipal Utility District [DOE/OSTI-8200, p. II-5]

Location Clay Station, CA [Ibid]

Reactor 873.0 MWe PWR ordered 08/00/67 [Ibid and WASH-1208, p. 4]

First Electricity 10/13/74 [NUREG-0020, 03/00/90, p. 2-358]

Designer/Builder Bechtel [Ibid]

Cost to Build $338.3 million [DOE/EIA-0473, p. 15]

Licensing Data CP received 10/11/68; OL received 08/16/74 [NUREG-1350, p. 82]

Date Closed 06/07/89 in response to a Sacramento County public referendum. [NUREG-0020, 03/00/90, p. 2-357]

Operating Data

- The plant's Cumulative SALP Rating was 2.00. Twelve Category 3 Findings were identified during seven SALP inspections, the first of which was performed in 1980. The Findings were spread across eight of eleven characteristics on the NRC inspection checklist. The most frequently cited Findings were in plant operations, radiological controls, and quality programs. [NUREG-1214, p. 2-71]
- The plant's Lifetime Capacity Factor was 36.1%. Forced outages totalled 43,288 hours (4.9 yrs) and the plant was on-line a total of 57,810 hours (6.6 yrs). [NUREG-0020, 03/00/90, p. 356]
- On May 22, 1986, the NRC identified the plant as one of 16 of the nation's worst nuclear power plants. [*The New York Times*, 07/16/86, p. A11] ✓
- During 1987-88, the plant was ranked as the nation's ninth worst operating nuclear power plant by Public Citizen, an organization founded by Ralph Nader. [*Nuclear Lemons*, 05/00/89, p. 4] ✓

Decommissioning The plant's spent fuel storage pool currently holds 403 assemblies. During 11/00/89, the utility began transferring fuel from the reactor building to an on-site storage pool. Dismantling the plant, which may not begin for another 50 years, is expected to cost $210 million. [SR/CNEAF/92-01, p. 146; and GAO/RCED-90-208, p. 24]

Problems

07/00/75 The reactor's control rod drives were energized without activating their cooling water system. All 69 drive motors overheated. Repairs took three months. [*The Silent Bomb*, p. 196; and *Nugget File*, p. 58] ✓

11/00/75 Several containment spray nozzles had been rendered inoperable by a painting contractor who placed masking tape over the nozzles and then forgot to remove the tape. [*Nugget File*, p. 59] ✓

03/20/77 Plant instrument readings were lost for about 70 minutes due to a short circuit in the main control room panel. During the ensuing black-out, reactor coolant temperatures fell 270°F, nearly cracking the vessel. The short circuit occurred when a plant operator, who was replacing a burned out light, accidently dropped a replacement bulb into the panel. [*Nuclear Age*, p. 241; and *Normal Accidents*, pp. 44 & 45] ✓

07/00/78 The utility was ordered to reduce power by 25% until modifications were made to its Emergency Core Cooling System (ECCS). The NRC found an error in the plant's original analyses. New calculations found a small pipe break would not automatically activate the ECCS. [*Nuclear News*, 06/00/78, p. 10] ✓

08/00/78 Serious shutdown problems were experienced following a turbine trip. [*Nuclear Age*, p. 218]

10/00/78 Westinghouse was awarded $3.3 million in a lawsuit against the utility. Six months after start-up, stress corrosion cracked the turbine. Repairs took until early 1976. Then, during 03/00/76, the plant shut down until 10/00/76 because insulation on generator coils melted. The utility failed to pay for $6.7 million in repairs. Westinghouse sued. [*Engineering News-Record*, 10/05/78, p. 49] ✓

02/00/80 During a lift in the reactor building, a two-ton cask fell when its supporting cable broke. The cask missed the reactor by inches. Two weeks later, in violation of NRC requirements, the same cable and crane were used to lift a seven-ton load. [*Nuclear Age*, p. 309] ✓

04/04/80 The utility was fined $25,000 for improperly aligned valves in the plant's emergency core cooling system. [*Nuclear News*, 05/00/80, pp. 34 & 35]

02/00/82 The utility was fined $120,000 for briefly deactivating two principal safety systems. [*Nuclear News*, 08/00/82, p. 50] ✓

10/02/85 The reactor was cooled too rapidly. The plant was shut down for the rest of the month to evaluate the cause and take corrective action. [*Nuclear News*, 02/00/86, p. 31] ✓

12/26/85 A station-wide power failure resulted in scramming the reactor. Valves that should have closed couldn't because they hadn't been lubricated since initially installed. The reactor began cooling off too fast and operators couldn't figure out how to slow the drop. The control room supervisor took charge and sent workers into the reactor building to close the valves manually. Eventually the drop was brought under control; however, not before 1,200 gallons of contaminated water spilled into the reactor building basement. A subsequent NRC study identified five violations contributed to the incident and imposed a $375,000 fine. The plant was down until 03/30/88. During the 27 month outage, 400 plant modifications were completed at a cost of $400 million not including $200 million for replacement electricity. [*Nuclear News*, 12/00/86, p. 36; *Nuclear News*, 07/00/87, p. 38; *Nuclear News*, 02/00/88, p. 35; *Nuclear News*, 04/15/88, p. 12A; *The New York Times*, 06/06/88, p. D7; and *The Wall Street Journal*, 10/01/87, p. 6; and *Nuclear Safety*, 04/00/87-06/00/87, pp. 254-255] ✓

00/00/86 Plant personnel were arrested for drug abuse. Studies indicated that workers may have made serious mistakes while under the influence of drugs. [*The Wall Street Journal*, 10/01/87, p. 6] ✓

09/00/87 The utility tried selling the plant. Pacific Gas & Electric proposed buying and then closing the plant. Duke Power, Quadrex, and a Bechtel/B&W team proposed buying and operating the plant. [*Nuclear News*, 10/00/87, p. 21; *Nuclear News*, 02/00/88, p. 36; *Nuclear News*, 09/00/88, p. 35; and *Nuclear News*, 05/00/89, pp. 27 & 28] ✓

11/00/87 In two separate incidents, about 10,000 gallons of radioactive waste water were accidently discharged into a nearby creek. [*Nuclear Age*, p. 331] ✓

04/07/89 The NRC and utility met to discuss recent incidents including boiling a steam generator dry and overpressurizing the Auxiliary Feedwater System. Also discussed was an Institute of Nuclear Power Operations letter urging management reforms prior to restarting the plant. [*Nuclear News*, 05/00/89, pp. 27 & 28] ✓

10/16/90 The Government Accounting Office issued a report identifying counterfeit fasteners, pipe fittings, circuit breakers, and fuses at Rancho Seco. [GAO/RCED-91-6, p. 16]

2. *TROJAN [05/20/76]*

General Data

Owner Portland General Electric [DOE/OSTI-8200, p. II-6]

Location Prescott, OR [Ibid]

Reactor 1075.0 MWe PWR ordered 11/00/68 [WASH-1206, p. 5]

First Electricity 05/20/76 [NUREG-1350, p. 85]

Designer/Builder Bechtel [Ibid]

Cost to Build $443.1 million [DOE/EIA-0485, p. 109]

Licensing Data

- CP received 02/08/71, OL received 11/21/75 [NUREG-1350, p. 85]
- Over its operating life, Trojan received about $900,000 in NRC fines -- $200,000 more than the national average for the time period. [*Los Angeles Times*, 11/01/92, p. D8; and DOE/EIA-0547, pp. 6 & 8]

Date Closed 11/09/92 [*The Energy Daily*, 01/06/93, p. 2]

Operating Data

- As of 06/30/90, the plant's Cumulative SALP Rating was 1.80, about average. Six Category 3 Findings were identified during the ten SALP inspections performed since 10/00/80. Three Findings pertained to QA matters. The other three concerned security, fire protection, and operating procedures. [NUREG-1214, p. 2-73]
- The plant's Lifetime Capacity Factor was 52%, well below the national average. Over its 16 year operating life, its forced outage rate was 13.1% (2.16 years). [*Nuclear News*, 09/00/92, p. 25; and *Nuclear Safety*, 04/00/82-06/00/92, p. 274]

Decommissioning Costs are expected to total $488 million. [*The Wall Street Journal*, 01/05/93, p. A4] ✓

Problems

10/00/74 During preoperational testing, eleven 48 volt relays were found that had incorrectly been labelled as 125 volt relays by the manufacturer. [*Nugget File*, p. 53] ✓

01/00/76 For three days the plant operated without steam sensors that had inadvertently not been reactivated following maintenance. [*Nugget File*, p. 59]

04/00/76 Plant personnel continued operating the reactor for 2½ hours following activation of alarms signalling the need to shut the reactor down. [*Nugget File*, p. 68] ✓

06/00/76 After being on line for two weeks, the plant was shut down for several weeks to repair a defective generator grounding system. [*Nuclear News*, 12/00/76, p. 96]

11/00/76 The state of Oregon sued the utility for discharging heated water into the Columbia River without having a QA Program for controlling and monitoring such thermal discharges. Such a QA Program was agreed to during a meeting with the state in early 1975. [*Nuclear News*, 10/00/76, p. 35] ✓

10/10/77 A bomb exploded at the plant's visitor center. Though no one was injured, damage to the building totalled $13,500. [*Nuclear News*, 12/00/77, pp. 38 & 39] ✓

05/26/78 The NRC ordered the plant to remain shut down, following refueling, until its control room walls were reinforced to withstand a design-basis earthquake. The plant returned to service on 01/02/79. The utility sued Bechtel, the original designer of the control room, for $75 million in damages. Bechtel counter-sued for $108 million. The suits were settled out-of-court during 03/00/81. [*Nuclear News*, 08/00/78, pp. 32 & 33; *Nuclear News*, 02/00/79, p. 34; and *Nuclear News*, 04/15/81, p. 96A] ✓

07/25/78 The utility was fined $20,500 for a radiation exposure incident. One worker received 27 rem and the other 17 rem. This was far more than the 3 rem/quarter allowed, and the 27 rem dose was the largest in the history of licensed nuclear power. [*Nuclear News*, 09/00/78, p. 55; 02/00/79, p. 46; and 04/00/81, p. 53] ✓

03/00/79 The utility permitted photographs by a movie studio of the inside of the plant which were then used to build sets, including a replica control room, for the anti-nuclear hit, *The China Syndrome*. [*Nuclear News*, 04/00/79, p. 24; and *Nucleonics Week*, 01/11/79, p. 8] ✓

11/08/79 Eleven (11) plant guards were arrested for drug trafficking. Following the arrests, the NRC began requiring drug and alcohol addiction testing of nuclear power plant guards. [*Nuclear News*, 01/00/80, p. 44; and *The New York Times*, 11/24/79, p. 10] ✓

06/00/82 The NRC imposed a $60,000 for disabling an emergency diesel generator and not testing the operability of the plant's two other emergency diesel generators. [*Nuclear News*, 07/00/82, p. 36]

09/29/83 The utility was fined $100,000 for failure to have required fire protection plans, procedures, and materials. [*Nuclear News*, 11/00/83, p. 73] ✓

03/00/86 The NRC fined the utility $100,000 for closing a Residual Heat Removal System valve, when it should have been left open, during plant operation and for improperly inspecting electrical cable splices during plant maintenance. [*Nuclear News*, 04/00/86, pp. 38 & 39; and *Nuclear News*, 12/00/86, p. 36] ✓

04/09/87 The NRC imposed a $50,000 fine for failing to detect and control the dispersion of highly radioactive dust throughout the reactor building. [*Nuclear News*, 08/00/87, p. 35]

05/00/89 The utility was fined $75,000 for failing to control design changes and the quality of materials used in plant modifications. [*Nuclear News*, 06/00/89, p. 33] ✓

08/00/89 NRC inspectors found two of the plant's emergency core cooling sumps clogged with up to 14 years of accumulated debris. The utility was fined $280,000. [*Nuclear News*, 12/00/89, p. 28] ✓

03/00/91 The plant was down for 11 months to repair steam generator tubes. The cost was $45 million not including $67 million for replacement power. [*Los Angeles Times*, 11/01/92, p. D1] ✓

08/10/92 The utility announced it would be closing the plant in 1996, because least-cost studies had found it would be cheaper than spending $200 million to replace its steam generators and complete other modifications required to keep the plant in operation. [*Nuclear News*, 09/00/92, p. 25]

11/09/92 The plant was forced to shut down because of new steam generator tube leaks. [*The Energy Daily*, 01/06/93, p. 2]

02/17/93 The utility sued Westinghouse claiming the manufacturer knew, as early as 1968, that its steam generator tubes were susceptible to corrosion and cracking and would need to be replaced within the 40-year life of the plant. [*Nuclear News*, 04/00/93, p. 27]

3. FORT ST. VRAIN [12/11/76]

General Data

Owner Public Service Company of Colorado [DOE/OSTI-8200, p. III-1]
Location Platteville, CO [Ibid]
Reactor 330.0 MWe HTGR ordered 03/00/65 [WASH-1208, p. 2]
First Electricity 12/11/76 [NUREG-1350, p. 90]

Designer Sargent & Lundy [WASH-1208, p. 2]
Builder Ebasco [NUREG-0020, 09/00/89, p. 2-168]
Cost to Build $274.1 million [DOE/EIA-0473, p. 15]
Licensing Data
- CP received 09/00/68; OL received 12/21/73 [WASH-1208, p. 2; and NUREG-1350, p. 90]
- During 1958, the AEC named Fort St. Vrain one of five new nuclear power plants eligible for special U.S. Government financing and other assistance. [DOE/MA-0152, p. 39]

Date Closed 08/18/89 [SECY-90-421, p. 3]
Operating Data
- The plant's Cumulative SALP Rating was 2.07. Category 3 Findings were identified during every one of eight SALP inspections dating back to 10/00/80. The 17 Category 3 Findings covered seven of the eleven NRC checklist characteristics. The most frequently cited Findings were in plant operations, maintenance, and licensing. [NUREG-1214, p. 2-64]
- The plant's Lifetime Capacity Factor was 14.7%, the second worst of plants operating during the 1970s and 1980s. Forced outages totalled 42,684 hours (4.9 yrs) and the plant was on-line a total of 40,532 hrs (4.6 yrs). [NUREG-0020, 09/00/89, p. 2-166; and *1984-85 Nuclear Power Safety Report*, p. D2]
- On 05/22/86, the NRC identified the plant as one of the 16 of the nation's worst nuclear power plants. [*The New York Times*, 07/16/86, p. A11] ✓

Decommissioning A total of 726 spent fuel assemblies were sent to Idaho National Engineering Laboratory. There are still 1428 assemblies at the plant, 504 in its storage pool and 978 in the reactor. An independent spent fuel storage facility is being built at the plant at a cost of $81 million to hold the assemblies pending a decision on their final disposal. Dismantling the plant is expected to be completed by 1997 and cost $124 million. [SR/CNEAF/92-01, p. 177; *Nuclear News*, 01/00/93, p. 23; and GAO/RCED-90-208, p. 23] ✓

Problems

06/00/75 Water seeped into the plant's emergency diesel generators during temporary storage. When the generators were started, the diesel's piston rings, pistons, and cylinders cracked. [*Nugget File*, p. 57] ✓

03/00/76 The reactor scrammed seven times in four days because of operator mistakes and design errors. [*Nugget File*, p. 67] ✓

12/11/76 Construction was completed six years behind schedule. General Atomics, the reactor manufacturer, paid $52 million in penalties. [*Engineering News-Record*, 02/02/78, p. 13] ✓

04/19/77 An NRC inspector passed through the main gate and several guard stations and entered the main control room without a security badge. The utility was fined $8000. [*1977 Annual NRC Report*, p. 101; and *Nuclear News*, 07/00/77, p. 38]

01/23/78 Fifteen workers were slightly contaminated when a valve failed releasing radioactivity. Six operators stayed and 275 other employees evacuated the plant site. The plant was shut down until 02/09/78. [*Engineering News-Record*, 02/02/78, p. 13; and *Nuclear News*, 03/00/78, p. 20] ✓

11/00/78 100°F variations in core temperature kept the reactor from operating at full power. This problem was first noticed during 10/00/77. [*Engineering News-Record*, 11/16/78, p. 23]

04/02/79 The plant's license was amended limiting operation to 70% of full power. This restriction was lifted 3½ years later. To compensate the utility for the power reduction, General Atomics agreed to a settlement of $180 million and free fuel for 5 years. [*Nuclear News*, 05/00/79, p. 58; and *Nuclear News*, 11/00/82, p. 34] ✓

06/23/84 The plant was shut down because of excessive moisture in the reactor's helium coolant. During the shutdown, 6 of 37 control rods failed to operate. The plant did not restart until 04/00/85 and during the outage the utility was involved in a dispute with the utility commission over whether customers should receive a $320,000 refund for each month the plant was out of service. [*Nuclear News*, 11/00/84, p. 60] ✓

06/28/89 Personnel opened a series of valves in the wrong order and, in so doing, released gaseous radioactive waste to the environment. [NUREG-0020, 09/00/89, pp. 2-168, 169, & 170] ✓

08/18/89 The reactor was shut down following control rod failures. [SECY-90-421, p. 3] ✓

08/25/89 Numerous cracks were discovered in the main steam ringheaders associated with the steam generators. On 08/29/89, the utility decided repairs would be too extensive to justify continued operation of the plant. [NUREG-0020, 09/00/89, p. 2-167]

4. THREE MILE ISLAND 2 [09/18/78]

General Data

Owner GPU Nuclear [DOE/OSTI-8200, p. III-2]
Location Middletown, PA [Ibid]
Reactor 906.0 MWe PWR ordered 02/00/67 [Ibid and WASH-1208, p. 3]
First Electricity 09/18/78 [NUREG-1250, p. 110]
Designer Burns & Roe [WASH-1208, p. 3]
Builder United Engineers & Constructors [NUREG-0020, 01/00/79, p. T-4]
Cost to Build $714.9 million [DOE/EIA-0485, p. 20]
Licensing Data CP received 11/25/69; OL received 02/08/78 [NUREG-1250, pp. 77 & 109]
Date Closed 03/28/79 [NUREG-1350, p. 90]

Operating Data

- As of 12/31/78, the plant's Cum. Capacity Factor was 85.1%. [NUREG-0020, 01/00/79, p. T-5]
- After the 03/28/79 accident, investigators identified the following maintenance and operating problems: a) foot-long mineral deposits hanging from leaking valves; b) contaminated equipment pulled from service and stored in uncontrolled areas of the plant; c) valves in the closed position that should have been open, d) valves that appeared on drawings but could not be found by station personnel, e) over 52 audible alarms in the control room, all of which went off during the accident, and f) control room gauges that were either out-of-service or went off-scale during the accident. Repair tags hanging from gauges prevented reading those that were in service. [*Nucleonics Week*, 10/29/79, pp. 7 & 8] ✓

Decommissioning On 04/15/90, the last of 152 tons of debris was removed from the reactor and sent to Idaho National Engineering Laboratory for analysis and disposal. $970 million was spent on this and other decommissioning work. The total cost of decommissioning is expected to be $1.4 billion. [*Nucleonics Week*, 10/29/79, p. 3; *The Washington Post*, 03/28/89, p. A8; *The New York Times*, 07/02/86, p. A10; NUREG-0090, p. 26; and *The New York Times*, 04/24/90, pp. C1 & C12] ✓

Problems

04/23/78 Plant startup was put on hold until 09/17/78 when main steam isolation valves failed to close. The problem was due to a design error and all five valves had to be replaced. [NUREG-1250, p. 110] ✓

11/03/78 A plant mechanic shut down the entire plant by tripping what he thought was a light switch. He tripped a condensate polisher switch. The utility's corrective action was to put a guard over the condensate polisher switch. [Ibid and *Nucleonics Week*, 10/29/79, p. 8]

01/15/79 The plant was shut down for two weeks after the reactor scrammed. It was restarted following repairs to the atmospheric dump bellows and several pressurizer instrumentation valves. [NUREG-1250, p. 111]

03/28/79 The reactor experienced a partial (52%) core melt-down. 200,000 residents were evacuated until the reactor was brought under control, and it was safe to return. Though some radioactivity was released, it was less than 10% of annual background radiation. [*Nucleonics Week*, 10/29/79, pp. 3-4; *Nuclear Age*, p. 218; and *The New York Times*, 04/24/90, p. C12] ✓

10/25/79 The utility was fined $155,000 for 134 violations of regulations between 10/00/78 and 03/00/79. [*Nuclear News*, 12/00/79, pp. 28 & 33] ✓

11/01/79 The utility was presented with an order to show cause, within 20 calendar days, why its licenses to operate Pennsylvania nuclear power plants should not be revoked. [Ibid] ✓

04/00/80 About 2000 lawsuits were filed against GPU by local residents and other affected organizations. In turn, the utility sued B&W, the reactor manufacturer, and the NRC for $4 billion. The suits alleged a defective B&W pressurizer relief valve caused the 03/28/79 accident. Also, they claimed that the NRC failed to notify the utility of a 09/00/77 feedwater transient at Davis-Besse that foreshadowed the 03/28/79 accident. [*Nuclear News*, 04/15/80, p. 22A; 01/00/82, p. 49; and 12/00/82, p. 40-42; and *Nuclear Age*, p. 226] ✓

5. SHOREHAM [07/06/85]

General Data

Owner Long Island Lighting [DOE/OSTI-8200, p. II-5]
Location Brookhaven, NY [Ibid]
Reactor 820.0 MWe BWR ordered 02/00/67 [Ibid and WASH-1208, p. 3]

First Electricity 07/07/85 [*The New York Times*, 09/17/85, p. B3; and *Nuclear News*, 08/00/85, p. 45]

Designer Stone & Webster [*Spectrum*, 11/00/87, p. 30]

Builder Long Island Lighting [Ibid]

Cost to Build $5.48 billion [DOE/EIA-0473, p. 29]

Licensing Data A CP was received 04/14/73. A "low-power" OL was received 02/12/85 and a "full-power" OL was received 04/21/89. On 07/20/91, the OL was converted to a "possess-only" OL. [NUREG-1350, p. 83; *Nuclear News*, 03/00/85, p. 31; *The New York Times*, 07/20/91, p. 22; and *Nucleonics Week*, 04/27/89, p. 11]

Date Closed 05/26/89; the plant was closed in response to a promise from the State of New York to help restore the utility's financial health. [*The New York Times*, 07/20/91, p. 22; and *Nuclear News*, 08/00/91, p. 79]

Operating Data

- Shoreham's Cumulative SALP rating was 1.73. Three Category 3 Findings were identified during seven SALP inspections, the first of which was performed in 1981. All three Findings were identified during 1986. NRC inspectors found that: a) utility management was preoccupied with licensing issues and not paying attention to procedural details and quality assurance problems; b) personnel training was poor and turnover excessive; and c) radiological controls were inadequate. [*The New York Times*, 07/20/86, pp. XXI-1 & 11; and NUREG-1214, p. 2-17]
- During the two years it was in operation, the NRC cited Shoreham with five NRC violations. [*Spectrum*, 11/00/87, p. 34] ✓
- Shoreham operated at less than 5% of full-power for a total of 30 hours. On 08/26/86, it produced 19 MW-hrs of commercial power. Over its 3.80 yr operating life, Shoreham had a Lifetime Capacity Factor of 0.0%. [*Nucleonics Week*, 04/27/89, p. 12; and *The New York Times*, 08/27/86, p. B3]

Decommissioning The Long Island Power Authority filed a decommissioning plan on 12/20/90. Dismantling the plant, which began 06/17/92, will take about two years and cost $186 million. During the interim, 560 assemblies are still being held in the plant's spent fuel storage pool. [*The New York Times*, 07/20/91, p. 22; SR/CNEAF/92-01, p. 131; *Nuclear News*, 08/00/92, p. 28; and *Nucleonics Week*, 04/27/89, p. 11]

Problems

03/26/69 The utility decided to increase the plant's capacity from 540 to 820 MWe. Stone & Webster told the utility this would not require increasing the size of the reactor building. Along with this change, the utility upgraded its order with General Electric to a Mark II reactor, a first-of-its-kind design. [*Spectrum*, p. 26] ✓

10/00/71 The utility placed a hold on design activities for one year pending resolution of a 07/23/71 U.S. Court of Appeals ruling, known as the "Calvert Cliffs Decision", that resulted in the AEC temporarily stopping the issuance of Construction Permits. [Ibid, p. 28] ✓

00/00/73 Piping systems had to be upgraded to meet ASME III requirements. New pipe was ordered to replace what was already on site, and construction was delayed until the new pipe was delivered. [Ibid, p. 29]

09/07/77 The utility took over responsibility for construction, replacing Stone & Webster. Productivity continued to decline. Cost overruns of $296 million were attributed to the utility's management of construction activities. [Ibid, pp. 30 & 33] ✓

00/00/80 Electrical cable trays had to be torn out and rerouted to meet new NRC regulations based on lessons learned from a 1975 fire at Browns Ferry 1&2. Cost overruns of $105 million were attributed to delays in responding to changing NRC piping and fire protection regulations. [Ibid, pp. 29 & 33] ✓

00/00/82 An agreement was reached with the NRC on how to reduce hydrodynamic loads on the suppression pool below the reactor. Tests conducted by General Electric in 1973 found that loads were higher than originally assumed. Required changes delayed start-up by two years. [Ibid, p. 31]

08/00/83 The crankshaft on one of three emergency diesel generators broke during testing. Cracks were found in the other two generator crankshafts and in the connecting rod bearings and pistons of all three generators. The crankshafts were not designed for the torsional loads they experienced during generator start-up. Replacing the generators delayed fuel loading by over a year and cost $619 million. [Ibid, p. 32] ✓

10/00/85 The plant completed low-power testing. Three reactor scrams and one manual shutdown occurred during the three-month testing period. One scram resulted from a valve failure and the other two were due to operator errors. The manual shutdown was due to a malfunctioning coolant level gauge. [Ibid, p. 34]

07/00/86 In response to lessons learned from the accident at Three Mile Island, the utility spent $30 million to build a special training center for Shoreham control room operators. [Ibid, p. 31] ✓

08/21/87 A federal court dismissed a $750 million suit by the utility against Stone & Webster for defects in the plant's three emergency diesel generators. [*Nuclear News*, 10/00/87, p. 24] ✓

11/18/88 President Reagan signed an Executive Order giving the Federal Emergency Management Agency authority to evacuate personnel near nuclear power plants when state and local governments are unwilling to do so. The order cleared the way for a 04/21/89 Operating License. [*The Washington Post*, 11/19/88, p. A1]

10/16/90 The General Accounting Office issued a report identifying use of counterfeit fasteners, circuit breakers, fuses, and other materials at Shoreham. [GAO/RCED-91-6, p. 16]

06/00/91 General Electric and Long Island Lighting agree to an out-of-court settlement. The utility had been asking for $400 million to compensate for damages it incurred using General Electric's allegedly inadequate suppression pool design. [*Nuclear News*, 08/00/91, p. 34] ✓

03/05/92 Title to Shoreham was transferred to the Long Island Power Authority whose sole function will be to decommission the plant. [*The Nuclear Monitor*, 03/23/92, p. 8]

1. WOLVERINE [05/00/58]

Owner Wolverine Electric Cooperative [*Atomic Energy Deskbook*, p. 613]

Location Hersey, MI [*Forum*, 02/00/56, p. 16]

Reactor 10.0 MWe aqueous homogeneous reactor. [Ibid]

Construction Permit Application During 00/00/56, in response to the AEC's "second round" request for PDRP proposals. [*Atomic Energy Handbook*, p. 613]

Cancelled During 05/00/58, the plant was cancelled because of "substantial" increases in estimated construction costs. Costs rose from $3.6 million to $14.4 million. [Ibid; *Forum*, 04/00/58, p. 10; and *Forum*, 06/00/58, p. 29]

2. CHUGACH [02/00/59]

Owner Chugach Electric Association [*Atomic Energy Deskbook*, p. 99]

Location Anchorage, AK [Ibid]

Reactor 10.0 MWe sodium-cooled heavy-water reactor [Ibid]

Construction Permit Application During 00/00/56, in response to the AEC's "second round" request for PDRP proposals. [Ibid]

Cancelled During 02/00/59, the plant was cancelled because "of the technical complexity of the project and the remote location of the plant." [Ibid and *Forum*, 03/00/59, p. 7]

3. FLORIDA WEST COAST [00/00/61]

Owner Florida West Coast Nuclear Group, Inc. [*1960 Annual AEC Report*, p. 406]

Location Tampa, FL [*Atomic Energy Deskbook*, p. 172]

Reactor 50.5 MWe HTGR, heavy water moderated [*1960 Annual AEC Report*, p. 406]

Construction Permit Application 12/10/59 [Ibid]

Cancelled During 1960, the Application was withdrawn for modification. The plant was cancelled in early 1961 because of rising technical and economic uncertainties. [Ibid and *Atomic Energy Deskbook*, p. 172]

4. RAVENSWOOD [11/14/63]

Owner Consolidated Edison [*1963 Annual AEC Report*, p. 432]

Location Queens, NY [Ibid]

Reactor 100.0 MWe PWR [Ibid]

Construction Permit Application 12/10/62 [Ibid]

Cancelled On 11/14/63, the Application was withdrawn for modification and never resubmitted. The plant was to be located across the East River from Manhattan's 72nd Street. [Ibid, pp. 363 & 432; and *Unacceptable Risk*, p. 65]

5. BODEGA BAY [11/04/64]

Owner Pacific Gas & Electric [*1963 Annual AEC Report*, p. 359]

Location Bodega Head, CA [Ibid, p. 432]

Reactor 325.0 MWe BWR [Ibid]

Construction Permit Application 12/31/62 [Ibid]

Cancelled On 11/04/64, the Application was withdrawn on advice of AEC staff. The plant was located next to the San Andreas fault. $4 million had been spent on site preparation and excavating a 73-foot deep reactor building foundation. [Ibid, p. 359, *Containing the Atom*, p. 99; and *1964 Annual AEC Report*, p. 318]

6. MALIBU [07/14/66]

Owner Los Angeles Water & Power Department [*1963 Annual AEC Report*, p. 432]

Location Corral Canyon, CA [Ibid]

Reactor 490.0 MWe PWR [Ibid]

Construction Permit Application 11/26/63 [Ibid]

Cancelled On 07/14/66, the ASLB ruled the plant must be designed for permanent ground displacement as a result of an earthquake, a virtual impossibility. [*1966 Annual AEC Report*, p. 59]

7. BURLINGTON 1 & 2 [08/00/67]

Owner Public Service of New Jersey [*1967 Annual AEC Report*, p. 336]

Location Burlington, NJ [Ibid]

Reactors 1050.0 MWe PWRs [Ibid]

Construction Permit Applications 12/13/66 [Ibid]

Cancelled During 08/00/67, the Applications were withdrawn because of ACRS and local opposition to nuclear plants sited 17 miles from Philadelphia. During 01/00/68, the Applications were resubmitted for two units (Salem 1 & 2) located 18 miles from Wilmington, DE. [Ibid, *Power*, 10/00/67, p. 117; and *1968 Annual AEC Report*, p. 114]

8. CRYSTAL RIVER 4 [03/25/68]

Owner Florida Power [*1968 Annual AEC Report*, p. 114]

Location Crystal River, FL [NUREG-1350, p. 72]

Reactor 825.0 MWe PWR [*1968 Annual AEC Report*, p. 111]

Construction Permit Application 08/00/67 [WASH-1208, p. 3]

Cancelled On 03/25/68, the Application was withdrawn because revised load growth projections indicated the plant would not be a prudent investment in generating capacity. [*1968 Annual AEC Report*, p. 114]

9. EASTON [08/20/68]

Owner Niagara Mohawk [*1967 Annual AEC Report*, p. 337]

Location Troy, NY [Ibid]

Reactor 766.0 BWR [Ibid]

Construction Permit Application 08/00/67 [Ibid]

Cancelled On 08/20/68, the Application was withdrawn because of difficulties obtaining site approvals from local governing bodies. The proposed site was located across the Hudson River from Saratoga National Historic Park. In 1966, the New York Power Authority took over Niagara Mohawk's reactor contract and used the reactor at its Fitzpatrick plant. [*1968 Annual AEC Report*, pp. 113, and WASH-1208, p. 5]

10. BOLSA ISLAND 1 & 2 [12/30/68]

Owner Los Angeles Water & Power Department [*1968 Annual AEC Report*, p. 114]

Location Huntington Beach, CA [Ibid]

Reactors 900.0 MWe PWRs [Ibid]

Construction Permit Applications 09/00/67 [Ibid]

Cancelled On 12/30/68, the Applications were withdrawn after the utility determined the plants were not economically justifiable. Initially, the plants were expected to cost $444 million and both generate electricity and desalinate water. However, by 08/00/68, the estimated cost had risen to $765 million. [Ibid; *AEC Fact Book*, p. E-26; *Power*, 10/00/66, p. 103; and *Power*, 08/00/68, p. 108]

11. BELL 1 & 2 (also called MILLIKEN) [04/00/69]

Owner New York State Electric & Gas [*1970 Annual AEC Report*, p. 84]

Location Lansing, NY [Ibid]

Reactors 838.0 MWe BWRs, Unit 1 reactor ordered 06/00/67 [*Power*, 10/00/68, p. S-9; and *1967 AEC Annual Report*, p. 339]

Construction Permit Applications 03/00/69 [*1969 Annual AEC Report*, p. 129]

Cancelled During 04/00/69, the plants were postponed indefinitely because of local opposition to the possible thermal pollution of Cayuga Lake. [Ibid and *AEC Fact Book*, p. E-27]

1. *ZIMMER 1 [01/14/84]*

General Data

Owner Cincinnati Gas & Electric [*Nuclear News*, 08/00/83, p. 98]

Location Moscow, OH [Ibid]

Reactor 810 MWe BWR ordered 09/00/69 [Ibid and WASH-1208, p. 5]

Designer Sargent & Lundy [Ibid]

Builder Kaiser [Ibid]

Construction Permit Received 10/27/72 [*1972 Annual AEC Report*, p. 15]

Date Cancelled 01/14/84 [*Engineering News Record*, 02/02/84, p. 10]

Percent Complete 97% [*Nuclear News*, 02/00/84, p. 25; and *The New York Times*, 06/17/84, p. D17]

Eventual Fate Zimmer was converted to a 1300 Mwe coal-fired plant. On 12/31/90, the plant began generating electricity [*Nuclear News*, 02/00/91, p. 32]

Plant Cost Data

- The cost of the plant had risen from an initial estimate of $240 million to $3.1 billion at the time it was cancelled. [*The New York Times*, 01/17/84, p. D17; and *The New York Times*, 01/18/84, p. 12]
- $1.72 billion had been spent on design and construction at the time the plant was cancelled. [*The New York Times*, 06/18/84, p. D1]
- $1.1 billion was spent converting the plant to a coal-fired unit. [*Nuclear News*, 02/00/91, p. 32]

Problems

04/20/80 The *Chicago Sun-Times* ran a story about a private detective, hired by the utility to look into employee time-cheating, who claimed he was fired for also finding quality problems, e.g., use of damaged piping materials and rubbish fires burning unattended inside the reactor building. [*Nuclear News*, 06/00/80, p. 44]

02/00/81 The NRC sent the utility a letter requesting that "*immediate action*" be taken to correct recurring problems with the quality of ongoing construction activities. [NUREG-1055, pp. A.33]

11/24/81 After a nine-month NRC investigation of allegations, the utility received a $200,000 fine for numerous quality assurance deficiencies. It was the largest fine assessed by the NRC against a plant under construction. An accompanying "Notice of Violation" mentioned harassment of inspectors, including one threat of physical violence; defective welds; and cable installation nonconformances. [*Nuclear News*, 01/00/82, p. 49]

04/08/82 The NRC ordered duplicate inspections of all construction activities. During early 08/00/82, the NRC permitted a 50% reduction in duplicate inspections. [*Nuclear News*, 09/00/82, p. 48]

05/27/82 Two reactor building QA inspectors were doused with a bucket of water containing urine. The bucket was activated by a trip wire. The next day the utility stopped all work at the project site and the NRC began an investigation of the incident. [*Nuclear News*, 07/00/82, p. 36]

07/00/82 The utility found that 100 of 450 welders that had completed questionable or defective welds were not properly qualified. [*Inside NRC*, 11/01/82, p. 1]

10/19/82 The utility stopped all repairs of past defects by Catalytic, Inc., after NRC inspectors found defects in the repairs. [Ibid]

10/28/82 NRC Commissioners are told that, in addition to a records "*mess*," substantial problems requiring extensive rework had been found in the areas of "*structural steel, weld quality, heat number traceability, and cable separation*." [Ibid]

11/12/82 The NRC ordered all work at Zimmer stopped. In a 10-page order, it cited defects in 70% of structural steel welds, inadequate documentation and qualification of welders and QA personnel, alteration of records, and untraceable materials. To restart work, the NRC ordered the utility to hire an independent third-party to conduct an audit of its QA program and management practices. [*Nucleonics Week*, 11/18/82, p. 1; *Nuclear News*, 12/00/82, pp. 23 & 24; and *Nucleonics Week*, 12/09/82, p. 2]

11/16/82 Bechtel was hired to replace Kaiser as construction manager. The NRC promptly questioned the selection since many of the construction problems identified at Midland 1&2, a Bechtel project, were the same as those at Zimmer. [*Nucleonics Week*, 12/09/82, pp. 1&2]

12/00/82 A Federal grand jury was empaneled to hear the results of an FBI investigation of harassment of Zimmer inspectors and falsification and destruction of QA records. [*Inside NRC*, 11/15/82, p. 1]

08/22/83 A 491-page independent Zimmer management audit report was presented to the NRC. The report attributed QA problems to a: *1)* fossil power plant mentality and tendency to place QA behind cost and schedule considerations; and *2)* failure to establish an comprehensive set of integrated project procedures. It attributed problems with the completeness, accuracy, and traceability of QA records to a tendency to rely on "*informal communication within small groups.*" [NUREG-1055, p. A.37,; and *Nuclear News*, 09/00/83, p. 24]

11/00/83 The NRC rejected a request to resume construction with Kaiser construction crews working under Bechtel's supervision. Several days later the utility requested permission to use Bechtel versus Kaiser construction crews. [*Nucleonics Week*, 11/24/83, p. 2; and *The New York Times*, 11/24/83, p. D12]

01/21/84 The utility, after consulting with its other partners, decided to convert Zimmer to a coal-fired plant. The decision was prompted by financial difficulties and a recent study that found conversion would be cheaper than proceeding ahead in view of "*licensing uncertainties*". [*Nuclear News*, 02/00/84, p. 25]

01/25/84 A Bechtel offer to buy Zimmer was rejected. Bechtel planned to complete the plant and operate it as a nuclear powered electric generating station. [*Engineering News-Record*, 02/02/84, p. 10]

06/17/84 A Ohio Public Utility Commission report found utility mismanagement was the reason for $775 million in overruns. It cited "mindboggling" design errors; for example, a main control panel whose warning lights were spaced so close they either burned out or had to be disconnected to reduce the risk of fire. [*Forbes*, 02/11/85, p. 90; *The New York Times*, 06/18/84, p. D1; and *The Wall Street Journal*, 06/19/84, p. 1]

05/00/85 Two out-of-court settlements were reached. In one, Kaiser agreed to pay the utility $1.7 million and voided $2.0 million in bills. In the other, utility directors agreed to pay stockholders $2.0 million. [*Nuclear News*, 06/00/85, p. 192]

11/00/87 Two out-of-court settlements were reached. In one, General Electric agreed to pay the utility $37 million and, in the other, Sargent & Lundy agreed to pay the utility $15 million. [*Nuclear News*, 12/00/87, p. 110]

2. *MARBLE HILL 1&2 [01/16/84]*

General

Owner Public Service Indiana [*Nuclear News*, 08/00/83, p. 98]
Location Madison, IN [*Nuclear News*, 02/00/84, p. 135]
Reactors Two 1130 MWe PWRs [*Nuclear News*, 08/00/83, p. 98]
Designer Sargent & Lundy [Ibid]
Builder Public Service Indiana [Ibid]
Construction Permit Received on 04/04/78 for both units [*Nuclear Industry*, 05/00/78, p. 20]
Date Cancelled 01/16/84 [*Nuclear News*, 02/00/84, p. 26]
Percent Complete 60% for Unit 1 and 37% for Unit 2 [Ibid, pp. 26 & 135]
Eventual Fate The plant was abandoned [*Nuclear News*, 12/00/84, p. 21]
Plant Cost Data

- The cost of the plant had risen from an initial estimate of $1.8 billion to $7.7 billion at the time it was canceled. [*Forbes*, 02/11/85, p. 95; and *The Wall Street Journal*, 06/19/84, p. 7]
- The utility had spent $2.8 billion on construction at the time it was cancelled. Public Service Indiana was able to "write off" $2.7 billion. [*Nuclear News*, 01/00/86, p. 40; and *Time*, 04/29/91, p. 56]

Problems

00/00/77 The utility was fined $12,500 for beginning construction prior to receiving a Construction Permit. [*Nuclear News*, 07/00/77, pp. 36 & 38]

03/00/79 The NRC identified severe cases of honeycomb in concrete. The utility agreed to upgrade its control of concrete work and retest the quality of previously placed concrete. [NUREG-1055, p. A.8]

04/00/79 Charles Cutshall, a former Marble Hill construction worker, notified the NRC that honeycomb in concrete was being patched over rather than chipped out and filled with grout. The National Board of Boiler and Pressure Vessel Inspectors identified problems with the quality of installed piping. The NRC began investigating both allegations. [NUREG-1055, p. A.8; *Nuclear News*, 01/00/80, p. 43; and *Nuclear News*, 09/00/79, p. 22]

07/20/79 Following discussions with the NRC about recurring problems with the quality of concrete construction, the utility agreed to stop further concrete work. [*Nuclear News*, 09/00/79, p. 22 & 111]

08/15/79 The NRC ordered the suspension of construction activities. NRC inspectors had, over the previous five months, identified widespread and severe honeycombing in concrete; problems with structural steel erection, piping installation, and the application of protective coatings; and serious inadequacies in staffing and managing construction activities. Over 500 honeycomb clusters were found, some up to 180 cubic feet in volume. The order prohibited the resumption of construction without NRC permission. [*Nuclear News*, 09/00/79, pp. 22 & 111; and *Normal Accidents*, p. 36]

11/27/79 During Congressional hearings into nuclear power plant problems, the NRC said it had turned over to the Justice Department evidence that quality assurance problems at Marble Hill may have included criminal activities. [*Nuclear News*, 01/00/80, p. 43]

12/00/81 Despite the objections of local citizen groups, the NRC gave the utility permission to resume all construction activities. [*Nuclear News*, 12/00/81, p. 69]

03/00/83 Due to quality control problems, the utility suspended all work on electrical and HVAC systems and, due to design problems, also postponed structural steel shipments to the site. [*Forbes*, 02/11/85, p. 95]

01/16/84 The utility announced it was financially unable to continue construction. A series of layoffs during the prior three months had reduced the on-site workforce to about 250. [*Nuclear News*, 02/00/84, pp. 26 & 135]

06/00/84 The utility rejected as too costly a proposal by Bechtel, Sargent & Lundy, and Westinghouse to complete the plant. [*The Wall Street Journal*, 06/19/84, p. 7; and *Nuclear News*, 12/00/84, p. 21]

07/00/88 In an out-of-court settlement, utility officers and their insurers agreed to pay stockholders $24.55 million. [*Nuclear News*, 09/00/88, p. 36]

02/00/89 In an out-of-court settlement, the utility agreed to pay Wabash Valley Power, a junior partner in the Zimmer project, $80 million in cash and $90 million in free electricity. [*Nuclear News*, 03/00/89, p. 36]

3. MIDLAND 1&2 [07/16/84]

General

Owner Consumers Power [*Nuclear News*, 08/00/83, p. 98]

Location Midland, MI [Ibid]

Reactors Two PWRs were ordered during 05/00/68, a 530 MWe reactor for Unit 1 and a 805 MWe reactor for Unit 2. [Ibid and WASH-1208, p. 4]

Designer/Builder Bechtel [*Nuclear News*, 08/00/83, p. 98]

Construction Permit Received during 12/15/72 for both units [*1972 Annual AEC Report*, p. 15]

Date Cancelled July 16, 1984 [*Nuclear News*, 08/00/84, p. 37]

Percent Complete 85% for each of the two units [Ibid]

Eventual Fate The plant was converted to a 1370 MWe gas-fired cogeneration facility. The plant began operation during 04/00/90. [*The Washington Post*, 04/10/90, pp. D1 & D2]

Plant Cost Data

- At the time it was canceled, the cost of the plant had risen to $6.0 billion from its original estimate of $267 million. [*Time*, 02/13/84, p. 39; and *The New York Times*, 01/17/84, p. D17]
- The utility had spent $4.2 billion on the plant up to the time it was cancelled. Another $800,000 was spent converting it to a cogeneration plant. [*The Washington Post*, 04/10/90, p. D1]

Problems

03/00/73 The Atomic Safety & Licensing Appeal Board ordered the utility to provide: *1)* a comprehensive report on QA actions that had been taken to assure the quality of past construction; and *2)* monthly reports on nonconformances associated with future construction work. [*Nucleonics Week*, 03/29/73, p. 3]

10/05/73 The Atomic Safety & Licensing Appeal Board found Bechtel's organization violated Criterion I of 10CFR50, Appendix B. It gave Bechtel 45 days to change its organization so that the Project QC Engineer and his inspectors no longer reported to the Project Superintendent. [*AEC Reports*, Vol. 6, pp. 816-820]

12/03/73 The NRC ordered the utility to "show cause" why all Midland construction activities should not be suspended. The order was in response to significant cadwelding deficiencies found during an NRC investigation of allegations made by two Midland construction workers. The NRC received the allegations during 10/00/73 and completed its investigation during 11/00/73. [*AEC Inspection Report*, 12/14/73, pp. 1-15]

12/00/74 Several construction workers told the *Ann Arbor Sun* that *1)* soil used in a dike around a cooling pond had not been tested; *2)* concrete aggregate had been used that had failed acceptance tests; *3)* rebar was not being tested at minimum frequencies; *4)* concrete slump tests were not being performed; and *5)* required tests were not being performed to avoid paying overtime. [*Nucleonics Week*, 12/05/74, p. 1]

00/00/76 Reinforcing steel was inadvertently omitted from the wall of a building. [*Ms. Magazine*, 01/00/85, p. 108; and *AEC Reports*, Vol. 18, p. 1125]

00/00/77 A large bulge occurred in the Unit 2 containment liner and errors were identified in the placement of post-tensioning system tendon ducts. *AEC Reports*, Vol. 18, p. 1125; and NUREG-1055, p. B.85]

08/12/77 Columnist Jack Anderson reported that the NRC was investigating the utility's ability to finance Midland and, 'a la Watergate, the utility was: *1)* trying to block witnesses from testifying; *2)* laundering testimony that might be damaging; and *3)* giving the NRC incomplete information. [*Nuclear News*, 09/15/77, p. 120B]

09/07/78 Construction was halted after Bechtel discovered excessive setting of the diesel generator building. By 10/27/78, it had settled 3.5 inches versus the 3.0 inches permitted over the life of the plant. The fill was placed between 1975 and 1977. [*Midland Daily News*, 12/02/78, p. 1; and *Midland Daily News*, 01/04/80, p. 1]

02/23/79 At a special prehearing conference, the Atomic Safety & Licensing Board (ASLB) agreed to consider 29 allegations by Mary Sinclair, a local freelance writer, pertaining to deficiencies in plant construction. After almost three years of deliberations, the utility was ordered to address 9 of her allegations in its Operating License Application. [*AEC Reports*, Vol. 16, pp. 2035-2047; and *Ms. Magazine*, 01/00/85, p. 64]

12/06/79 The NRC ordered the utility to stop all work associated with correcting settlement of the diesel generator building and other plant structures. Cracks from excessive settlement had been identified in the concrete walls of auxiliary building and service water intake structure. Settlement of the diesel generator building exceeded 7 inches and workers had begun tunneling under the diesel generator building to remove and replace poorly compacted fill material. [*AEC Reports*, Vol. 15, pp. 1062-1064; and *Midland Daily News*, 12/26/79, p. 1]

01/00/81 The NRC fined the utility $38,000 for deviating from procedures during the installation of HVAC systems by the Zack Company. This included deviations from procedures relating to procurement, materials selection, welding, and document control. [*Nuclear News*, 02/00/81, p. 43]

05/00/81 During a special investigation, the NRC identified serious deficiencies in previous QC inspections of piping supports and restraints and electrical cable installations. [*AEC Reports*, Vol. 18, pp. 1125 & 1126]

09/15/81 The Michigan Supreme Court blocked the utility's plan to sell stocks and bonds needed to finance further construction of Midland 1&2. [*Nuclear News*, 10/00/81, p. 18]

12/01/81 The Atomic Safety & Licensing Board opened six weeks of special hearings on action taken to investigate and correct: *1)* settlement of the auxiliary building and service water pump structure; *2)* settlement considerations and their impact on seismic models; *3)* settlement of the borated water storage tank and underground piping; and *4)* settlement of the diesel generator building. [*Nuclear News*, 01/00/82, pp. 55 & 56]

05/03/82 Albert Howard, a QA Supervisor, told the NRC he had been fired by the Zack Company for trying to prevent deficiencies in plant HVAC work. He gave the NRC documents that allegedly proved records were being altered/forged and Zack knew of serious quality deficiencies. [*AEC Reports*, Vol. 16, p. 2060]

07/00/82 The NRC formed a special Midland Section within its Region III Office devoted to giving increased attention to the quality assurance problems at Midland 1&2. [*AEC Reports*, Vol. 18, p. 1126]

12/02/82 The utility stopped most construction after an internal investigation revealed that there was insufficent evidence that past work was adequate or had been properly inspected. [*Nuclear News*, 11/00/83, p. 60]

02/08/83 The NRC fined the utility twice for a total $120,000 following an intensive investigation of diesel generator building construction. The first fine was $60,000 for a breakdown in the utility's QA program. The NRC cited: *1)* multiple instances of failing to follow procedures, drawings, and specifications; *2)* supervisors who failed to identify and correct unacceptable work; *3)* managers who allowed a backlog of 16,000 inspections to accumulate; and *4)* QA personnel who failed to identify problems. The second fine, also for $60,000, was for instructing QC personnel to suspend inspections if they observed too many deficiencies. [*Inside NRC*, 02/21/83, pp. 11-13; *AEC Reports*, Vol. 18, p. 1126; and *Nuclear News*, 03/00/83, pp. 47 & 50]

02/15/83 The Government Accountability Office asked the Advisory Committee on Reactor Safeguards to look into the significance of cracks in structures that had been experiencing excessive settlement. [*Inside NRC*, 02/21/83, pp. 12 & 13]

07/00/83 Dow Chemical declared as "void" its contract to buy steam from Midland 1 and filed suit for $60 million claiming it was not properly advised of problems during construction. The utility countersued for $440 million. [*The New York Times*, 08/23/83, p. D4; and *The New York Times*, 11/10/33, pp. D1 & D4]

10/06/83 The NRC approved the utility's plan to resume construction. It called for reinspecting all accessible, previously completed work; retraining site personnel; revising QC procedures; and independent oversight by Stone & Webster of the plan's implementation. [*Nuclear News*, 11/00/83, pp. 60 & 61]

10/22/83 The utility issued a "stop work order" because of concerns about controls being applied to changes to drawings. Bechtel modified its drawing change control process. [*Nuclear News*, 03/00/84, p. 59]

10/25/83 The NRC ordered the utility to conduct a "management appraisal" into why soil was being excavated in violation of requirements in a 07/00/82 amendment to the Midland Construction Permit. [Ibid]

01/17/84 The NRC ordered the utility to map cracks in the concrete of the plant's auxiliary building and service water pump building. [*The New York Times*, 01/18/84, p. 12]

06/20/84 The utility said, unless it could negotiate a cost-recovery plan with the Michigan Public Service Commission by 07/01/84, it would have to cancel the plant. [*Nuclear News*, 07/00/84, pp. 27 & 28]

07/16/84 The utility announced it was cancelling the plant and, unless it could recover past construction costs, it would have to consider bankruptcy. [*Nuclear News*, 08/00/84, p. 37]

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TABLE 1
Source of 10CFR50, Appendix B, Requirements

BY SENTENCE	CRITERION																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	O	X	R	M	M	R	M	R	M	R	M	M	M	M	R	M	M	N
2	R	R	O	N	R	R	M	A		R	P		M	R	M	R	R	R
3	A	R	R			R	P	A		M	R			X	M	M	R	N
4	P	R	R				P			O	A						M	N
5	P	M	R				M										A	
6	M	M	P														A	
7	O	M	R															
8	O	R	N															
9	N	M	R															
10		M	R															

LEGEND **A** = *ASME III Code, Winter 1967 Addenda, December 31, 1967* **M** = *MIL-Q-9858A, December 16, 1963* **N** = *NHB 5300.4 (1B), April 1969* **O** = *Other* **P** = *Public Comments* **R** = *RDT F2-2, June 1969* **X** = *Unknown*

BY SOURCE DOCUMENT	CRITERION																		TOTAL	PCT
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
RDT F2-2	1	4	7		1	3	3	1		2	1			1	1	1	2	1	29	38.2
MIL-Q-9858A	1	5		1	1				1	2	1	1	2	1	2	2	2		22	28.9
ASME III Code	1							2			1						2		6	7.9
NHB 5300.4	1		1	1														3	6	7.9
Public Comments	2		1				2				1								6	7.9
Other	3		1							1									5	6.6
Unknown		1												1					2	2.6
TOTAL	9	10	10	2	2	3	5	3	1	5	4	1	2	3	3	3	6	4	76	100.0

TABLE 2
June 1969 Public Comments on Proposed 10CFR50, Appendix B

ORGANIZATION	DATE	CRITERION																				TOT CMTS	CMTS INC
		GEN	INTRO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
Stone & Webster	06/09					1		1					1	1			1	1	1			7	5
Westinghouse	06/09	3	2	1	3	2			1	2	1	1	3				1	1	1	2	1	25	14
Hanford Contractors	06/11	1	1	2	1	1		1		1	1				1		2					12	5
Idaho Nuclear Corp.	06/11	5																				5	0
United Engineers	06/11	2			2	2	1						1									8	2
William O'Donnell	06/11					2																2	0
Combustion Eng'rg	06/12		1			4					1		1		1							8	5
American Elect. Power	06/13	1	1			1																3	0
Consolidated Edison	06/13					1																1	1
Gulf General Atomic	06/14			1		1																2	0
Gilbert Associates	06/16		1			1	1				1											4	2
Ralph Parsons Co.	06/16	1	2	1	2	2	1	1	1	1		2	1	2	1	1		1	2	1	1	24	3
Babcock & Wilcox	06/17	1	2	1	2	3					1											10	4
Atomic Indust. Forum	06/18	1	1		1	2	1	1	1	1	1		2	1				1	1	1	1	17	2
Yankee Atomic Electric	06/18	1																				1	0
Florida Power & Light	06/24	1				1																2	0
Southern Calif. Edison	06/24	1	1			2											1		1			6	2
General Electric	06/30		2			1		1	1	1			1	1			1		1			10	6
Total Comments		18	14	6	11	27	4	5	4	6	6	3	10	5	3	1	6	4	7	4	3	147	
Comments Incorporated		0	3	1	4	10	1	3	0	4	3	0	6	3	2	0	3	2	5	0	1		51

NOTES: *1) Column "GEN" contains "Generic" comments. 2) A bolded number means the AEC incorporated one or more, not necessarily all, of the reviewer's comments on that criterion. Total comments actually incorporated appear in the bottom row and far right column. 3) Pacific Gas & Electric sent the AEC a letter, dated 06/13/69, supporting Westinghouse's comments. 4) "Hanford Contractors" were several companies at the AEC's Hanford Nuclear Reservation whose comments were collected by the AEC's Richland Operations Office and sent to AEC Headquarters on 06/11/69.*

TABLE 3
Shifts 10CFR50 QA Requirements

CRITERIA		REVISION											
		ZION DRAFT		04/17/69 DRAFT		06/27/70 ISSUE		09/11/71 REVISION		01/20/75 REVISION		WITH TMI REQMTS	
		Words	*Percent*	Words	*Percent*	Words	*Percent*	Words	*Percent*	Words	*Percent*	Words	*Percent*
PROGRAM ADMINISTRATION		**199**	***44.2***	**684**	***39.2***	**728**	***36.6***	**728**	***36.3***	**898**	***41.3***	**1006**	***43.3***
I.	Organization	43	*9.6*	177	*10.1*	134	*6.7*	134	*6.7*	304	*14.0*	330	*14.2*
II.	QA Program	70	*15.6*	186	*10.7*	259	*13.0*	259	*12.9*	259	*11.9*	313	*13.5*
V.	Instructions, Procedures & Drawings	14	*3.1*	39	*2.2*	52	*2.6*	52	*2.6*	52	*2.4*	52	*2.2*
VI.	Document Control	26	*5.8*	80	*4.6*	85	*4.3*	85	*4.2*	85	*3.9*	113	*4.9*
XVII.	QA Records	19	*4.2*	117	*6.7*	113	*5.7*	113	*5.6*	113	*5.2*	113	*4.9*
XVIII.	Audits	27	*6.0*	85	*4.9*	85	*4.3*	85	*4.2*	85	*3.9*	85	*3.6*
III.	**DESIGN CONTROL**	**30**	***6.7***	**212**	***12.1***	**306**	***15.4***	**306**	***15.3***	**306**	***14.1***	**347**	***14.9***
PROCUREMENT		**59**	***13.1***	**194**	***11.1***	**232**	***11.7***	**238**	***11.9***	**238**	***10.9***	**238**	***10.2***
IV.	Procurement Document Control	40	*8.9*	74	*4.2*	73	*3.7*	73	*3.6*	73	*3.3*	73	*3.1*
VII.	Control of Purchased Items & Services	19	*4.2*	120	*6.9*	159	*8.0*	165	*8.2*	165	*7.6*	165	*7.1*
CONSTRUCTION & MANUFACTURING*		**134**	***29.8***	**565**	***32.3***	**639**	***32.0***	**648**	***32.2***	**648**	***29.8***	**648**	***27.9***
VIII.	Identification & Control of Items	27	*6.0*	69	*3.9*	82	*4.1*	82	*4.1*	82	*3.8*	82	*3.5*
IX.	Control of Special Processes	0	*0.0*	39	*2.2*	38	*1.9*	38	*1.9*	38	*1.7*	38	*1.6*
X.	Inspection	27	*6.0*	115	*6.6*	150	*7.5*	150	*7.5*	150	*6.9*	150	*6.5*
XI.	Test Control	0	*0.0*	94	*5.4*	125	*6.3*	128	*6.4*	128	*5.9*	128	*5.5*
XII.	Control of Measuring & Test Equipment	22	*4.9*	47	*2.7*	33	*1.7*	33	*1.6*	33	*1.5*	33	*1.4*
XIII.	Handling, Storage & Shipping	33	*7.3*	54	*3.1*	55	*2.8*	55	*2.7*	55	*2.5*	55	*2.4*
XIV.	Inspection, Test & Operating Status	0	*0.0*	83	*4.7*	98	*4.9*	104	*5.2*	104	*4.7*	104	*4.5*
XV.	Nonconforming Items	25	*5.6*	64	*3.7*	58	*2.9*	58	*2.9*	58	*2.7*	58	*2.5*
XVI.	**CORRECTIVE ACTION**	**28**	***6.2***	**91**	***5.2***	**86**	***4.3***	**86**	***4.3***	**86**	***4.0***	**86**	***3.7***
TOTAL		**450**	***100.0***	**1746**	***100.0***	**1991**	***100.0***	**2006**	***100.0***	**2176**	***100.0***	**2325**	***100.0***

* *These criteria also apply to operating nuclear power plants*

TABLE 4

Nuclear Power Plant Performance, All Licensed Plants

TIME PERIOD	NUMBER OF PLANTS	COMPOSITE AVERAGES			
		MWe	Build Time (Yrs)	Lifetime Capacity Factor	Cum. SALP Rating
OPERATING NUCLEAR POWER PLANTS					
LICENSED BEFORE 07/27/70					
Subtotal/Average	6	518.2	3.7	61.0	2.09
LICENSED AFTER 07/27/70					
CP Issued Before 04/17/69	40	819.7	6.1	61.4	1.80
CP Issued Between 04/17/69 and 07/27/70	12	867.6	6.5	58.2	1.89
CP Issued After 07/27/70	51	1070.8	10.3	67.7	1.74
Subtotal/Average	103	949.7	8.2	64.1	1.78
TOTAL/AVERAGE	109	918.9	7.9	64.0	1.79
PERMANENTLY CLOSED NUCLEAR POWER PLANTS					
LICENSED BEFORE 07/27/70					
Subtotal/Average	15	99.1	- 4.5	38.9	Note 1
LICENSED AFTER 07/27/70					
CP Issued Before 04/17/69 [Note 2]	2	601.5	7.1	25.4	2.03
CP Issued Between 04/17/70 and 07/27/70 [Note 3]	1	906.0	8.8	85.1	Note 1
CP Issued After 07/27/70 [Note 4]	2	947.5	8.7	27.4	1.76
Subtotal/Average	5	800.8	8.1	38.1	1.90
TOTAL/AVERAGE	20	277.4	5.5	36.8	N/A
ALL NUCLEAR POWER PLANTS					
LICENSED BEFORE 07/27/70					
Operating Plants	6	518.2	3.8	59.6	2.05
Permanently Closed Plants	15	99.1	4.5	38.9	N/A
All Plants	21	218.8	4.3	45.2	N/A
LICENSED AFTER 07/27/70					
Operating Plants	103	949.7	8.2	64.1	1.78
Permanently Closed Plants	5	800.8	8.1	38.1	N/A
All Plants	108	942.7	8.2	62.9	1.78

NOTES: 1) SALP ratings were not available, because the NRC did not start performing SALP inspections until after the March 1979 accident at Three Mile Island. **2)** Rancho Seco and Fort St. Vrain received CPs during 1968. **3)** Three Mile Island 2 received a CP during November 1969. **4)** Trojan received a CP during 1971 and Shoreham received a CP during 1973.

REFERENCES: 1) Table 6 was the basis for data on plants licensed before 07/27/70. **2)** Supplement VI was the basis for plants shut down after 1970. **3)** For plants licensed after 07/27/70, MWe and build times were based on, *NUREG-1350, Nuclear Regulatory Commission Information Digest*, U.S. Nuclear Regulatory Commission, Washington, DC, March 1990. **4)** For plants licensed after 07/27/70, Lifetime Capacity Factors were based on "Operating U.S. Power Reactors," *Nuclear Safety*, U.S. Department of Energy, Washington, DC, April-June 1991, pp. 275-281. **5)** For plants licensed after 07/27/70, Cumulative SALP Ratings were based on NUREG-1214, *Historical Data Summary of the Systemmatic Assessment of Licensee Performance*, U.S. Nuclear Regulatory Commission, Washington, DC, August 1990.

TABLE 5
Public Citizen's Ranking of Nuclear Power Plants Built Prior to 1971

NO.	PLANT[1]	FIRST ELECTRICITY	REACTOR AGE[2] (YEARS)	REACTOR POWER (MWe)	ON NRC PROBLEM LIST?	RANK (Worst to Best)[3]			
						Average	1984-85	1987-88	1989-90
1	Oyster Creek	09/23/69	17.76	620	Yes	8	13	5	5
2	La Crosse	04/26/68	19.01	48	No	33	33	Note 4	Note 4
3	Dresden 2	04/13/70	17.50	772	No	33	19	69	11
4	Nine Mile Point 1	11/09/69	17.63	610	Yes	34	52	43	6
5	Haddam Neck	08/07/67	19.89	569	No	35	57	21	26
6	**Robinson 2**	**09/26/70**	**16.75**	**665**	**No**	**36**	**50**	**40**	**17**
7	San Onofre 1	07/16/67	19.95	436	No	43	54	46	30
8	**Millstone 1**	**11/29/70**	**16.57**	**654**	**No**	**49**	**73**	**41**	**32**
9	**Monticello**	**03/05/71**	**16.31**	**536**	**No**	**51**	**59**	**50**	**43**
10	Big Rock Point	12/08/62	24.55	69	No	54	53	16	94
11	Ginna	12/02/69	17.56	470	No	62	71	73	41
12	Yankee Rowe	11/10/60	26.62	167	No	68	68	47	85
13	**Point Beach 1**	**11/06/70**	**16.64**	**485**	**No**	**90**	**79**	**Note 5**	**101**
				Total Operating Plants		94	81	89	111
				Total Attributes/Plant		11	8[6]	10[7]	14[8]

NOTES

*1) Plants in bold type were started up after 10CFR50, Appendix B, was issued for use on 06/27/70. **2)** For other than La Crosse (see Note 4), reactor ages are as of 07/01/87, midway between the composite 1984-90 reporting periods. **3)** Shaded areas cover plants that were in the "Poorest 50%" for that reporting period. **4)** The Public Citizen did not rank La Crosse during 1987-88 and 1989-90, because the plant was permanently closed on 04/30/87. **5)** The Public Citizen did not rank Point Beach 1 during 1987-88. The reason is not known. **6)** Attributes were: a) 1984 Scrams, b) 1985 Scrams, c) 1984-85 SALP (Systematic Assessment of Licensee Performance) Rating, d) 1984 Licensee Event Reports (LERs), e) 1985 LERs, f) 1984 Capacity Factor (CF), g) 1985 CF, h) and Cum. CF. Because 81 operating plants were ranked with 32 plants under construction, the 13 listed plants fared better than they would if only compared to other operating plants. **7)** Attributes were: a) 1987-88 Scrams, b) 1987-88 SALP Rating, c) 1987-88 LERs, d) 1987-88 CF, e) 1987-88 Forced Outages, f) 1987-88 Operating & Maintenance Costs, g) 1983-87 Major Repair & Backfit Costs, h) 1987-88 NRC Violations, i) 1986-87 Plant Personnel Radiation Exposures, and j) 1986 Offsite Radiation Releases. Results were somewhat skewed because overall rankings were based on total points and plants only received points if they made one of ten "Worst 20" lists. **8)** Attributes were the same as for 1987-88, updated for 1989-90, except that the Public Citizen dropped "Major Repair & Backfit Costs" and added: a) Safety System Actuations, b) Significant Operating Events, c) Safety System Failures, d) Low Level Waste Shipments, and e) Spent Fuel in Storage.*

TABLE 6
Performance Data on Nuclear Power Plants Built Prior to 1971

NO.	PLANT	FIRST ELECT.	MWe	INITIAL EXPENSE		ELECT. OUTPUT		PAIN & AGONY	
				Build Time (Yrs)	Cost ($M)	Plant Life (Yrs)	Lifetime Capacity Factor	Cum. SALP Rating	Major Problems
1	EBR-1[UL]	12/20/51	0.15	2.00	3.3	12.00	3.5	---	3
2	Shippingport[UL]	12/18/57	60.0	2.75	74.0	24.77	47.9	---	4
3	SL-1[UL]	10/24/58	0.30	2.50	2.6	1.32	66.4	---	1
4	WTR	08/01/59	60.0	2.15	20.0	0.70	N/A	---	1
5	Dresden 1	04/15/60	200.0	3.86	51.0	18.54	50.6	---	8
6	Yankee Rowe[DP]	11/10/60	167.0	3.02	52.4	31.14	71.5	1.36	6
7	Indian Point 1	09/16/62	265.0	6.26	263.0	12.12	37.8	---	5
8	Saxton	11/16/62	3.2	2.75	6.2	9.38	26.5	---	3
9	Big Rock Point[DP]	12/08/62	69.0	2.43	26.2	30.07	56.3	1.69	7
10	Humboldt Bay	04/18/63	65.0	2.36	24.2	13.21	60.6	---	5
11	Hallam[DP]	05/29/63	75.0	2.89	60.3	1.26	23.2	---	3
12	Elk River[DP]	08/24/63	22.0	3.60	14.4	4.44	59.7	---	4
13	Piqua[DP]	11/04/63	11.4	3.68	8.2	2.16	32.7	---	3
14	CVTR[DP]	12/18/63	17.0	3.54	19.3	3.04	46.9	---	3
15	Bonus[DP]	08/14/64	16.5	4.56	18.0	3.80	12.4	---	6
16	Hanford-N[UL]	04/08/66	860.0	6.85	145.0	20.66	43.7	---	8
17	Pathfinder[DP]	07/25/66	58.5	6.12	25.8	1.19	15.8	---	2
18	Fermi 1[DP]	08/05/66	60.9	10.00	48.8	6.32	0.1	---	6
19	Peach Bottom 1[DP]	01/27/67	40.0	4.85	28.1	7.76	44.5	---	7
20	San Onofre 1[DP]	07/16/67	436.0	4.28	98.5	23.89	51.0	1.81	14
21	Haddam Neck[DP]	08/07/67	569.0	3.12	109.3	25.41	72.4	1.46	6
22	La Crosse[DP]	04/26/68	48.0	5.08	19.1	19.01	49.0	2.03	6
23	Oyster Creek	09/23/69	620.0	4.69	91.4	23.28	51.6	2.01	20
24	Nine Mile Point 1	11/09/69	610.0	4.49	150.5	23.15	54.7	1.81	11
25	Ginna	12/02/69	470.0	3.52	64.9	23.08	73.8	1.62	8
26	Dresden 2	04/13/70	772.0	4.17	101.3	22.72	57.2	1.80	17
27	***ROBINSON 2***	*09/26/70*	*569.0*	*3.36*	*76.4*	*22.27*	*60.6*	*1.81*	*9*
28	***POINT BEACH 1***	*11/06/70*	*485.0*	*3.21*	*60.6*	*22.16*	*72.8*	*1.60*	*7*
29	***MILLSTONE 1***	*11/29/70*	*654.0*	*4.52*	*92.0*	*22.09*	*70.6*	*1.37*	*11*
30	***MONTICELLO***	*03/05/71*	*53[illegible].0*	*3.62*	*88.8*	*21.83*	*69.9*	*1.52*	*5*

NOTES: 1) Shaded areas cover nuclear power plants with current Operating Licenses. 2) Data is from Supplement V. 3) "Major Problems" are high-lighted with a check (✓) in Supplement. 4) Plants in capital letters were licensed after 10CFR50, Appendix B, was issued for use. 5) Plants marked with a DP-designator were Power Reactor Demonstration Plants and those marked with an UL-designator were unlicensed plants. 6) Plant lives are based on the age of the plant at the time it was permanently shut down or, if still operating, its age as of 12/31/92.

TABLE 7
Author's Ranking of Nuclear Power Plants Built Prior to 1971

RANK (Worst to Best)	PLANT	FIRST ELECTRICITY	MWe	POINTS			
				Total	Initial Expense	Electrical Output	Pain & Agony
1	Fermi 1[DP]	08/05/66	60.0	27.8	8.3	10.0	9.5
2	Indian Point 1	09/16/62	265.0	25.7	9.2	8.9	7.7
3	Bonus[DP]	08/14/64	16.5	25.5	7.5	9.9	8.1
4	SL-1[UL]	10/24/58	0.3	24.7	4.9	9.8	10.0
5	EBR-1[UL]	12/20/51	0.15	24.5	5.3	9.9	9.3
6	Pathfinder[DP]	07/05/66	60.0	24.3	7.3	10.0	7.0
7	Peach Bottom 1[DP]	01/27/67	40.0	24.1	7.4	9.2	7.5
8	Hallam[DP]	05/29/63	75.0	23.9	6.1	9.9	7.9
9	WTR	08/01/59[4]	60.0[4]	23.7	4.0	9.9[4]	9.8
10	CVTR[DP]	12/18/63	17.0	23.1	6.4	9.7	7.0
11	San Onofre 1[DP]	07/16/67	436.0	22.9	6.6	8.2	8.1
12	Piqua[DP]	11/04/63	11.4	22.1	5.1	9.8	7.0
13	Elk River[DP]	08/24/63	22.0	21.5	5.0	9.4	7.1
14	Saxton	11/16/62	3.2	21.3	5.5	9.4	6.5
15	La Crosse[DP]	04/26/68	48.0	21.2	6.9	7.8	6.5
16	Hanford-N[UL]	04/08/66	860.0	21.1	6.2	7.9	7.0
17	Dresden 1	04/15/60	200.0	20.3	5.2	7.8	7.3
18	Shippingport[UL]	12/18/57	60.0	19.9	7.3	7.3	5.3
19	Nine Mile Point 1	11/09/69	610.0	19.6	6.4	5.7	7.5
20	Oyster Creek	09/23/69	620.0	19.4	4.9	6.0	8.5
21	Humboldt Bay	04/18/63	65.0	18.9	4.3	8.1	6.5
22	Dresden 2	04/13/70	772.0	18.6	4.6	5.4	8.6
23	***MILLSTONE 1***	*11/29/70*	*654.0*	*16.8*	*4.9*	*4.4*	*7.5*
24	***ROBINSON 2***	*09/26/70*	*665.0*	*16.2*	*4.0*	*5.1*	*7.1*
25	Ginna	12/02/69	470.0	15.6	4.6	4.2	6.8
26	Big Rock Point[DP]	12/08/62	69.0	15.2	4.4	5.5	5.3
27	Yankee Rowe[DP]	11/10/60	167.0	14.5	4.8	5.1	4.6
28	Haddam Neck[DP]	08/07/67	569.0	14.3	3.8	4.3	6.2
29	***MONTICELLO***	*03/05/71*	*536.0*	*13.7*	*4.6*	*4.4*	*4.7*
30	***POINT BEACH 1***	*11/06/70*	*485.0*	*13.5*	*4.4*	*4.3*	*4.8*

NOTES: 1) Shaded areas cover plants with active Operating Licenses. 2) Plants in capital letters were licensed after 10CFR50, Appendix B, was issued for use. 3) Plants with a DP-designator were Power Reactor Demonstration Plants; those with an UL-designator were unlicensed. 4) WTR was a 60.0 MWt test reactor started up during 1959.

TABLE 8
Performance of Closed Nuclear Plants Licensed After 1970

NO.	PLANT	FIRST ELECT.	MWe	INITIAL EXPENSE			ELECTRICAL OUTPUT			PAIN & AGONY			TOTAL POINTS
				Build Time (Yrs)	Cost ($M)	Points	Plant Life (Yrs)	Lifetime Capacity Factor	Points	Cum. SALP Rating	Major Problems	Points	
1	Rancho Seco	10/13/74	873.0	6.01	338.3	4.3	14.62	36.1	8.9	2.00	15	8.8	22.0
2	Trojan	05/20/76	1075.0	5.29	460.0	3.7	16.47	52.0	8.0	1.80	14	8.3	20.0
3	Fort St. Vrain	12/11/76	330.0	8.25	274.1	6.6	11.69	14.7	9.4	2.07	10	8.2	24.2
4	Three Mile Island 2	09/18/78	906.0	8.81	714.9	5.1	0.55	85.1	9.8	N/A	7	9.9	24.8
5	Shoreham	07/08/85	820.0	12.24	5480.0	9.8	3.80	0.0	10.0	1.73	9	9.6	29.4

NOTES
1. The majority of data in this table is based on information in Supplement VI.
2. "Initial Expense" points took into consideration plant size and average construction costs and durations during the late 1960s and early 1970s as reported in DOE/EIA-0485, *An Analysis of Nuclear Power Plant Construction Costs*, U.S. Department of Energy, Washington, DC, 1990.
3. "Major Problems" are highlighted with a check (✓) in Supplement VI.

TABLE 9
Nuclear Power Plants Cancelled Since 1970

1972 (4 PLANTS)
Perryman 1&2
Verplank 1&2

1974 (7 PLANTS)
Tyrone 2
Quanicassee 1&2
Vidal 1&2
Vogtle 3&4 (0%, 0%)

1975 (14 PLANTS)
Fermi 3
Pilgrim 3
Barton 3&4
Fulton 1&2
Orange 1&2
St. Rosalie 1&2
Somerset 1&2
Summit 1&2

1976 (1 PLANT)
Allens Creek 2

1977 (10 PLANTS)
Ft. Calhoun 2
Sears Isle
Barton 1&2
Douglas Point 1&2
South Dade 1&2
Surry 3&4 (0%, 0%)

1978 (14 PLANTS)
Haven 2
North Coast 1
Zimmer 2

1978 - CONT'D
Blue Hills 1&2
Sundesert 1&2
South River 1, 2 & 3
Atlantic 1, 2, 3 & 4

1979 (8 PLANTS)
Greene County
Tyrone 1 (0%)
New England 1&2
Palo Verde 4&5
Stanislaus 1&2

1980 (16 PLANTS)
Forked River (6%)
Haven 1
North Anna 4 (4%)
Sterling (0%)
Davis-Besse 2&3 (0%, 0%)
Erie 1&2
Greenwood 2&3
Jamesport 1&2 (0%, 0%)
Montague 2&3
New Haven 1&2

1981 (6 PLANTS)
Bailly (1%)
Callaway 2 (1%)
Hope Creek 2 (18%)
Pilgrim 2
Harris 3&4 (1%, 1%)

1982 (18 PLANTS)
Allens Creek 1
North Anna 3 (9%)

1982 - CONT'D
Vandalia
Black Fox 1&2 (0%, 0%)
Cherokee 2&3 (0%, 0%)
Hartsville B1&2 (17%, 7%)
Pebble Springs 1&2
Phipps Bend 2&3 (25%, 5%)
WNP 4&5 (24%, 16%)
Perkins 1, 2 & 3

1983 (6 PLANTS)
Cherokee 1 (18%)
Clinch River (1%)
Clinton 2 (0%)
Harris 2 (4%)
Skagit 1&2

1984 (10 PLANTS)
River Bend 2 (0%)
Zimmer 1 (97%)
Hartsville A1&2 (44%, 34%)
Marble Hill 1&2 (60%, 37%)
Midland 1&2 (85%, 85%)
Yellow Creek 1&2 (35%, 3%)

1988 (2 PLANTS)
Carroll 1&2

1989 (1 PLANT)
Seabrook 2 (23%)

1990 (1 PLANT)
Grand Gulf 2 (33%)

LEGEND:
1. Plants in bold letters received Construction Permits prior to cancellation.
2. Plants in italics received Limited Work Authorizations (LWAs) prior to cancellation.
3. Numbers in parenthesis represent construction percent complete at time of cancellation.

NOTES:
1. Most of the information in this table came from DOE/EIA-0438, *Commercial Nuclear Power 1991*, U.S. Department of Energy, Washington, DC, August 1991, pp. 105-110; NUREG-1350, *Nuclear Regulatory Commission Information Digest*, Volume 2, U.S. Nuclear Regulatory Commission, Washington, DC, March 1990, pp. 92-94; and *Nuclear News* biannual "World List of Nuclear Power Plants." © 1975-1989 by American Nuclear Society
2. At various times prior to cancellation, Haven 1&2 had been called Koshkonong 1&2, Stanislaus 1&2 called Mendocino 1&2, North Coast 1 called Aguirre, Vandalia called Central Iowa, and Hope Creek 2 called Newbold Island 2.
3. Nuclear plants that have been deferred include Bellefonte 1&2 (85%, 56%), Perry 2 (44%), and WNP 1&3 (63%, 75%). Based on DOE/EIA-0438 (pp. 101-102), Perry 2 and WNP 3 are the most likely to eventually be cancelled.

TABLE 10
Significance of Appendix B Weaknesses

WEAKNESS		SIGNIFICANCE			WEAKNESS CARRIED OVER INTO NQA-1?	REMARKS
Para	Title	Major	Moderate	Minor		
5.2 REDUNDANCY						
5.2.2	Organization			1	No	
5.2.3	Special Processes			2	Yes	
5.2.4	Design Verification	9			Yes	See Note 1
5.2.5	Acceptance Criteria		4		Yes	NQA-1 is being revised to partially correct this weakness
5.2.6	Document Changes		6		Yes	NQA-1 is being revised to partially correct this weakness
5.2.7	Identification & Control			2	Yes	
5.3 TERMINOLOGY						
5.3.2	Items			1	No	
5.3.3	Measures			1	No	
5.3.4	Instructions			3	Yes	
5.3.5	Equipment			2	Yes	
5.3.6	Audit Procedures			2	Yes	
5.4 GROUPING OF REQUIREMENTS						
5.4.2	Criterion IV		5		Yes	The distribution of procurement documents should be controlled
5.4.3	Criterion XIII			2	Yes	
5.4.4	Criterion XV	8			Yes	See Note 2
5.5 BALANCE						
5.5.2	Management	10			Yes	See Note 3
5.5.3	Design Control		7		No	See Note 4
5.5.4	Safety Analysis Reports		6		Yes	Three Mile Island and Midland had *SAR* problems
5.5.5	Order Entry		5		Yes	Procurement documents should require order entry procedures
5.5.6	QA Program Documents	8			Yes	See Note 5
5.5.7	Surveillances			3	Yes	NQA-1 is being revised to correct this weakness
5.5.8	Operation & Maintenance	8			Yes	See Note 6
5.5.9	Decommissioning		4		Yes	NQA-1 is being revised to correct this weakness

WEAKNESS SCALE **Major:** 10, 9, and 8 **Moderate:** 7, 6, 5, and 4 **Minor:** 3, 2, and 1

NOTES

1. *Design errors overlooked during initial design verification have been the second leading reason for equipment failures at operating plants. Refer to Section 6.0 for design problems at Trojan, Fort St. Vrain, Three Mile Island, and Zimmer.*
2. *Promptly recognizing potential adverse quality trends was identified as a generic nuclear industry problem in NUREG-1055. Refer to Section 6.0 for trending problems at Rancho Seco, Zimmer, Marble Hill, and Midland.*
3. *NUREG-1055 identified management apathy to be the biggest reason for quality problems in the nuclear industry. Refer to Section 6.0 for management-related problems at Rancho Seco, Trojan, Fort St. Vrain, Three Mile Island, Shoreham, Zimmer, Marble Hill, and Midland.*
4. *During March 1979, five plants were shut down for several months after errors were found in a computer program used to calculate seismic stresses in piping systems. Refer to Section 6.0 for siting problems at Shoreham.*
5. *NRC studies identified a lack-of-detail in procedures as one of the main reasons for abnormal occurrences at operating plants. Refer to Section 6.0 for problems with construction procedures at Zimmer.*
6. *Improper maintenance has been the main reason for equipment failures at operating plants. Refer to Section 6.0 for operating and maintenance problems at Rancho Seco, Fort St. Vrain, and Three Mile Island.*

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