A Short History of Nuclear Regulation, 1946 - 1999

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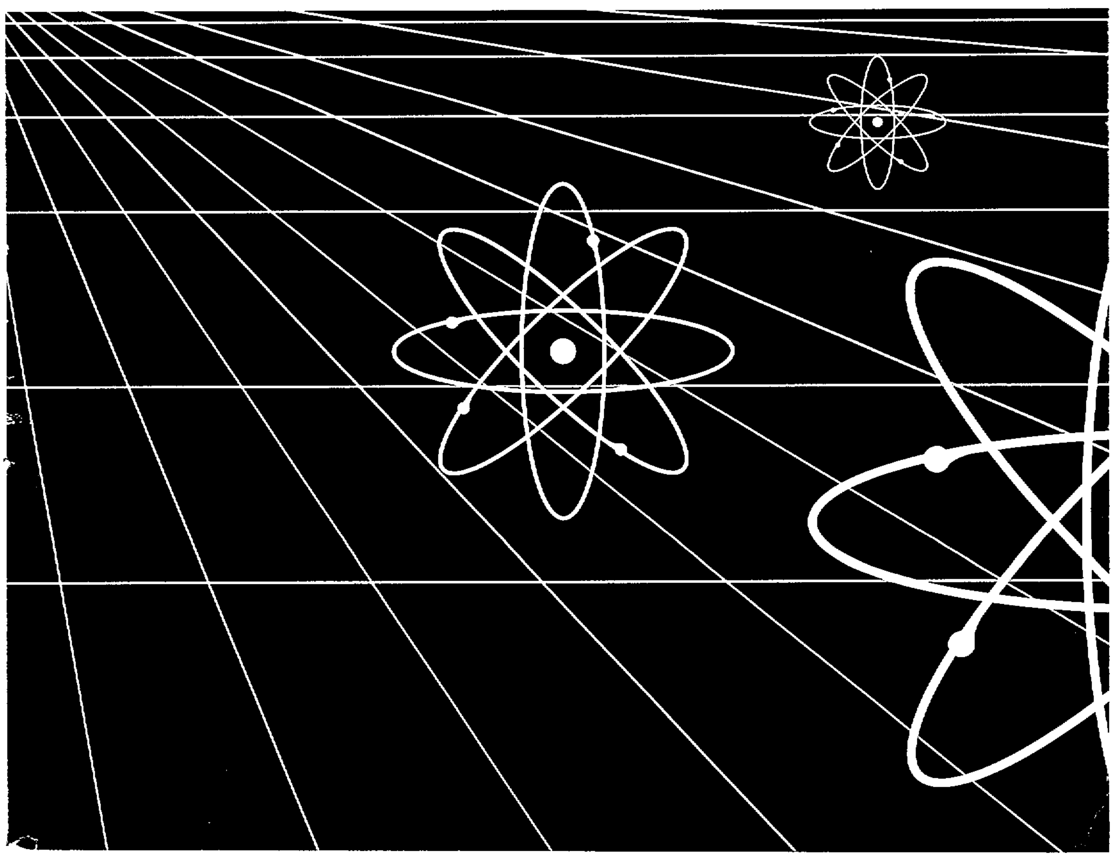

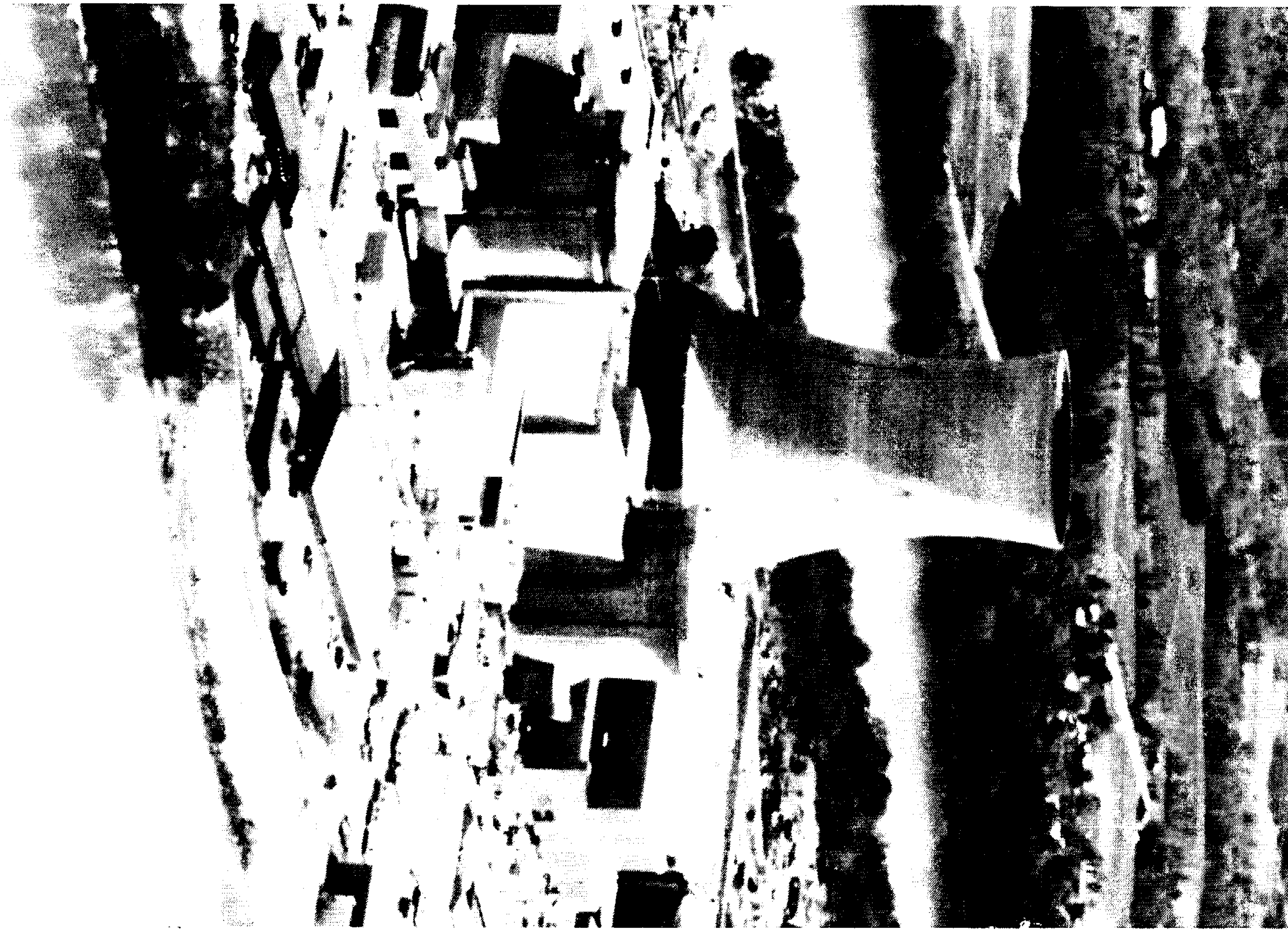

Preface

History, automobile maker Henry Ford once said, "is more or less . . . bunk." Philosopher George Santayana was more charitable in his assessment of the discipline when he declared that "those who fail to study the past are condemned to repeat it." In a sense, both Ford and Santayana were right. Much of the past has little meaning or importance for the present and deservedly remains forgotten in the dustbins of history. But other parts of the past need to be remembered and studied in order to make sense out of the present. Today's events are a direct outgrowth of yesterday's, and understanding the history of any given problem is essential to approaching it knowledgeably. It is the task of the historian to gather evidence, to separate what is important from what is not, and to explain key events and decisions of the past.

This short history of nuclear regulation provides a brief overview of the most significant events in the agency's past. Space limitations prevent discussion of all the important occurrences, and even the subjects that are included cannot be covered in full detail. The first chapter of this account is drawn from the first volume of the NRC's history, *Controlling the Atom: The Beginnings of Nuclear Regulation, 1946–1962* (University of California Press, 1984). The second chapter is largely based on the second volume of the NRC's history, *Containing the Atom: Nuclear Regulation in a Changing Environment, 1963–1971* (University of California Press, 1992). The findings and conclusions on events that occurred after 1971 should be regarded as preliminary and tentative; they are not based on extensive research in primary sources. It is my hope, however, that this overview will help explain how the past has shaped the present and illuminate the considerations that have influenced regulatory decisions and procedures over the years. It is also my hope that this outline will suggest that history should be viewed as something more valuable than "bunk."

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Chapter 1

The Formative Years of Nuclear Regulation, 1946–62

The use of atomic bombs against the Japanese cities of Hiroshima and Nagasaki in August 1945 ushered in a new historical epoch, breathlessly labeled in countless news reports, magazine articles, films, and radio broadcasts as the "Atomic Age." Within a short time after the end of World War II, politicians, journalists, scientists, and business leaders were suggesting that peaceful applications of nuclear power could be as dramatic in their benefits as nuclear weapons were awesome in their destructive power. Nuclear physicist Alvin M. Weinberg told the Senate's Special Committee on Atomic Energy in December 1945: "Atomic power can cure as well as kill. It can fertilize and enrich a region as well as devastate it. It can widen man's horizons as well as force him back into the cave." *Newsweek* reported that "even the most conservative scientists and industrialists [are] willing to outline a civilization which would make the comic-strip prophecies of Buck Rogers look obsolete." Observing that ideas for the civilian uses of atomic energy ranged "from the practical to the fantastic," it cited a few examples: atomic-powered airplanes, rockets, and automobiles, large electrical generating stations, small "home power plants" to provide heat and electricity in individual homes, and tiny atomic generators wired to clothing to keep a person cool in summer and warm in winter.

Developing nuclear energy for civilian purposes, as even the most enthusiastic proponents recognized, would take many years. The government's first priority was to maintain strict control over atomic technology and to exploit it further for military purposes. The Atomic Energy Act of 1946, passed as tensions with the Soviet Union were developing into the cold war, acknowledged in passing the potential peaceful benefits of atomic power. But it emphasized the military aspects of nuclear energy and underscored the need for secrecy, raw materials, and production of new weapons. The 1946 law did not allow for private, commercial application of atomic energy; rather, it created a virtual government monopoly of the technology. To manage the nation's atomic energy programs, the act established the five-member Atomic Energy Commission (AEC).

In 1954, Congress passed new legislation that for the first time permitted the wide use of atomic energy for peaceful purposes. The 1954 Atomic Energy Act redefined the atomic energy program by ending the government monopoly on technical data and making the growth of a private commercial nuclear industry an urgent national goal. The measure directed the AEC "to encourage widespread participation in the development and utilization of atomic energy for peaceful purposes." At the same time, it instructed the agency to prepare regulations that would protect public health and safety from radiation hazards. Thus, the 1954 act assigned the AEC three major roles: to continue its weapons program, to promote the private use of atomic energy for peaceful applications, and to protect public health and safety from the hazards of commercial nuclear power. Those functions were in many respects inseparable and incompatible, especially when combined in a single agency. The competing responsibilities and the precedence that the AEC gave to its military and promotional duties gradually damaged the agency's credibility on regulatory issues and undermined public confidence in its safety program.

The AEC's regulatory program was most directly affected by the agency's commitment to encouraging the rapid growth of civilian nuclear power. The initial impetus for peaceful atomic development came mostly from considerations other than meeting America's energy demands. In the early 1950s, projections of future energy requirements predicted that atomic power would eventually play an important role in the nation's energy supplies, but they did not suggest an immediate need to construct atomic power reactors. The prevailing sense of urgency, at least among government leaders, that led to the 1954 Atomic Energy Act and to the growth of commercial nuclear power derived instead largely from the fear of falling behind other nations in fostering peaceful atomic progress. The strides that Great Britain was making in the field seemed disturbing enough, but the possibility that the Soviet Union might surpass the United States in civilian power development was even more ominous. AEC commissioner Thomas E. Murray described a "nuclear power race" in a 1953 speech and warned that the "stakes are high." He added: "Once we become fully conscious of the possibility that power hungry countries will gravitate toward the USSR if it wins the nuclear power race, . . . it will be quite clear that this power race is no Everest-climbing, kudos-providing contest." Like Murray, many government officials emphasized that surrendering America's lead in expanding the peaceful applications of atomic energy would deal a severe blow to its international prestige and world scientific dominance.

The eagerness to push for rapid civilian nuclear development was intensified by an impulse to show that atomic technology could serve constructive purposes as well as destructive ones. The assertions made shortly after World War II that atomic energy could provide spectacular advances that would raise living standards throughout the world remained unproven and largely untested. As the nuclear arms race took on more terrifying proportions with the development of thermonuclear bombs, the desire to demonstrate the benefits of atomic energy became more acute. President Dwight D. Eisenhower, spurred by the detonation of the Soviet Union's first hydrogen device, starkly depicted the horror of nuclear warfare in a widely publicized address to the United Nations in December 1953. At the same time, he emphasized that "this greatest of all destructive forces can be developed into a great boon, for the benefit of all mankind." Eisenhower's appeal for peaceful nuclear progress and his affirmation of the potential blessings of civilian atomic energy were echoed by many other high government officials.

By 1954, a broad political consensus viewed the development of nuclear energy for civilian purposes as a vital goal. The Atomic Energy Act of that year resulted partly from perceptions of the long-range need for new energy sources, but mostly from the immediate commitment to maintain America's world leadership in nuclear technology, enhance its international prestige, and demonstrate the benefits of peaceful atomic energy. It infused the atomic power program with a sense of urgency, and in that atmosphere, the AEC established its developmental and regulatory policies. The 1954 act gave the AEC wide discretion on how to proceed. Despite the general agreement on ultimate objectives, the means by which they should be accomplished soon created sharp differences.

The AEC favored a partnership between government and industry in which private firms would play an integral role in demonstrating and expanding the use of atomic power. "The Commission's program," AEC chairman Lewis L. Strauss explained, "is directed toward encouraging development of the uses of atomic energy in the framework of the American free enterprise system." It was the AEC's conviction, he added, "that competitive economic nuclear power . . . would be most quickly achieved by construction and operation of full-scale plants by industry itself." To accomplish its objectives, the AEC announced a "power demonstration reactor program" in January 1955. The agency offered to perform research and development on power reactors in its national laboratories, to subsidize additional research undertaken by industry under fixed-sum contracts, and to waive for seven years the established fuel use charges for the loan of fissionable materials (which the government would continue to own). For their part, private utilities and vendors would supply the capital for construction of nuclear plants and pay operating expenses other than fuel charges. The purpose of the demonstration program was to stimulate private participation and investment in exploring the technical and economic feasibility of different reactor designs. At that time, no single reactor type had clearly emerged as the most promising of the several that had been proposed.

The AEC's incentives received a mixed response from private industry. For several years, some utility executives had shown a keen interest in investigating the use of nuclear fission for generating electricity. But commercial applications of atomic energy had been thwarted by the severe limitations on access to technical information dictated by the 1946 Atomic Energy Act. In 1953, when the Joint Committee on Atomic Energy, created by the 1946 act to carry out congressional oversight of the AEC, conducted public hearings on peaceful atomic development, spokesmen for private firms emphasized that industrial progress was possible only if the restrictions on obtaining data were eased. By opening nuclear technology to commercial applications, the 1954 Atomic Energy Act largely satisfied those complaints. From the perspective of utility companies, the act offered an opportunity to participate in nuclear development and gain experience in a technology that promised to help meet long-term energy demands. Vendors of reactor components welcomed the prospects of expanding their markets, not only in the United States but also in foreign countries where the need for new sources of power was more immediate.

The enthusiasm of the private utility industry for nuclear power development, however, was tempered by other considerations. Although experiments with AEC-owned reactors had established the technical feasibility of using nuclear fission to produce electricity, many scientific and engineering questions remained to be answered. Despite the financial inducements the AEC offered through its power demonstration reactor program, the capital and operating costs of atomic power were certain to be much higher than those of fossil fuel plants, at least in the early stages of development. Across the industry, the prospects of realizing short-term profits from nuclear power were dim. An American Management Association symposium in 1957 concluded: "The atomic industry has not been—and is not likely to be for a decade—attractive as far as quick profits are concerned." When Lewis Strauss made his oft-quoted statement in 1954 that nuclear power could provide electricity "too cheap to meter," he was referring to long-term (and far-fetched) hopes rather than to immediate realities. He knew as well as industry analysts that the heavy investments required were a major impediment to the growth of nuclear power.

In addition to financial considerations, recognition of the hazards of the technology intensified industry's reservations about nuclear power. Based on experience with government test reactors and the prevailing faith in the ability of scientists and engineers to solve technological problems, the AEC and industry leaders regarded the chances of a disastrous atomic accident as remote. But they did not dismiss the possibility entirely. Francis K. McCune, general manager of the Atomic Products Division of General Electric, told the Joint Committee in 1954 that "no matter how careful anyone in the atomic energy business may try to be, it is possible that accidents may occur."

Mindful of both the costs and the risks of atomic power, the electric utility industry responded to the 1954 Atomic Energy Act and the AEC's demonstration program with restraint. Although many utilities were interested in exploring the potential of nuclear power, few were willing to press ahead rapidly in the face of existing uncertainties. The AEC was gratified, and rather surprised, that by August 1955 five power companies—either as individual utilities or as consortiums—had announced plans to build nuclear plants. Two decided to proceed without government assistance and three others submitted proposals for projects under the AEC's power demonstration program.

The Joint Committee on Atomic Energy was less impressed with the response of private industry to the 1954 act and the AEC's incentives. The Democratic majority on the committee favored a larger government role in accelerating nuclear development, which conflicted with the AEC's commitment to encouraging maximum private participation. The issue became a major source of contention between the AEC and the Joint Committee, contributing a philosophical dispute to relations that were already strained by political differences and a bitter personal feud between Strauss and Joint Committee chairman Clinton P. Anderson.

In 1956, two Democratic members of the Joint Committee, Representative Chet Holifield and Senator Albert Gore, introduced legislation directing the AEC to construct six pilot nuclear plants, each of a different design, in order to "advance the art of generation of electrical energy from nuclear energy at the maximum possible rate." Supporters of the bill contended that the United States was falling behind Great Britain and the Soviet Union in the quest for practical and economical nuclear power. Opponents of the measure denied that the United States had surrendered its lead in atomic technology and insisted that private industry was best able to expedite further development. Strauss declared that "we have a civilian program that is presently accomplishing far more than we had reason to expect in 1954." The Gore-Holifield bill was defeated by a narrow margin in Congress, but the views it embodied and the impatience of the Joint Committee for rapid development placed a great deal of pressure on the AEC to show that its reactor programs were producing results.

The AEC's determination to push nuclear development through a partnership in which private industry played a vital role had a major impact on the agency's regulatory policies. The AEC's fundamental objective in drafting regulations was to ensure that public health and safety were protected without imposing overly burdensome requirements that would impede industrial growth. Commissioner Willard F. Libby articulated an opinion common among AEC officials when he remarked in 1955: "Our great hazard is that this great benefit to mankind will be killed aborning by unnecessary regulation." Other proponents of nuclear development shared those views. They realized that safety was indispensable to progress; an accident could destroy the fledgling industry or at least set it back many years. At the same time, they worried that regulations that were too restrictive or inflexible would discourage private participation and investment in nuclear technology.

The inherent difficulty the AEC faced in distinguishing between essential and excessive regulations was compounded by technical uncertainties and limited operating experience with power reactors. The safety record of the AEC's own experimental reactors engendered confidence that safety problems could be resolved and the possibility of accidents kept to "an acceptable calculated risk." But experience to that time offered little definitive guidance on some important technical and safety questions, such as the effect of radiation on the properties of reactor materials, the durability of steel and other metals under stress in a reactor, the ways in which water reacted with uranium, thorium, aluminum, and other elements in a reactor, and the measures needed to minimize radiation exposure in the event of a large accident.

The AEC's regulatory staff, created soon after the passage of the 1954 Atomic Energy Act, confronted the task of writing regulations and devising licensing procedures rigorous enough to assure safety but flexible enough to allow for new findings and rapid changes in atomic technology. Within a short time the staff drafted rules and definitions on radiation protection standards, distribution and safeguarding of fissionable materials, and reactor operators' qualifications. It also established procedures for licensing privately-owned reactors. The 1954 act outlined a two-step procedure for granting licenses. If the AEC found the safety analysis submitted by a utility for a proposed reactor to be acceptable, it would issue a construction permit. After construction was completed and the AEC determined that the plant fully met safety requirements, the applicant would receive a license to load fuel and begin operation.

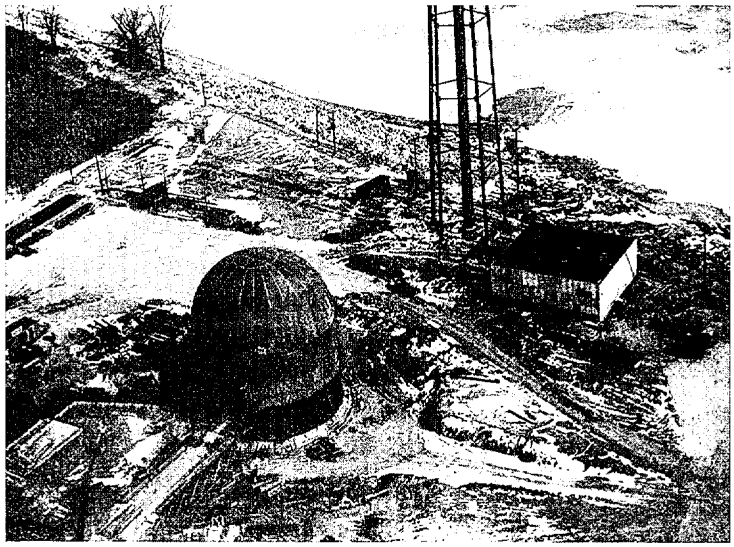
Because of the uncertainties in technical knowledge and the AEC's goal of encouraging different reactor designs, the agency had to judge license applications on a case-by-case basis. The early state of the technology precluded the possibility of formulating universal standards for all aspects of reactor engineering. The regulatory staff reviewed the information that applicants supplied on the suitability of the proposed site, construction specifications, a detailed plan of operation, and safety features. The proposal received further scrutiny from a panel of outside experts, the Advisory Committee on Reactor Safeguards (ACRS). The ACRS, composed of part-time consultants who were recognized authorities on various aspects of reactor technology, conducted its own independent review of the application. The recommendations of the staff and the ACRS went to the commissioners, who made the final decision on whether or not to approve a construction permit or operating license. (Later, the Commission delegated consideration of regulatory staff and ACRS judgments to panels drawn from the "Atomic Safety and Licensing Board" while retaining final jurisdiction in licensing cases if it chose to review a board ruling).

The AEC did not require that a prospective power reactor owner submit finalized technical data on the safety of a facility to receive a construction permit. The agency was willing to grant a conditional permit as long as the application provided "reasonable assurance" that the projected plant could be constructed and operated at the proposed site "without undue risk to the health and safety of the public." The two-step licensing system enabled the AEC to authorize construction of nuclear plants while allowing time to investigate any outstanding safety questions and prescribe modifications in initial plans. Agency officials recognized that the wisdom of permitting construction to proceed without first resolving all potential safety problems was disputable, but they saw no alternatives in light of the existing state of the technology and the commitment to rapid development of atomic power. They were confident that regulatory requirements were adequate to guard against the hazards of nuclear generating systems. The AEC acknowledged, however, that it could not eliminate all risks. C. Rogers McCullough, chairman of the ACRS, informed the Joint Committee in 1956 that because of technical uncertainties and limited operating experience, "the determination that the hazard is acceptably low is a matter of competent judgment."

It soon became apparent how the AEC's judgment on safety issues could be influenced by its ambition to promote the private development of nuclear power. The Commission's actions in granting a construction permit for a commercial fast breeder reactor, despite the reservations of the ACRS, ignited an acrimonious controversy with the Joint Committee and raised questions about the AEC's regulatory program. In January 1956, the Power Reactor Development Company (PRDC), a consortium of utilities led by Detroit Edison, applied for a permit to build a fast breeder in Lagoona Beach, Michigan, located on Lake Erie within thirty miles of both Detroit and Toledo, Ohio. The AEC had already received applications for two privately-financed light-water reactors, but the PRDC proposal was the first to come in under the power demonstration program.

The fast breeder reactor that the PRDC planned was far more advanced in its technological complexity than light-water models, with which scientists and engineers had greater experience and familiarity. After review of the PRDC's application and discussions with company representatives, the ACRS concluded in an internal report to the Commission that "there is insufficient information available at this time to give assurance that the PRDC reactor can be operated at this site without public hazard." The ACRS also expressed uncertainty that its questions about the reactor's safety could be resolved within the PRDC's proposed schedule for obtaining an operating license. The ACRS urged that the AEC expand its experimental programs with fast breeders to seek more complete data on the issues the PRDC application raised.

The public dispute over the PRDC case was triggered by statements of Chairman Strauss and Commissioner Murray in congressional budget hearings. After the AEC requested a supplemental appropriation for the civilian power program, the commissioners were subjected to sharp criticism by Clarence Cannon, chairman of the House Appropriations Committee, when they appeared to testify in June 1956 on the need for the expenditures. Cannon, a strong public power advocate, badgered Strauss about private industry's lack of progress in atomic development and suggested that the PRDC had no "intention of building this reactor at any time in the determinable future." Strauss, anxious to show that



PRDC reactor under construction, 1958.

industry was making good headway, replied: "They [PRDC] have already spent eight million dollars of their own money to date on this project. I told you they were breaking ground on August 8. I have been invited to attend the ceremony; I intend to do so." Inadvertently, he had revealed that he planned to attend the ground breaking ceremony for a reactor whose construction permit was still being evaluated by the AEC.

During hearings the following day, Commissioner Murray, in an effort to demonstrate the need for research and development funds, disclosed the conclusions of the ACRS on the PRDC application. Murray was so uneasy about the safety implications of the committee's report that he went to see Joint Committee chairman Anderson and outlined its contents.

Members of the Joint Committee were angered and disturbed by the revelations of Strauss and Murray, not only because of safety concerns but also because the AEC had failed to inform them officially about the reservations of the ACRS. The AEC was obliged by the 1954 Atomic Energy Act to keep the Joint Committee "fully and currently informed" about its activities, and committee members believed that in the case of the ACRS report the agency had failed to carry out its charge. The Joint Committee immediately requested a copy of the ACRS document. The AEC was reluctant to agree, and after long deliberation, offered to deliver a copy only if the Joint Committee would keep it "administratively confidential." The committee refused to accept the report under those conditions. The AEC was even less accommodating with the state of Michigan. When Governor G. Mennen Williams, who learned of the ACRS report from Senator Anderson, asked the AEC for a copy, it refused on the grounds that "it would be inappropriate to disclose the contents of internal documents."

Meanwhile, the AEC's regulatory staff was completing its review of the PRDC's application. The staff took a more optimistic view of the safety of the proposed reactor than had the ACRS. Since the company had agreed to perform tests on the questions raised by the committee, the staff recommended that it be granted a construction permit. On August 2, 1956, the Commission decided to issue the permit by a vote of three to one (Murray was the dissenter). It acknowledged the concerns of the ACRS by inserting the word "conditional" in the construction permit to emphasize that the company would have to settle the uncertainties about safety before receiving an operating license. Commissioner Harold S. Vance summarized the majority's reasoning during discussion of the application. "We are doing something that we ordinarily would not do," he said, "in that we would not ordinarily issue a construction permit unless we were satisfied that reasonable safety requirements had been met." But he added: "It may be some time before reasonable assurance can be obtained. If we were to delay the construction permit until then, it might delay a very important program. If we didn't think that the chances were very good that all these questions would be resolved, we would not issue the permit."

The AEC's decision elicited angry protests from the Joint Committee. Congressman Holifield, citing Strauss's earlier announcement of his plans to attend the groundbreaking ceremonies for the plant, charged that the AEC chairman was acting in a "reckless and arrogant manner." Anderson accused the agency of conducting "star chamber" proceedings and pledged that the Joint Committee would "ascertain the full facts involved in this precipitate action."

The Joint Committee soon acted to prevent a recurrence of the AEC's conduct in the PRDC case. Anderson ordered the committee staff to prepare a study of the AEC's licensing procedures and regulatory organization, including consideration of whether regulatory and promotional responsibilities should be carried out by separate agencies. The staff concluded that the creation of separate agencies was inadvisable at the time, principally because of the difficulty of recruiting qualified personnel for purely regulatory functions. It did, however, suggest other reforms in the AEC's regulatory structure and procedures. Anderson implemented his staff's proposals by introducing legislation to establish the ACRS as a statutory body, direct that its reports on licensing cases be made public, and require public hearings on all reactor applications. The AEC opposed all three measures, but muted its objections because Anderson presented them as amendments to a bill to provide indemnity insurance for reactor owners, which the agency strongly favored.

The AEC regarded indemnity legislation as essential for stimulating private investment in nuclear power, a view that industry spokesmen and the Joint Committee on Atomic Energy shared. Since they recognized that the chances of a severe reactor accident could not be reduced to zero, even the most enthusiastic industry proponents of atomic power were reluctant to push ahead without adequate liability insurance. Private insurance companies would offer up to $60 million of coverage per reactor, an amount that far exceeded what was available to any other industry in the

United States. But in the event of a serious accident, it seemed insufficient to pay claims for deaths, injuries, and property damages in areas surrounding the malfunctioning plant.

Therefore, industry executives sought a government program to provide additional insurance protection. H. R. Searing, chairman of the board of Consolidated Edison, declared that although his company would proceed with the construction of its Indian Point plant near New York City it would not load fuel and begin operation unless the insurance question were resolved. General Electric's Francis McCune went even further by telling the Joint Committee in 1957 that if Congress did not enact indemnity legislation, his company would stop work on Commonwealth Edison's Dresden station, then under construction. He suggested that without a government insurance plan, the market for civilian atomic energy would collapse and vendors would withdraw from the field.

Spurred by the industry's concerns, both the AEC and the Joint Committee considered methods by which the government could provide additional liability insurance for reactor owners. Their efforts culminated in legislation introduced by Senator Anderson and Congressman Melvin Price, which proposed that the government underwrite $500 million of insurance beyond the $60 million available from private companies. The AEC initially opposed setting a specific upper limit on the amount because there was no reliable way to estimate the possible damages from a reactor accident. But Anderson, wanting to avoid a "blank check" for industry, rather arbitrarily decided on the $500 million figure. The bill stipulated that Congress could authorize additional payments if necessary and also required that reactor owners contribute funds to the insurance pool as their plants were licensed. With strong support from the AEC and the industry, Congress passed the Price-Anderson bill in August 1957. In final form, the measure included Anderson's reforms of the AEC's licensing procedures. Although the agency disliked Anderson's amendments, it accepted them to avoid jeopardizing or retarding approval of the indemnity bill. The Price-Anderson Act was a regulatory measure in effect because it provided insurance protection to victims of a nuclear accident, but it was largely promotional in motivation. Industry, the AEC, and the Joint Committee believed that it would remove a serious obstacle to private atomic development.

The PRDC case and the Price-Anderson Act clearly illustrated the AEC's emphasis on developmental rather than regulatory efforts. The precedence that the AEC gave to promoting the growth of nuclear power resulted from a number of considerations. The 1954 Atomic Energy Act made it a national goal to encourage the widespread use of atomic energy for peaceful purposes, but private industry was often hesitant to assume the costs and risks of development. Therefore, the AEC sought to persuade or induce private interests to invest in nuclear power. This seemed particularly urgent because of the intense pressure the Joint Committee placed on the agency to speed progress and its persistent threat to require the AEC to construct prototype plants if private firms failed to act promptly. One important way that the AEC pursued its objective of private development was to write regulations designed to protect public safety without being overly burdensome to industry.

Safety questions were largely a matter of judgment rather than something concrete or quantifiable, and AEC officials found it easier to assume that such issues had been or would be satisfactorily resolved than to assume that reactors would be built. When it issued a construction permit for the PRDC fast breeder reactor, for example, the Commission's vision of an advanced technology plant that showed the effectiveness of its power demonstration reactor program outweighed the reservations of the ACRS. Though aware of the implications that safety questions posed for the development of the technology, the AEC believed that nuclear science, in due time, would provide the answers to any outstanding problems. In short, the desire for tangible signs of promise was more compelling than first resolving more ethereal safety issues.

The AEC's emphasis on stimulating atomic development did not mean that it was inattentive to safety issues. The regulations that the staff drafted shortly after passage of the 1954 Atomic Energy Act reflected careful consideration of the best scientific information and judgment available at the time. The AEC recognized and publicly acknowledged the possibility of accidents in such a new and rapidly changing technology; it never offered absolute assurances that accidents would not occur. Nevertheless, it believed that compliance with its regulations would make the chances of a serious accident very small. The agency did not view its developmental efforts as more important than regulatory policies, but it clearly viewed the need to encourage industrial growth as more immediate.

By 1962, the AEC's efforts to stimulate private participation in nuclear power development had produced some encouraging results. In a report to President Kennedy, the agency proudly pointed out that in the short time since atomic technology had been opened to private enterprise, six "sizeable" power reactors had begun operation, and two of those had been built without government subsidies. Despite industry's lingering concerns about the costs of nuclear power relative to fossil fuels, the AEC's developmental and regulatory programs had fostered the initial growth of commercial nuclear power. The agency predicted that by the year 2000 nuclear plants might provide up to fifty percent of the nation's electrical generating capacity. Despite the AEC's claims, the future of the nuclear industry remained precarious. The fourteen reactors in operation or under construction were still far from being commercially competitive or technologically proven, and interest in further development among utilities appeared to be flagging. Both the AEC and Joint Committee were acutely aware of and deeply disturbed about those uncertainties.

To make matters worse from the perspective of nuclear proponents, there were signs of increasing public opposition to, or at least concern about, nuclear power hazards. In the early days of nuclear power development, public attitudes toward the technology were highly favorable, as the few opinion polls on the subject revealed. Press coverage of nuclear power was also overwhelmingly positive. An article in *National Geographic* in 1958, for example, concluded that "abundant energy released from the hearts of atoms promises a vastly different and better tomorrow for all mankind." In the late 1950s and early 1960s, however, the public became more alert to and anxious about the hazards of radiation, largely as a result of a major controversy over radioactive fallout from nuclear weapons testing. One result was that the public became increasingly troubled about the risks of exposure to radioactivity from any source, including nuclear power.

Before World War II, the dangers of radiation were a matter of interest and concern mostly to a relatively small group of scientists and physicians. Within a short time after the discovery of x-rays and natural radioactivity in the 1890s, scientific investigators concluded that exposure to radiation could cause serious health problems, ranging from loss of hair and skin irritations to sterility and cancer. Ignorance of the hazards of x-rays and radium and use of them for frivolous purposes led to tragic consequences for people who received large doses of radiation. As experience with and experimental data on the effects of radiation gradually accumulated, professionals developed guidelines to protect x-ray technicians and other radiation workers from excessive exposure.

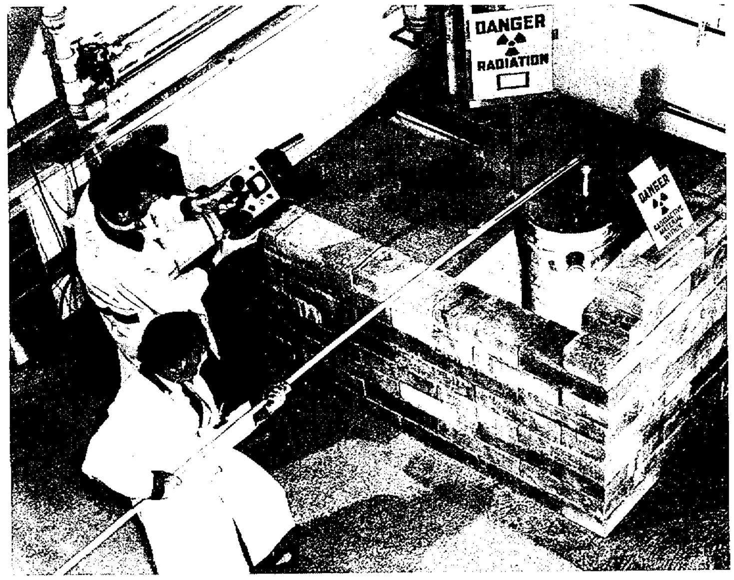
In 1934, a recently-formed American committee representing professional societies and x-ray equipment manufacturers recommended for the first time a quantitative "tolerance dose" of radiation, 0.1 roentgen per day of whole-body exposure from external sources. Committee members believed that levels of radiation below the tolerance dose were generally safe and unlikely to cause injury "in the average individual." The same year, an international radiation protection committee composed of experts from five nations took similar action. Neither body regarded its recommended tolerance dose as definitive because empirical evidence remained fragmentary and inconclusive. They were confident, however, that available information made their proposals reasonable and provided an adequate margin of safety for the relatively small number of individuals exposed to radiation in their jobs.

Then came Hiroshima. The dawn of the atomic age made radiation safety a vastly more complex task for two reasons. First, nuclear fission created many radioactive isotopes that did not exist in nature. This meant that instead of considering only x-rays and radium, professionals in the field of radiation protection had to evaluate the hazards of new radioactive substances about which even less was known. Second, the problem of radiation safety extended to significantly larger segments of the population who might be exposed to radiation from the development of new applications of atomic energy. Radiation protection broadened from a medical issue of limited proportions to a public health question of, potentially at least, major dimensions.

As a result of the drastically altered circumstances, scientific authorities reassessed their recommendations on radiation protection. They modified their philosophy of radiological safety by abandoning the concept of "tolerance dose," which assumed that exposure to radiation below the specified limits was generally harmless. Experiments in genetics indicated that reproductive cells were highly susceptible to damage from even small amounts of radiation. By the early 1940s, most scientists had rejected the idea that exposure to radiation below a certain threshold was inconsequential, at least for genetic effects. The American committee of radiation experts, named the National Committee on Radiation Protection (NCRP) in 1946, took action that reflected the consensus of opinion by replacing the terminology of "tolerance dose" with "maximum permissible dose," which it thought better conveyed the principle that no quantity of radiation was certifiably safe. It defined the permissible dose as that which "in the light of present knowledge, is not expected to cause appreciable bodily injury to a person at any time during his lifetime." While acknowledging the possibility of suffering harmful effects from radiation in amounts below the allowable limits, the NCRP emphasized that the permissible dose was based on the belief that "the *probability* of the occurrence of such injuries must be so low that the risk should be readily acceptable to the average individual."

Because of the growth of atomic energy programs and the substantial increase in the number of individuals working with radiation sources, the NCRP decided by 1948 to reduce its recommended occupational exposure limits to fifty percent of the 1934 level. Its international counterpart, named the International Commission on Radiological Protection (ICRP) after World War II, adopted the same maximum permissible dose. The new maximum permissible whole body dose that the NCRP and ICRP recommended was 0.3 roentgens per six-day work week, measured by exposure of the "most critical" tissue in blood-forming organs, gonads, and lens of the eye. Higher limits applied for less sensitive areas of the body. In addition to the levels established for exposure to x-rays or gamma rays, the NCRP and ICRP also issued maximum permissible concentrations in air and water of a list of radioactive isotopes that give off alpha or beta particles, known as "internal emitters." Alpha and beta particles cannot penetrate into vital human tissue from outside the body, but if they enter the body by consumption of contaminated food or water or by breathing of contaminated air, they can pose a serious health hazard.

The allowable limits established by both groups applied only to radiation workers, but because of the genetic effects of radiation and the possibility that other people could be exposed in an accident or an emergency, each also issued guidelines for larger segments of the population. In view of the greater sensitivity of young persons to radiation, the NCRP recommended that the occupational maximum permissible dose be reduced by a factor of ten for anyone under age eighteen. The ICRP went further by proposing a limit of one-tenth the occupational level for the general population. Neither committee had any legal authority or official standing, but since their recommendations reflected the findings and opinions of leading experts in the field of radiation protection, they exercised decisive influence on government agencies



Researcher at Brookhaven National Laboratory removes plug from lead shield containing radioactive materials. Man at his left holds Geiger counter to monitor radiation levels.

concerned with radiological safety. The AEC used the NCRP's occupational limits in its own installations, and after passage of the 1954 Atomic Energy Act, in its regulations for licensees. The agency's radiation protection regulations, which were first issued for public comment in 1955 and became effective in 1957, followed the NCRP's recommendations for radiation workers and set a permissible dose of one-tenth the occupational level for members of the general population potentially affected by the operations of licensees.

In the immediate postwar period, deliberations over the risks of radiation and permissible exposure levels were confined mostly to scientific circles. Concern about radiation moved from the rarified realms of scientific and medical discourse to the front page as a result of the fallout controversy. The testing of nuclear weapons in the atmosphere by the United States, the Soviet Union, and Great Britain produced radioactive fallout that spread to populated areas far from the sites of the explosions. The fallout debate made radiation hazards a bitterly contested political issue for the first time. Scientists disagreed sharply about how serious a risk fallout presented to the population, and the question became a prominent subject in news reports, magazine stories, political campaigns, congressional hearings, and scientific studies. This not only called public attention to the potential health hazards of relatively small amounts of radiation (as opposed to acute exposure), but also made clear that scientists did not know a great deal about the effects of low-level radiation.

The fallout controversy affected the AEC's regulatory program in two important ways. First, it led to a tightening of the agency's radiation standards. In response to increasing public concern and the findings of scientific groups, the NCRP and the ICRP both lowered their recommended permissible levels of exposure. They acted to provide a larger margin of safety but emphasized that there was no evidence that the previous levels had been dangerously high. They reduced their limits for occupational exposure to an average of 5 rem per year after age eighteen while continuing tosuggest that population levels be restricted to ten percent of occupational levels (0.5 rem per year) for individuals. They added a new stipulation that, for genetic reasons, the average level for large population groups should not exceed one-thirtieth of the occupational limit, or 0.17 rem per year. The AEC promptly adopted the new recommendations as a part of its regulations; it issued them for comments in 1959 and made them effective on January 1, 1961.

The fallout debate further influenced the AEC's regulatory program by arousing public anxieties about the health effects of low-level radiation. This was evident, for example, in citizen protests against the dumping of low-level radioactive wastes in ocean waters. The AEC had authorized the dumping of such wastes under prescribed conditions for over a decade, but it became a subject of controversy only after the fallout issue sensitized public opinion to radiation hazards. In a similar manner, the first widespread objections to the construction of proposed nuclear power plants arose in the wake of the fallout debate. Citizen protests against the construction of the Ravenswood plant in the heart of New York City in 1963 and the Bodega Bay plant on the coast of California near the boundary of the San Andreas fault in 1963-64 played a vital role in aborting both projects.

At the end of the first decade that followed passage of the 1954 Atomic Energy Act, the prospects for rapid nuclear power development were mixed. Impressive strides had been taken, to be sure, but many uncertainties remained. Public support for the technology appeared to be strong but, as Ravenswood and Bodega Bay had shown, it could not be taken for granted. Beginning in the mid-1960s, however, a variety of considerations fueled an unanticipated boom in the nuclear power industry that resolved some of the unknowns about nuclear progress while raising a host of new questions for the AEC's regulatory staff.

Chapter 2

The Nuclear Power Debate, 1963 – 75

During the late 1950s and early 1960s the use of nuclear power to generate electricity was a novel and developing technology. Since relatively few plants were operating, under construction, or on order, the scope of the AEC's regulatory functions such as reactor siting, licensing, and inspection was still limited. During the later 1960s, however, the nation's utilities rapidly increased their orders for nuclear power stations, participating in what Philip Sporn, past president of the American Electric Power Service Corporation, described in 1967 as the "great bandwagon market." At the same time, the size of plants being built also expanded dramatically. The sudden arrival of commercially competitive nuclear power placed unprecedented demands on the AEC's regulatory staff and raised new safety problems that reactor experts had not considered previously. The surge in reactor orders and the growth in the size of individual reactors also spurred new concerns about the environmental impact of nuclear power and intensified public uneasiness about the safety of the technology.

The bandwagon market was an outgrowth of several developments that enhanced the appeal of nuclear power to utilities in the mid- and late 1960s. One was the intense competition between the two leading vendors of nuclear plants, General Electric and Westinghouse. In 1963, General Electric made a daring move to increase its reactor sales and to convince utilities that nuclear power had arrived as a safe, reliable, and cost-competitive alternative to fossil fuel. It offered a "turnkey" contract to Jersey Central Power and Light Company to build the 515 electrical megawatt Oyster Creek plant near Toms River, New Jersey. For a fixed cost of $66 million, General Electric agreed to supply the entire plant to the utility (the term "turnkey" suggested that the utility would merely have to turn a key to start operating the facility). The company's bid was successful, winning out not only over Westinghouse but also over manufacturers of coal-fired units. General Electric expected to lose money on the Oyster Creek contract, but hoped that the plant would help to stimulate the market for nuclear power.

The Oyster Creek contract opened the "turnkey era" of commercial nuclear power and came to symbolize the competitive debut of the technology. Glenn T. Seaborg, chairman of the AEC, told President Johnson that it represented an "economic breakthrough" for nuclear electricity. Westinghouse followed General Electric's lead in offering turnkey contracts for nuclear plants, setting off a fierce corporate battle. The turnkey plants were a financial blow for both companies; their losses ran into the hundreds of millions of dollars before they stopped making turnkey arrangements. One General Electric official commented: "It's going to take a long time to restore to the treasury the demands we put on it to establish ourselves in the nuclear business." But the turnkey contracts fulfilled General Electric's hopes of stirring interest among and orders from utilities. They played a major role in triggering the bandwagon market.

There were other important considerations that convinced a growing number of utilities to buy nuclear plants. One was the spread of power pooling arrangements among utilities, which encouraged the construction of larger generating stations by easing fears of excess capacity and over-expansion. A utility with extra or reserve power could sell it to other companies through interconnections. The desirability and feasibility of using larger individual plants worked to the benefit of nuclear vendors. They emphasized that bigger plants would produce "economies of scale" that would cut capital costs per unit of power and improve efficiency. This helped to overcome a major disadvantage of nuclear power relative to fossil fuel—the heavy capital requirements for building atomic plants. During the late 1960s designs for nuclear facilities leap-frogged from the 500 to the 800 to the 1000 electrical megawatt range even though operating experience was still limited to units in the range of 200 megawatts or less. The practice of "design by extrapolation" had been employed for fossil-fuel units since the early 1950s. Before the mid-1960s this approach appeared to work well, and it was natural that vendors extended it to nuclear units.

In addition to turnkey contracts, system interconnections, and increasing unit size, growing national concern about air pollution in the 1960s made nuclear power more attractive to utilities. Coal plants were major contributors to the deterioration of air quality and were obvious targets for clean-up efforts. As the campaign to improve the environment gained strength, the electric-utility industry became more mindful of the cost of pollution control in fossil-fuel plants. They increasingly viewed nuclear power as a good alternative to paying the expenses of pollution abatement in coal-fired units.

The bandwagon market for nuclear power reached its peak during 1966 and 1967, exceeding, in the words of a General Electric official, "even the most optimistic estimates." In 1965, the year before the reactor boom gathered momentum, nuclear vendors sold four nuclear plants with a total of 17 percent of the capacity that utilities purchased that year. In 1966, by contrast, utilities bought 20 nuclear units that made up 36 percent of the electrical capacity committed. The following year nuclear vendors sold 31 units that represented 49 percent of the capacity ordered. In 1968, the number of reactor orders dropped to 17, but the percentage of the capacity filled with nuclear plants remained high at 47 percent.

The bandwagon market orders were large facilities that far exceeded the size of operating reactors. Between 1963, when the 515 electrical megawatt Oyster Creek reactor was ordered, and 1969, when the plant began operation, the AEC issued 38 construction permits for units that were larger than Oyster Creek. Of those plants, 28 were in the range of 800 to 1100 megawatts. The degree of extrapolation from small plants to mammoth ones was a matter of concern even to some strong nuclear advocates. By the late 1960s, it was apparent that design by extrapolation was not as successful as anticipated earlier. "We hoped the new machines would run just like the old ones we're familiar with," complained one utility executive about his huge coal-burning stations. But, he added, "they sure as hell don't."

The rapid increase in the number of reactor applications and in the size of proposed plants placed enormous burdens on the AEC's regulatory staff. The flood of applications inevitably caused licensing delays because the staff lacked enough qualified professionals. Between 1965 and 1970, the size of the regulatory staff increased by about 50 percent, but its licensing and inspection case load increased by about 600 per cent. The average time required to process a construction permit application stretched from about a year in 1965 to over 18 months by 1970. The growing backlog drew bitter complaints from utilities applying to build plants and from nuclear vendors. One utility executive predicted that if delays became commonplace, "it can safely be asserted that the splendid promise of nuclear power will have had a very short life." Another was even more critical, calling the licensing process "a modern day Spanish Inquisition" carried out by "AEC engineers, scientists, and consultants [who] have no serious economic discipline." The AEC attempted to streamline its licensing procedures but found it impossible to reduce review time or to satisfy the demands of the industry.

The licensing process lengthened not only because of the number of applications that the AEC had to evaluate but also because of the complexity of the proposals it received. The growth in the size of reactors and the practice of design by extrapolation raised many complex safety issues that could not be easily resolved. The exercise of careful judgment in assessing reactor applications was always critical, but it became even more so as utilities campaigned to build plants closer to populated regions. Although the AEC adopted an informal prohibition against "metropolitan siting" in urban locations (such as the proposed Ravenswood plant in downtown New York), it was more receptive to "suburban siting" fairly close to urban populations. This reduced the emphasis on one traditional means of protecting the public from the consequences of a nuclear accident—"remote siting." It placed greater dependence on the other general method of shielding the public from the effects of an accident—engineered safeguards (a term later superseded by "engineered safety features") that were built into the plant. Even as the relative importance of engineered safeguards increased in the 1960s, questions arose about their reliability in preventing a massive release of radioactivity to the environment in the event of a severe accident.

The engineered safeguards in nuclear plants differed in design and operation, but they served the same basic functions. A number of systems were placed in reactors to remove heat and reduce excessive pressure if an accident occurred. They included, for example, passive core sprays and pressure suppression pools, "safety injection" systems that would shoot large volumes of water into the reactor vessel, and combinations of filters, vents, scrubbers, and air circulators that would collect and retain radioactive gases and particles released by an accident. The final line of defense if the engineered safeguards failed was the containment building, a large, often dome-shaped structure that surrounded the reactor and associated steam-producing equipment as well as the safety systems.

Reactor experts were confident that in almost any situation the engineered safety features built into a plant and the containment structure would protect the public from the effects of an accident. But they were troubled by the possibility that a chain of events could conceivably take place that would bypass or override the safety systems, and in the worst case, breach containment. "No one is in a position to demonstrate that a reactor accident with consequent escape of fission products to the environment will never happen," Clifford K. Beck, the AEC's deputy director of regulation, told the Joint Committee in 1967. "No one really expects such an accident, but no one is in a position to say with full certainty that it will not occur."

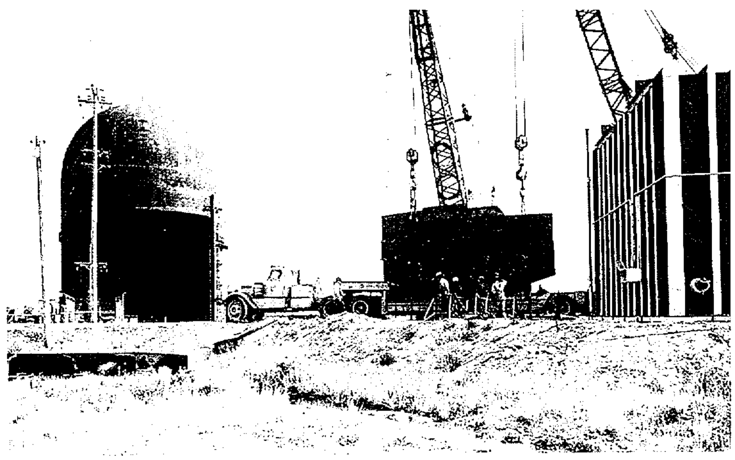
The AEC strived to reduce the likelihood of an accident to a minimum. It based its decisions on the safety of reactor designs and plant applications on operating experience, engineering judgment, and experiments with test reactors. Experience with the first commercial reactors had been encouraging; it had provided a great deal of information that was useful in understanding reactor science. But it was of limited application to the newer and larger reactors that utilities were building by the late 1960s. The rapid growth in reactor size placed a premium on the careful use of engineering judgment. In order to decrease the chances of a major accident that could threaten public health, the AEC required multiple back-up equipment and redundancies in safety designs. It also employed conservative assumptions about the ways in which an accident might damage or incapacitate safety systems in its evaluation of reactor proposals.

The regulatory staff sought to gain as much experimental data as possible to enrich its knowledge and inform its collective engineering judgment. This was especially vital in light of the many unanswered questions about reactor behavior. The AEC had sponsored hundreds of small-scale experiments since the early 1950s that had yielded key information about a variety of reactor safety problems. But they provided little guidance on the issue of greatest concern to the AEC and the ACRS by the late 1960s—a core meltdown caused by a loss-of-coolant accident.

Reactor experts had long recognized that a core melt was a plausible, if unlikely, occurrence. A massive loss of coolant could happen, for example, if a large pipe that fed cooling water to the core broke. If the plant's emergency cooling systems also failed, the build-up of "decay heat" (which resulted from continuing radioactive decay after the reactor shut down) could cause the core to melt. In older and smaller reactors, the experts were confident that even under the worst conditions—an accident in which the loss of coolant melted the core and it, in turn, melted through the pressure vessel that held the core—the containment structure would prevent a massive release of radioactivity to the environment. As proposed plants increased significantly in size, however, they began to worry that a core melt could lead to a breach of containment. This became their primary focus partly because of the greater decay heat the larger plants would produce and partly because nuclear vendors did not add to the size of containment buildings in corresponding proportions to the size of reactors.

The greatest source of concern about a loss-of-coolant accident in large reactors was that the molten fuel would melt through not only the pressure vessel but also through the thick layer of concrete at the foundation of the containment building. The intensely radioactive fuel would then continue on its downward path into the ground. This scenario became known as the "China syndrome," because the melted core would presumably be heading through the earth toward China. Other possible dangers of a core meltdown were that the molten fuel would breach containment by reacting with water to cause a steam explosion or by releasing elements that could combine to cause a chemical explosion. The precise effects of a large core melt were uncertain, but it was clear that the results of spewing radioactivity into the atmosphere could be disastrous. The ACRS and the regulatory staff regarded the chances of such an accident as low; they believed that it would occur only if the emergency core cooling system (ECCS), made up of redundant equipment that would rapidly feed water into the core, failed to function properly. But they acknowledged the possibility that the ECCS might not work as designed. Without containment as a fail-safe final line of defense against any conceivable accident, they sought other means to provide safeguards against the China syndrome.

At the prodding of the ACRS, which first sounded the alarm about the China syndrome, the AEC established a special task force to look into the problem of core melting in 1966. The committee, chaired by William K. Ergen, a reactor safety expert and former ACRS member from Oak Ridge National Laboratory, submitted its findings to the AEC in October 1967. The report offered assurances about the improbability of a core meltdown and the reliability of emergency core cooling designs, but it also acknowledged that a loss-of-coolant accident could cause a breach of containment if ECCS failed to perform. Therefore, containment could no longer be regarded as an inviolable barrier to the escape of radioactivity. This represented a milestone in the evolution of reactor regulation. In effect, it imposed a modified approach to reactor safety. Previously, the AEC had viewed the containment building as the final independent line of defense against the release of radiation; even if a serious accident took place the damage it caused would be restricted to the plant. Once it became apparent that under some circumstances the containment building might not hold, however, the key to protecting the public from a large release of radiation was to prevent accidents severe enough to threaten containment. And this depended heavily on a properly designed and functioning ECCS.



LOFT reactor under construction, 1969.

The problem facing the AEC's regulatory staff was that experimental work and experience with emergency cooling was very limited. Finding a way to test and to provide empirical support for the reliability of emergency cooling became the central concern of the AEC's safety research program. Plans had been underway since the early 1960s to build an experimental reactor, known as the Loss-of-Fluid-Tests (LOFT) facility, at the AEC's reactor testing station in Idaho. Its purpose was to provide data about the effects of a loss-of-coolant accident. For a variety of reasons, including weak management of the test program, a change of design, and reduced funding, progress on the LOFT reactor and the preliminary tests that were essential for its success were chronically delayed. Despite the complaints of the ACRS and the regulatory staff, the AEC diverted money from LOFT and other safety research projects on existing light-water reactor designs to work on the development of fast-breeder reactors. A proven fast breeder was an urgent objective for the AEC and the Joint Committee; Seaborg described it as "a priority national goal" that could assure "an essentially unlimited energy supply, free from problems of fuel resources and atmospheric contamination."

To the consternation of the AEC, experiments run at the Idaho test site in late 1970 and early 1971 suggested that the ECCS in light-water reactors might not work as designed. As a part of the preliminary experiments that were used to design the LOFT reactor, researchers ran a series of "semiscale" tests on a core that was only nine inches long (compared with 144 inches on a power reactor). The experiments were run by heating a simulated core electrically, allowing the cooling water to escape, and then injecting the emergency coolant. To the surprise of the investigators, the high steam pressure that was created in the vessel by the loss of coolant blocked the flow of water from the ECCS. Without ever reaching the core, about 90 percent of the emergency coolant flowed out of the same break that had caused the loss of coolant in the first place.

In many ways the semiscale experiments were not accurate simulations of designs or conditions in power reactors. Not only the size, scale, and design but also the channels that directed the flow of coolant in the test model were markedly different than those in an actual reactor. Nevertheless, the results of the tests were disquieting. They introduced a new element of uncertainty into assessing the performance of ECCS. The outcome of the tests had not been anticipated and called into question the analytical methods used to predict what would happen in a loss-of-coolant accident. The results were hardly conclusive but their implications for the effectiveness of ECCS were troubling.

The semiscale tests caught the AEC unprepared and uncertain of how to respond. Harold Price, the director of regulation, directed a special task force he had recently formed to focus on the ECCS question and to draft a "white paper" within a month. Seaborg, for the first time, called the Office of Management and Budget to plead for more funds for safety research on light-water reactors. While waiting for the task force to finish its work, the AEC tried to keep information about the semiscale tests from getting out to the public, even to the extent of withholding information about them from the Joint Committee. The results of the tests came at a very awkward time for the AEC. It was under renewed pressure from utilities facing power shortages and from the Joint Committee to streamline the licensing process and eliminate excessive delays. At the same time, Seaborg was appealing—successfully—to President Nixon for support of the breeder reactor, and controversy over the semiscale tests and reactor safety could undermine White House backing for the program. By the spring of 1971, nuclear critics were expressing opposition to the licensing of several proposed reactors, and news of the semiscale experiments seemed likely to spur their efforts.

For those reasons, the AEC sought to resolve the ECCS issue as promptly and quietly as possible. It wanted to settle the uncertainties about safety without arousing a public debate that could place hurdles in the way of the bandwagon market. Even before the task force that Price established completed its study of the ECCS problem, the Commission decided to publish "interim acceptance criteria" for emergency cooling systems that licensees would have to meet. It imposed a series of requirements that it believed would ensure that the ECCS in a plant would prevent a core melt after a loss-of-coolant accident. The AEC did not prescribe methods of meeting the interim criteria, but, in effect, it mandated that manufacturers and utilities set an upper limit on the amount of heat generated by reactors. In some cases, this would force utilities to reduce the peak operating temperatures (and hence, the power) of their plants. Price told a press conference on June 19, 1971 that although the AEC thought it impossible "to guarantee absolute safety," he was "confident that these criteria will assure that the emergency core cooling systems will perform adequately to protect the temperature of the core from getting out of hand."

The interim ECCS criteria failed to achieve the AEC's objectives. News about the semiscale experiments triggered complaints about the AEC's handling of the issue even from friendly observers. It also prompted calls from nuclear critics for a licensing moratorium and a shutdown of the eleven plants then operating. Criticism expressed by the Union of Concerned Scientists (UCS), an organization established in 1969 to protest misuse of technology that had recently turned its attention to nuclear power, received wide publicity. The UCS took a considerably less sanguine view of ECCS reliability than that of the AEC. It sharply questioned the adequacy of the interim criteria, charging, among other things, that they were "operationally vague and meaningless." Scientists at the AEC's national laboratories, without endorsing the alarmist language that the UCS used, shared some of the same reservations. As a result of the uncertainties about ECCS and the interim criteria, the AEC decided to hold public hearings that it hoped would help resolve the technical issues. It wanted to prevent the ECCS question from becoming a major impediment to the licensing of individual plants.

The AEC insisted that its critics had exaggerated the severity of the ECCS problem. The regulatory staff viewed the results of the failed semiscale tests as serious but believed that the technical issues the experiments raised would be resolved within a short time. It did not regard the tests as indications that existing designs were fundamentally flawed and it emphasized the conservative engineering judgment it applied in evaluating plant applications. But the ECCS controversy damaged the AEC's credibility and played into the hands of its critics. Instead of frankly acknowledging the potential significance of the ECCS problem and taking time to fully evaluate the technical uncertainties, the AEC acted hastily to prevent the issue from undermining public confidence in reactor safety or causing licensing delays. This gave credence to the allegations of its critics that it was so determined to promote nuclear power and develop the breeder reactor that it was inattentive to safety concerns.

By the time that the ECCS issue hit the headlines, other questions about the environmental effects of nuclear power had eroded public support for the technology. The problem of industrial pollution and the deteriorating quality of the natural environment took on growing urgency as a public policy issue during the 1960s. The increasing public and political concern with environmental protection, occurring at the same time that demand for electricity was doubling every ten years or so, placed utilities in a quandary. As an article in *Fortune* magazine put it: "Americans do not seem willing to let the utilities continue devouring . . . ever increasing quantities of water, air, and land. And yet clearly they also are not willing to contemplate doing without all the electricity they want. These two wishes are incompatible. That is the dilemma faced by the utilities."

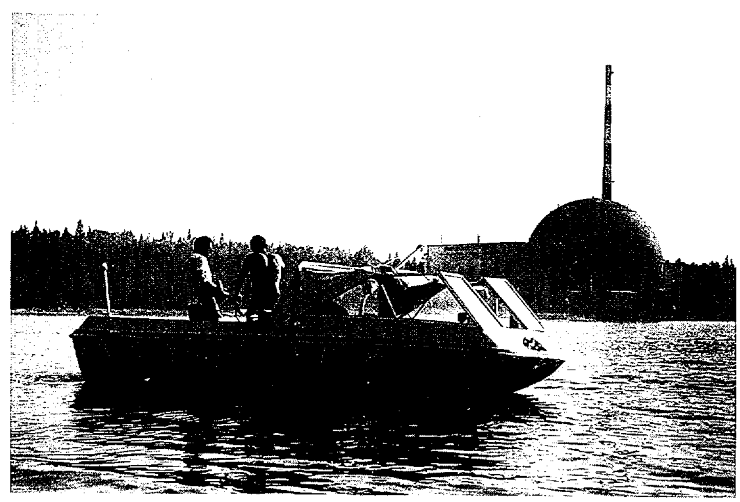
Utilities increasingly viewed nuclear power as the answer to that dilemma. It promised the means to meet demand for power without causing air pollution, and environmental concerns were a major spur to the growth of the great bandwagon market. Environmentalists recognized the benefits of nuclear power compared to fossil fuel, but they were more equivocal in their attitudes toward the technology than were industry representatives. Their ambivalence was perhaps best summarized by the statement of a leading environmental spokesman in 1967: "I think most conservationists may welcome the coming of nuclear plants, though we are sure they have their own parameters of difficulty."

Officials of the AEC actively promoted the idea that nuclear power provided the answer to both the environmental crisis and the energy crisis. Seaborg was especially outspoken on this point. Although he acknowledged that nuclear power had some adverse impact on the environment, he insisted that its effects were much less harmful than those of fossil fuel. In comparison with coal, he once declared, "there can be no doubt that nuclear power comes out looking like Mr. Clean."

The view of nuclear power as beneficial to the environment relative to conventional fuels was undermined in the late 1960s by a major controversy over the effects of waste heat from nuclear plants on water quality, widely known as "thermal pollution." Thermal pollution resulted from cooling the steam that drove the turbines to produce electricity in either a fossil fuel or nuclear plant. The steam was condensed by the circulation of large amounts of water, and in the process the cooling water was heated, usually by 10 to 20 degrees fahrenheit, before being returned to the body of water from which it came. This problem was not unique to nuclear plants but it was more acute in them, largely because fossil plants used steam heat more efficiently than nuclear ones. The problem of thermal pollution created more anxiety than previously during the 1960s because of the growing number of plants, the larger size of those plants, and the increasing inclination of utilities to order nuclear units.

Thermal pollution caused concern because it was potentially harmful to many species of fish. It could also disrupt the ecological balance in rivers and streams, allowing plants to thrive that made water look, taste, and smell unpleasant. Technical solutions to deal with thermal pollution were available, but they required extra costs in the construction and operation of steam-electric plants. Cooling towers of different designs or cooling ponds, for example, would greatly alleviate the release of waste heat to the source body of water. Utilities resisted adding cooling apparatus to the plants they planned to build, however, because of the expense and an appreciable loss of generating capacity.

Advocates of stronger federal action to protect the environment in the news media, Congress, and state and federal agencies urged the AEC to require its licensees to guard against the effects of thermal pollution. The AEC refused on the grounds that it lacked the statutory authority to impose regulations on hazards other than radiation. It argued that the 1954 Atomic Energy Act restricted its regulatory jurisdiction to radiological dangers, a view that the Department of Justice and federal courts upheld. This did not placate the AEC's critics, who accused it of ignoring a serious problem that nuclear plants exacerbated. Several members of Congress introduced legislation to grant the AEC authority over thermal pollution but the agency opposed those measures unless fossil fuel plants had to meet the same conditions. The AEC feared that nuclear power would be placed at a competitive disadvantage if plant owners had to provide cooling equipment that was not required on fossil-burning facilities.



Researchers from Argonne National Laboratory take measurements of the thermal discharge plume from the Big Rock Point Nuclear Power Plant on Lake Michigan.

The AEC came under increasing criticism for its position. The most prominent attack appeared in a *Sports Illustrated* article in January 1969. It assailed the AEC for failing to regulate against thermal pollution and attributed its inaction to a fear of the "financial investment that power companies would have to make . . . to stop nuclear plants from frying fish or cooking waterways wholesale." The article was a distorted and exaggerated presentation, but it contributed to a growing perception that instead of being a solution to the dilemma of producing electricity without causing serious environmental damage, nuclear power was a part of the problem.

Eventually the controversy over thermal pollution died out. One reason was that Congress passed legislation that gave the AEC authority to regulate against thermal pollution and that applied to most fossil fuel plants as well. A more important reason was that utilities increasingly took action to curb the consequences of discharging waste heat. Although they initially resisted the calls for cooling equipment, they soon found that the costs of responding to litigation, enduring postponements in the construction or operation of new plants, or suffering a loss of public esteem were less tolerable than those of building cooling towers or ponds. By 1971, most nuclear plants being built or planned for inland waterways (where the problem was most acute) included cooling systems. But the legacy of the thermal pollution debate lingered on. It undermined confidence in the AEC and wakened public doubts about the environmental impact of nuclear power. It played a vital role in transforming the ambivalence that environmentalists had demonstrated toward the technology into strong and vocal opposition. As a result of the thermal pollution issue, the AEC and the nuclear industry frequently found themselves included among the ranks of enemies of the environment.

The thermal pollution question was the first but not the only debate over the effects of nuclear power that aroused widespread public concern in the late 1960s and early 1970s. A major controversy that arose over the effects of low-level radiation from the routine operation of nuclear plants also fed fears about the expanding use of the technology. Drawing on the recommendations of the National Committee on Radiation Protection, the AEC had established limits for public exposure to radiation from nuclear plants of 0.5 rem per year for individuals. To determine the allowable release of radioactive effluents from a plant, it assumed that a person stood outdoors at the boundary of the facility 24 hours a day, 365 days a year. Licensees generally met the requirements easily. In 1968, for example, releases from most plants measured less than three percent of the permissible levels for liquid effluents and less than one percent for gaseous effluents.

The conservative assumptions of the AEC and the performance of operating plants did not prevent criticism of the AEC's radiation standards. A number of observers suggested that, in light of the uncertainties about the effects of low-level radiation, the AEC's regulations were insufficiently rigorous and should be substantially revised. This first emerged as a widely-publicized issue when the state of Minnesota, responding to questions raised by environmentalists, stipulated in May 1969 that a plant under construction must restrict its radioactive effluents to a level of about three percent of that allowed by the AEC.

The adequacy of the AEC's radiation standards became even more contentious in the fall of 1969, when two prominent scientists, John W. Gofman and Arthur R. Tamplin, suggested that if everyone in the United States received the permissible population dose of radiation, it would cause 17,000 (later revised to 32,000) additional cases of cancer annually. Gofman and Tamplin worked at Livermore National Laboratory, funded by the AEC, and their position as insiders gave their claims special credibility. They initially proposed that the AEC lower its limits by a factor of ten and later urged that it require zero releases of radioactivity.

Gofman and Tamplin not only argued that the existing standards of the AEC and other radiation-protection organizations were inadequate but also challenged the prevailing consensus that the benefits of nuclear power were worth the risks. Gofman was especially harsh in his analysis; he insisted that in its radiation protection regulations, "the AEC is stating that there is a risk and their hope that the benefits outweigh the number of deaths." He added: "This is legalized murder, the only question is how many murders."

The AEC denied Gofman's and Tamplin's assertions on the grounds that they extrapolated from high doses to estimate the hazards of low-level exposure, and that, furthermore, it was impossible for the entire nation to receive the levels of radiation that applied at plant boundaries. Most authorities in the field of radiation protection agreed with the AEC that the risks of effluents from nuclear power were far smaller than Gofman and Tamplin maintained. Nevertheless, in an effort to provide an extra measure of protection, reassure the public, and undercut the appeal of its critics, in June 1971 the AEC issued for public comment new "design objectives" for nuclear plants that would, in effect, reduce the permissible levels of effluents by a factor of about one hundred. This action elicited protests from industry representatives and from radiation-protection professionals, but it did not impress many critics, who expressed doubt that the AEC would enforce the new guidelines. The controversy focused public attention, once again, on the effects of low-level radiation, but it did little to clarify a complex and ambiguous issue.

In addition to the objections that its positions on thermal pollution and radiation standards stirred, the AEC provoked sharp criticism for its response to the National Environmental Policy Act (NEPA). The law, passed by Congress in December 1969 and signed by President Nixon on January 1, 1970, required federal agencies to consider the environmental impact of their activities. The measure was in many ways vague and confusing and it gave federal agencies broad discretion in deciding how to carry out its mandate. The AEC acted promptly to comply with NEPA, but its procedures for doing so brought protests from environmentalists. The agency took a narrow view of its responsibilities under NEPA. In a proposed regulation that it issued in December 1970, it included, for the first time, non-radiological issues in its regulatory jurisdiction. But it also stipulated that it intended to rely on the environmental assessments of other federal and state agencies (rather than conducting its own), it agreed to consider environmental issues in licensing board hearings only if raised by a party to the proceeding, and it postponed any review of NEPA issues in licensing cases until March 1971.

The AEC declined to take an expansive view of its responsibilities under NEPA for several reasons. One was the conviction that the routine operation of nuclear plants was not a serious threat to the environment and, indeed, was beneficial compared to burning fossil fuel. The major products of nuclear power generation that affected the environment, radiation releases and thermal discharges, were covered by other legislation. Furthermore, implementation of NEPA might divert the AEC's limited human resources from tasks that were more central to its mission. The regulatory staff was "all but overwhelmed" by the flood of reactor applications and did not relish the idea of having to spend large amounts of time on environmental reviews. Most importantly, the AEC feared that weighing environmental issues other than radiation and thermal releases would cause unwarranted delays in licensing plants. The time required for evaluating applications was already increasing and the AEC worried that NEPA could force a "quantum leap" in the length of the process. It sought to strike a balance between environmental concerns and the need for electrical power in framing its regulations.

Environmentalists complained that the AEC had failed to fulfill the purposes of NEPA and took the agency to federal court over the application of the AEC's regulations to the Calvert Cliffs nuclear units, then under construction on the Chesapeake Bay in rural Maryland. On July 23, 1971, the United States Court of Appeals for the District of Columbia handed down a ruling that was a crushing defeat for the AEC. The court sternly rebuked the agency in its most widely-quoted statement: "We believe that the Commission's crabbed interpretation of NEPA makes a mockery of the Act." The Calvert Cliffs decision was, in the words of

Nucleonics Week, a "stunning body blow" to the AEC and the nuclear industry.

The Calvert Cliffs decision was another in a series of setbacks for the AEC and nuclear power. It was apparent by the summer of 1971 that public distrust of the AEC was growing and support for nuclear power was declining. The cumulative effect of controversies over ECCS, thermal pollution, radiation standards, NEPA, and other issues eroded public confidence in the AEC's commitment to safety and raised doubts about the benefits of nuclear power. Antinuclear activists capitalized on growing uneasiness about the health and environmental effects of the technology. Some of the critics were well-informed and responsible in their arguments, but others were one-sided and inaccurate. Attempts by nuclear proponents to correct a plethora of misleading and exaggerated stories, advertisements, speeches, and other presentations inevitably failed to win as much attention or produce the same effect. To make matters worse for the AEC, it suffered from the general disillusionment with the government, established institutions, and science that prevailed by the late 1960s, largely as a result of the Vietnam war. One college student summarized the situation after listening to a debate between Victor Bond, a radiation expert from Brookhaven National Laboratory, and a vocal AEC critic: "Dr. Bond sounds good but we can't believe him. He works for the government."

By the summer of 1971, the AEC was an embattled agency, largely though not exclusively because of regulatory issues. Seaborg, after serving as chairman for ten years, resigned his post in July 1971 and Nixon appointed James R. Schlesinger, assistant director of the Office of Management and Budget, to take his place. Schlesinger was determined to make the AEC more responsive to environmental concerns and to improve its tarnished public image. As an important first step in those efforts, he and William O. Doub, who took a seat on the Commission at the same time that Schlesinger assumed the chairmanship, concluded that the AEC should not appeal the Calvert Cliffs ruling, and, after considering the alternatives, their colleagues agreed. The AEC announced its decision on August 26, 1971.

The AEC's response to the Calvert Cliffs decision brought a storm of protests from utilities who feared long delays in the licensing of plants that were nearly ready for operation. Schlesinger explained the AEC's new position in a speech he delivered to a meeting of industry groups in Bal Harbour, Florida on October 20, 1971. He told his audience that although the long-term outlook for nuclear power appeared "bullish," the pace of development depended on two variables: "first, the provision of a safe, reliable product; second, achievement of public confidence in that product." Schlesinger declared that the AEC's policy of promoting and protecting the industry had been justified to help nuclear power get started, but since the industry was "rapidly approaching mature growth," the AEC must redefine its responsibilities. "You should not expect the AEC," he announced, "to fight the industry's political, social, and commercial battles." Rather, he added, the agency's role was "primarily to perform as a referee serving the public interest." The message of Schlesinger's speech was unprecedented; it proclaimed a sharp break with the AEC's history and a new direction in the agency's approach to its regulatory duties.

Schlesinger's efforts to narrow the divisions between nuclear proponents and critics and to recover the AEC's regulatory credibility produced, at best, mixed results. Many environmentalists were pleased with the AEC's acceptance of the Calvert Cliffs ruling and with Schlesinger's Bal Harbour speech. Their guarded optimism about Schlesinger's attitudes was perhaps best summarized by the title of an article about him in *National Wildlife* magazine: "There's a *Bird Watcher* Running the Atomic Energy Commission." But major differences between the AEC and environmentalists remained; many of the same issues that had aroused concern before Schlesinger's arrival continued to generate controversy.

One of those issues was the reliability of emergency core cooling systems. In light of the objections to the interim acceptance criteria for ECCS that the AEC had published in June 1971, the agency decided to hold a rulemaking hearing on the issue that would apply to all licensing cases. It hoped that this would avoid repeating the same procedures and deliberating over the same questions in case-by-case hearings and that generic hearings would provide a means to resolve issues common to all plants. The ECCS hearings got underway in early 1972 and stretched into 135 days over a period of a year and a half. When they ended, the transcripts of the proceedings filled more than 22,000 pages. The ECCS hearings led to a final rule that made some small but important revisions in the interim criteria. They also produced acrimonious testimony and front-page headlines that often reflected unfavorably on the AEC's safety programs and that further damaged its credibility.

Another issue that undermined confidence in the AEC in the early 1970s was its approach to high-level radioactive waste disposal. The growth of the nuclear power industry made the safe disposal of intensely radioactive spent fuel rods and other waste materials an increasingly urgent matter. The AEC had investigated means of dealing with reactor wastes for years, but had not found a solution to the problem. As early as 1957, a scientific consensus had concluded that deep underground salt beds were the best repositories for long-lived and highly radioactive wastes. In 1970, in response to increasing expressions of concern about the lack of a policy for high-level waste disposal from scientific authorities, members of Congress, and the press, the AEC announced that it would develop a permanent repository for nuclear wastes in an abandoned salt mine near Lyons, Kansas. It aired its plans without conducting thorough geologic and hydrologic investigations, and the suitability of the site was soon challenged by the state geologist of Kansas and other scientists. The uncertainties about the site generated a bitter dispute between the AEC on the one side and members of Congress and state officials from Kansas on the other. It ended in 1972 in great embarrassment for the AEC when the reservations of those who opposed the Lyons location proved to be well-founded.

In addition to debates over ECCS and high-level waste disposal, questions over reactor design and safety, quality assurance, the probability of a major reactor accident, and other issues fueled the controversy over nuclear power. The number of contested hearings for plant licenses steadily grew. The ongoing controversy frustrated Schlesinger's hopes of increasing public confidence in the AEC and of defusing the conflicts between opposing views. By highlighting the issues on which the AEC's performance was suspect, it also obscured the requirements that the regulatory staff imposed over the protests and against the wishes of the nuclear industry, the high standards that it demanded in the design and construction of nuclear plants, and the conservative assumptions that it applied in evaluating plant applications and formulating radiation-protection regulations.

As the nuclear power debate continued, the AEC came under increasing attacks for its dual responsibilities for developing and regulating the technology. This became a major argument that nuclear critics cited in their indictments of the AEC; it was, said one, "like letting the fox guard the henhouse." The question of creating separate agencies to promote and to regulate the civilian uses of nuclear energy had arisen within a short time after passage of the 1954 Atomic Energy Act, but in the early stages of nuclear development it had seemed premature and unwarranted. It gained greater support as both the industry and antinuclear sentiment grew, and it took on greater urgency after the Arab oil embargo and the energy crisis of 1973-74. One of President Nixon's responses to the energy crisis was to ask Congress to create a new agency that could focus on, and presumably speed up, the licensing of nuclear plants. After much debate, Congress divided the AEC into the Energy Research and Development Administration and the Nuclear Regulatory Commission in legislation it passed in 1974. The Energy Reorganization Act, coupled with the 1954 Atomic Energy Act, constituted the statutory basis for the NRC.

The new agency inherited a mixed legacy from its predecessor, marked both by 20 years of conscientious regulation and by unresolved safety questions, substantial antinuclear activism, and growing public doubts about nuclear power.

Chapter 3

The Nuclear Regulatory Comission and Three Mile Island

The Nuclear Regulatory Commission began its operations as a separate agency in January 1975. In many ways, it carried on the legacy inherited from the AEC. It performed the same licensing and rule-making functions that the regulatory staff had discharged for two decades. It also assumed some new administrative and regulatory duties. The NRC, unlike the AEC's regulatory staff, was the final arbiter of regulatory issues; its judgment on safety questions was less susceptible to being overridden by developmental priorities. This did not mean that the NRC acted without regard to industry concerns or that its officials always agreed on policy matters, but it did mean that the agency's statutory mandate was clearly focused on ensuring the safety of nuclear power.

The NRC devoted a great deal of attention during its first few months to organizational tasks. At the same time it carried out a variety of regulatory responsibilities. It continued to review plant applications and to issue construction permits and operating licenses for new units. The NRC deliberated over a number of pressing problems shortly after its establishment. One issue that received particular notice, both within and outside of the NRC, was the safeguarding of nuclear materials. The term "safeguards" applied to the prevention of theft, loss, or diversion of nuclear fuel or other materials or the sabotage of nuclear plants. This question took on greatly increased importance and visibility in the early 1970s because of growing apprehension about the activities and intentions of terrorist groups. There was a wave of terrorist bombings, assassinations, hijackings, and murders at that time, perhaps the most shocking of which was the murder of Israeli athletes at the 1972 Olympics.

The increase in such attacks around the world raised new concerns that terrorists would be able to build an atomic bomb, which was underscored by the well-publicized warnings of some nuclear experts that making a bomb was not terribly difficult for anyone who obtained the necessary materials. As a result, the AEC, and after its abolition, the NRC, substantially strengthened regulatory requirements for the transportation of nuclear materials and for nuclear plant security. The NRC also devoted considerable attention to the export of nuclear materials to foreign countries. The United States was by far the leading supplier of nuclear fuel and other materials for the production of nuclear power abroad, and the NRC exercised important responsibilities for ensuring that nuclear exports did not encourage the proliferation of nuclear weapons or make them available to terrorists.

Despite the prominence of safeguards problems, the cental issue for the NRC at the time of its creation remained reactor safety. There were two events in the early months of the NRC's existence that commanded the particular attention of the agency and the public. The first was a major fire at TVA's Browns Ferry nuclear plants near Decatur, Alabama in March 1975. In the process of looking for air leaks in an area containing trays of electrical cables that operated the plants' control room and safety systems, a technician set off the fire. He used a lighted candle to conduct the search, and the open flame ignited the insulation around the cables. The fire raged for over seven hours and nearly disabled the safety equipment of one of the two affected units. The accident was a blow to the public image of nuclear power and the recently-established NRC. It focused new attention on preventing fires from threatening plant safety and on the possibility of "common-mode failures," in which a single cause could initiate a chain of events that incapacitated even redundant safety features.

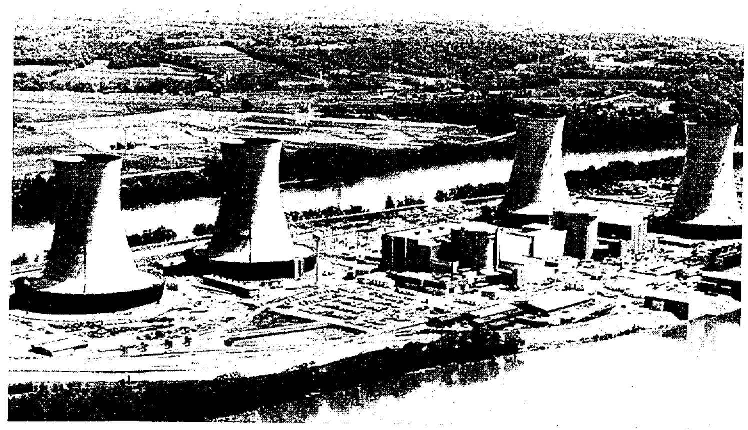
The second source of unusually extensive discussion and considerable controversy shortly after the NRC began operations was the publication of the final version of the "Reactor Safety Study" that the AEC had commissioned in 1972. The purpose of the study was to estimate the probability of a severe reactor accident, an issue that the AEC had never found a satisfactory means of addressing. To direct the study the AEC had recruited Norman C. Rasmussen, a professor of nuclear engineering at MIT. Rasmussen, assisted by AEC staff members, applied new methodologies and sophisticated "fault-tree" analyses to project the likelihood of a serious nuclear accident. The final Rasmussen report, released in

October 1975, concluded that in comparison to other risks, including fires, explosions, toxic chemicals, dam failures, airplane crashes, earthquakes, tornadoes, and hurricanes, those from nuclear power were very small.

The Rasmussen report, while hailed as a pioneering effort that enlightened a complex subject, also drew criticism from both inside and outside the NRC. Some authorities suggested that the study failed to account for the many paths that could lead to major accidents. Others complained that the data in the report did not support its executive summary's conclusions about the relative risks of nuclear power. After considering the arguments on both sides of the issue, the Commission in January 1979 issued a policy statement that withdrew its full endorsement of the study's executive summary.

Within a short time, discussion of severe nuclear accidents ceased to be strictly a matter of theoretical projections. On March 28, 1979, an accident at Unit 2 of the Three Mile Island nuclear station near Harrisburg, Pennsylvania made the issue starkly and alarmingly real. As a result of a series of mechanical failures and human errors, the accident (researchers later determined) uncovered the reactor's core and melted about half of it. The immediate cause of the accident was a pressure relief valve that stuck open and allowed large volumes of reactor coolant to escape. The reactor operators misread the signs of a loss-of-coolant accident and, for several hours, failed to take action to cool the core. Although the plant's emergency cooling systems began to work according to design, the operating crew decided to reduce the flow from them to a trickle. By the time that the nature of the accident was recognized and the core was flooded with coolant, the reactor had suffered irreparable damage.

The credibility of the nuclear industry and the NRC fared almost as badly. Uncertainty about the causes of the problem, confusion about how to deal with it, conflicting information from government and industry experts, and contradictory appraisals about the



Three Mile Island, looking southeast. The accident occurred in the reactor at the right of the photograph.

level of danger in the days following the accident often made the authorities appear inept, deceptive, or both. Press accounts fed public fears and fostered a deepening perception of a technology that was out of control. Walter Cronkite told television viewers that as a result of the accident, "the danger faced by man for tampering with natural forces, a theme from the myths of Prometheus to the story of Frankenstein, moved closer to fact from fancy." Newspapers ran headlines warning, for example, of a "RACE WITH NUCLEAR DISASTER" and "RISK OF MELTDOWN." Long after the technological dangers had subsided, the psychological effects of the TMI accident lingered on.

In some ways, the TMI accident produced reassuring, or at least encouraging, information for reactor experts about the design and operation of the safety systems in a large nuclear plant. Despite the substantial degree of core melting that occurred, containment was not breached. From all indications, the amount of radioactivity released into the environment as a result of the accident was very low. One estimate suggested that of 66 million curies of iodine-131 in the reactor at the time of the accident, only 14 or 15 curies escaped. Further, the emergency core cooling systems worked effectively once plant operators allowed them to run according to design.

Those findings were overshadowed by the unsettling disclosures of TMI. It focused attention on possible causes of accidents that the AEC/NRC and the nuclear industry had not considered extensively. Their working assumption had been that the most likely cause of a loss-of-coolant accident was a break in a large pipe that fed coolant to the core. But the destruction of the core at TMI had resulted not from a large pipe break but from a relatively minor mechanical failure that operator errors had drastically compounded.

Perhaps the most distressing revelation of TMI was that an accident so severe could occur at all. Neither the AEC/NRC or the industry had ever claimed that a major reactor accident was impossible, despite multiple and redundant safety features built into nuclear plants. But they had regarded it as highly unlikely, to the point of being nearly incredible. The TMI accident demonstrated graphically that serious consequences could arise from unanticipated events. This enhanced the credibility of nuclear critics who had argued for years that no facility as complex as a nuclear plant could be made fool-proof. Public opinion polls taken after TMI showed a significant erosion in support for nuclear power. One survey found for the first time that the number of respondents who opposed building more nuclear units exceeded those who favored new plants. At the same time, the polls indicated that the public did not want to abandon nuclear power or close existing plants.

The NRC responded to TMI by re-examining the adequacy of its safety requirements and imposing new regulations to correct deficiencies. It placed much greater emphasis on "human factors" in plant performance in an effort to avoid a repeat of the operator errors that had exacerbated the accident. The agency developed new requirements for operator training, testing and licensing, and for shift scheduling and overtime. In cooperation with industry groups, it promoted the increased use of reactor simulators and the careful assessment of control rooms and instrumentation. In addition, the agency expanded its resident inspector program to station at least two of its inspectors at each plant site.

The NRC devoted greater attention to other problems that had received limited consideration before TMI. They included the possible effects of small failures that could lead to major consequences, such as happened at Three Mile Island. The agency sponsored a series of studies on the ways in which "small breaks and transients" could threaten plant safety. A second area on which the NRC focused was the evaluation of operational data from licensees. It established a new Office for Analysis and Evaluation of Operational Data to systematically review information from and the performance of operating plants. This action reflected the belated recognition that malfunctions similar to those at TMI had occurred at other plants, but the information had never been assimilated or disseminated.

The NRC undertook other initiatives as a result of TMI. It decided to survey radiation protection procedures at operating plants in order to assess their adequacy and to look for ways to improve existing regulations. It expanded research programs on problems that TMI had highlighted, including fuel damage, fission-product release, and hydrogen generation and control. In light of the confusion and uncertainty over evacuation of the areas surrounding TMI during the accident, the NRC also sought to upgrade emergency preparedness and planning. Those and other steps it took in the wake of the accident were intended to reduce the likelihood of a major accident, and, in the event one occurred, to enhance the ability of the NRC, the utility, and the public to cope with it.

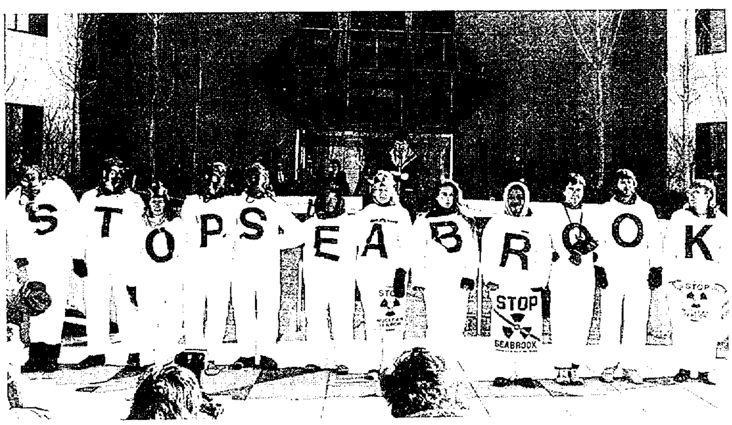
While the NRC was still deliberating over and revising its requirements in the aftermath of TMI, another event shook the industry and further undercut public support for nuclear power. This time, the NRC was a distant though interested observer rather than a direct participant. On April 26, 1986, unit 4 of the nuclear power station at Chernobyl in the USSR underwent a violent explosion that destroyed the reactor and blew the top off it. The explosion and subsequent fire in the graphite core spewed massive amounts of radioactivity into the environment. The accident occurred during a test in which operators had turned off the plant's safety systems and then lost control of the reactivity in the reactor. Without emergency cooling or a containment building to stop or at least slow the escape of radiation, the areas around the plant quickly became seriously contaminated and a radioactive plume spread far into other parts of the Soviet Union and Europe. Although the radiation did not pose a threat to the United States, one measure of its intensity in the Soviet Union was that levels of iodine-131 around Three Mile Island were three times as high after Chernobyl than they were after the TMI accident.

The design of the Chernobyl reactor was entirely different than that of U. S. plants, and the series of operator blunders that led to the accident defied belief. Supporters of nuclear power emphasized that a Chernobyl-type accident could not occur in commercial plants in the United States (or other nations) and that American reactors featured safety systems and containment to prevent the release of radioactivity. But nuclear critics pointed to Chernobyl as the prime example of the hazards of nuclear power. A representative of the Union of Concerned Scientists remarked: "The accident at Chernobyl makes it clear. Nuclear power is inherently dangerous." A popular slogan that quickly appeared on the placards of European environmentalists was: CHERNOBYL IS EVERYWHERE. The Chernobyl tragedy was a major setback to the hopes of nuclear proponents to win public support for the technology and to spur orders for new reactors. U. S. utilities had not ordered any new plants since 1978 and the number of cancellations of planned units was growing. "We're in trouble," conceded a spokesman for the Atomic Industrial Forum. "If the calls I have received from people in the industry are a good indication, they are all very worried."

The Chernobyl accident added a new source of concern to long-standing controversies over the licensing of several reactors in the United States. In the aftermath of Three Mile Island, the NRC had suspended the granting of operating licenses for plants that were in the pipeline. The "licensing pause" for fuel loading and low-power testing ended in February 1980. In August 1980 the NRC issued the first full-power operating license (to North Anna-2 in Virginia) since TMI. In the following nine years it granted full-power licenses to over forty other reactors, most of which had received construction permits in the mid-1970s. In 1985 it authorized the undamaged Three Mile Island Unit 1, which had been shut down for refueling at the time of the TMI-2 accident, to resume operation.

Although many of the licensing actions aroused little opposition, others triggered major controversies. The two licensing cases that precipitated what were perhaps the most bitter, protracted, and widely publicized debates were Seabrook in New Hampshire and Shoreham on Long Island, New York. The key, though hardly the sole, issue in both cases was emergency planning. The Three Mile Island accident had vividly demonstrated the deficiencies in existing procedures for coping with an off-site nuclear emergency. The lack of effective preparation had produced confusion, uncertainty, and panic among members of the public faced with the prospect of exposure to radiation releases from the plant. After the accident, the NRC, prodded by Congress to improve emergency planning, adopted a rule that required each nuclear utility to come up with a plan for evacuating the population within a ten mile radius of its plant(s) in the event of a reactor accident. The rule applied to plants in operation and under construction. It called for plant owners to work with state and local police, fire, and civil defense authorities to put together an emergency plan that would be tested and evaluated by the NRC and the Federal Emergency Management Agency (FEMA). The NRC expected cooperation between federal, state and local government officials to upgrade emergency plans and provide better protection for the public if a serious nuclear accident occurred.

The NRC did not, however, anticipate that state and local governments would try to prevent the operation of nuclear plants by refusing to participate in emergency preparations. That was precisely what the states of New York and Massachusetts sought to do in the cases of Shoreham and Seabrook. In New York, Governor Mario M. Cuomo and other state officials claimed that it would be impossible to evacuate Long Island if Shoreham suffered a major accident. Although plant proponents pointed out that emergency plans did not require the evacuation of all of Long Island if a serious accident occurred, the state refused to join in emergency planning procedures or drills. The NRC granted Shoreham a low-power operating license, but the state and the utility, Long Island Lighting, eventually reached a settlement in which the company agreed not to operate the plant in return for concessions from the state.



Opponents of a full-power license for Seabrook express their views at NRC headquarters in Rockville, Maryland, 1990.

A similar issue arose at Seabrook, though the outcome was different. The plant is located in the state of New Hampshire, but the ten mile emergency planning zone extended across the state line into Massachusetts. By the time that construction of the plant was completed, Massachusetts Governor Michael S. Dukakis, largely as a result of Chernobyl, had decided that he would not cooperate with emergency planning efforts for Seabrook. New Hampshire officials worked with federal agencies to prepare an emergency plan, but Massachusetts, arguing that crowded beaches near the Seabrook plant could not be evacuated in the event of an accident, refused. As a result of the positions of New York regarding Shoreham and Massachusetts regarding Seabrook, in 1988 the NRC adopted a "realism rule," which was grounded on the premise that in an actual emergency state and local governments would make every effort to protect public health and safety. Therefore, in cases in which state and/or local officials declined to participate in emergency planning, the NRC and FEMA would review and evaluate plans developed by the utility. On that basis, the NRC issued an operating license for the Seabrook plant. The arguments that raged over emergency planning and other issues at Shoreham and Seabrook attracted a great deal of attention, spawned heated controversy, and raised anew an old question of the relative authority of federal, state, and local governments in licensing and regulating nuclear plants.

The lengthy and laborious licensing procedures that applicants had to undergo in the cases of Shoreham (which had received a construction permit in 1973), Seabrook (which had received a construction permit in 1977), and other reactors stirred new interest in simplifying and streamlining the regulatory process. It seemed apparent that the complexity of the licensing process was a major deterrent to utilities who might consider building nuclear plants. By the late 1980s, the nuclear option looked more appealing to some observers, including some environmentalists, because of growing concern about the consequences of burning fossil fuel, especially acid rain and global warming. Furthermore, nuclear vendors were advancing new designs for plants that greatly reduced the chances of TMI-type and other severe accidents.

One way that the NRC proposed to facilitate licensing procedures was to replace the traditional two-step process with a one-step system. This would ease the burden on applicants, but it raised a vitally important question: what level of detail would the NRC require in applications for advanced plants in order to satisfy its concerns about their safety? The agency had never required the detailed technical information in construction permit proposals that it expected in operating license applications, but in a one-step licensing process it was unclear how much data would be needed to evaluate and certify safety designs.

After long discussions that reflected differing views among commissioners, staff, and nuclear vendors, the NRC reached a decision on what constituted an "essentially complete design." It established a "graded approach" in which the level of detail that an applicant would be required to submit varied according to the system's, structure's, or component's relationship to plant safety. The objective of the NRC's action was to ensure safety while providing flexibility for the development of new designs.

While the NRC was deliberating over a number of new regulatory procedures and problems, it was also reviewing some old issues. The most prominent of those questions was radiation standards. The NRC had begun work on revising its radiation protection regulations in the aftermath of Three Mile Island. Although the AEC had issued "design objectives" that in effect reduced the permissible levels of radioactive effluents from nuclear plants in the 1970s, the basic regulations for occupational and population exposure had remained unchanged since 1961 (an average of 5 rem per year for radiation workers and 0.5 rem annually for individuals in the general population). Based upon new recommendations of the NCRP and the ICRP and upon new research findings, the NRC tightened its regulations in several regards, the most prominent of which was to restrict population exposure to 100 (rather than 500) millirem per year.

Despite new scientific information and epidemiological studies, the health effects of low-level radiation remained a source of uncertainty and controversy. Some studies provided results that were very reassuring about the hazards of radiation emissions from nuclear plants. A major survey conducted by the National Cancer Institute, for example, found no increased risk of cancer in 107 counties in the United States located near 62 nuclear power plants. But other evidence was more disquieting, such as a cluster of cancer cases near the Pilgrim reactor in Massachusetts and a high incidence of leukemia in children around the Sellafield reprocessing plant in Britain.

None of the studies on the effects of low-level radiation was, or claimed to be, definitive. The subject continued to be a source of interest to and debate among scientists. It also continued to be a source of considerable anxiety to the public. The most graphic evidence of public apprehension about radiation was the reaction to the NRC's announcement of a new policy on radiation levels that were "below regulatory concern" (BRC). In June 1990, the NRC published a policy statement outlining its plans to establish rules and procedures by which small quantities of low-level radioactive materials could be largely exempted from regulatory controls. The agency proposed that if radioactive materials did not expose individuals to more than 1 millirem per year or a population group to more than 1000 person-rem per year, they could be eligible for the exemption from full-scale regulatory control. This would not be granted automatically; the NRC would consider requests for exemptions for sites that met the dose criteria through its rulemaking or licensing processes. It intended that the BRC policy would apply to consumer products, landfills, and other sources of very low levels of radiation. The NRC explained that the BRC policy would enable it to devote more time and resources to major regulatory issues and thereby better protect public health and safety.

The NRC's announcement of its intentions on BRC was greeted with a firestorm of protest from the public, Congress, the news media, and antinuclear activists. Some critics suggested that the agency was defaulting on its responsibility for public health and that BRC would allow the nuclear industry to discard dangerously radioactive wastes in public trash dumps. It was, alleged one antinuclear group, "a trade-off of people's lives in favor of the financial interests of the nuclear industry." In public meetings that the NRC held to explain BRC, aroused citizens called repeatedly for the resignation of the commissioners or their indictment under criminal charges. Eventually, the Commission terminated action on the BRC issue. The outcry over BRC underscored the difficulty of even attempting to sponsor a calm and reasoned discussion on the subject of radiation hazards.

The uproar over BRC was one of several indications of how the regulatory environment had changed since the passage of the 1954 Atomic Energy Act made possible the development of nuclear power for electrical generation. A public that had welcomed the growth of nuclear power in the 1950s had become skeptical of the technology and suspicious of those responsible for its safety. Nuclear plants had become larger, more complicated, and more costly to build. The longest running nuclear plant until its closure in 1992, Yankee Rowe in Massachusetts, had a capacity of 175 electrical megawatts and was constructed for about $39 million. By comparison, for example, Seabrook had a capacity of 1150 electrical megawatts and cost over $6 billion to build. The length and complexity of the licensing process had grown commensurately. The owners of Yankee Rowe applied for a construction permit in 1956 and received an operating license in 1960 without a murmur of protest. Seabrook's owners applied for a construction permit in 1973 and received an operating license in 1990 after long legal proceedings and many angry demonstrations. The contrasts between Yankee Rowe and Seabrook were results of a series of inter-related technological, administrative, and political developments that shaped the history of nuclear regulation.

Chapter 4

New Issues, New Approaches

The focus of the NRC's activities gradually shifted away from licensing requirements for new plants to overseeing the safety of operating plants. Since it received no applications for construction permits after 1978 and had completed work on most operating license applications a decade later, it devoted much less attention and fewer resources to its licensing responsibilities. During the first half of the 1980s, the NRC's deliberations and policy decisions were in large measure a response to Three Mile Island. By the latter part of the decade, however, the agency was addressing a wide range of new questions relating to the safety of the about 100 plants in operation. Not surprisingly, the issues it considered often raised difficult and divisive questions for which there were no ready answers.

One of the first and most important issues that the NRC tackled as it turned its attention to the regulation of operating nuclear plants was maintenance. It estimated in 1985 that more than 35 percent of the "abnormal occurrences" that it had reported to Congress over the previous ten years were directly attributable to maintenance deficiencies. Many of the problems arose from human errors, such as failing to follow procedures, installing equipment incorrectly, or using the wrong parts to make repairs. The need for improvements in maintenance was underscored when an incident at the Davis-Besse plant in Ohio resulted in the loss of all feedwater in 1985. Failures in feedwater pumps, including auxiliary pumps that had not been tested or maintained, caused what could have produced a major accident.

The nuclear industry was well aware of shortcomings in maintenance programs and took steps to make improvements. The NRC applauded the efforts of the industry but insisted that licenses still "had a long way to go in the maintenance area." Therefore, in June 1988 the Commission directed the NRC staff to draft a maintenance rule as a matter of "HIGHEST priority." In June 1991, despite industry objections that a rule was not necessary, the Commission voted to issue a regulation that required adequate maintenance programs of all commercial nuclear plants. It acknowledged the substantial improvements that many licensees had made, but it concluded that an industry-wide regulation was still necessary. The NRC worked with the industry to establish procedures for monitoring the effectiveness of maintenance programs.

Another key issue that the NRC considered was the decommissioning of plants, the final step of the life cycle for operating facilities. Between 1947 and 1975, a total of 50 nuclear plants, including five small experimental power reactors, were decommissioned. In the late 1970s, this experience gave the NRC confidence that decommissioning of nuclear plants would not present major problems when their licenses expired. In response to an investigation by the U.S. General Accounting Office, congressional hearings, and a petition from environmental organizations, however, the NRC took a closer look at the subject. In 1984, the staff reported to the Commission that existing regulations covered decommissioning in a "limited, vague, or inappropriate way and are not fully adequate." As a result, the NRC drafted a rule that required licensees to specify how they planned to ensure that sufficient funding was available to clean up the sites on which their plants were located and to make certain that radiation levels at decommissioned sites were low enough to allow the land to be used for other purposes. After soliciting public comments and making modest revisions in the draft, the NRC published a final rule in 1988.

The decommissioning rule was much more comprehensive than earlier NRC regulations but it did not resolve all of the issues that arose on the subject. Within a short time after the rule became final, the agency faced an unprecedented and unanticipated question—what to do about funding for "prematurely shut down reactors." Three plants, including Shoreham, closed well before their operating licenses expired, which raised questions about how to pay for costs of decommissioning reactors that had not operated long enough to accumulate adequate funding. This issue was underscored by the costs of decommissioning the Yankee Rowe plant, which ran much higher than projected. While the NRC wrestled with this question, it also deliberated over the level of radiation that should be permitted at the sites of decommissioned plants. This issue generated opposing views and sometimes sharp differences between the NRC and the Environmental Protection Agency.

As decommissioning issues were debated, the NRC devoted considerable attention and resources to the question of license renewal. While some utilities were closing reactors long before their 40-year operating licenses expired, others were weighing the possibility of extending the lives of plants beyond 40 years. The 40-year licensing period for nuclear plants was a rather arbitrary compromise written into the 1954 Atomic Energy Act that was not based on technical grounds or operating experience. In the late 1970s, industry groups closely examined the issue of plant life extension for the first time. The Electric Power Research Institute, for example, concluded that reconditioning of old plants offered potentially major benefits, but it cautioned that the benefits depended on financial considerations as well as on technical assessments, environmental issues, and projections of power availability. Those uncertainties were compounded by industry's concern that the NRC was not prepared to address the issues surrounding license renewal promptly and knowledgeably.

In 1985, the NRC, prodded by Chairman Nunzio J. Palladino, undertook a careful analysis of license renewal. The agency had sponsored research on the critical question of the safety effects of plant aging for years, but many technical questions remained to be answered. License renewal also raised complex legal and policy issues. The NRC staff cited the "central regulatory question" that plant life extension presented: "What is an adequate licensing basis for renewing the operating license of a nuclear power plant?"

The NRC deliberated over this issue and its corollaries for several years. Eventually, it decided that the maximum length of an extended license would be 20 years. It also concluded that using the existing regulatory requirements governing a plant would offer reasonable assurance of adequate protection if its license were renewed, provided that the "current licensing basis" was modified to account for age-related safety issues. In 1991, the Commission approved a regulation on the technical requirements for license renewal. After considering ways to evaluate the environmental consequences of license renewal, the NRC elected to develop a generic environmental impact statement that covered effects that were common to all or most nuclear plants. In April 1998, Baltimore Gas and Electric became the first utility to apply for license renewal for its Calvert Cliffs plants on the Chesapeake Bay. Duke Energy Corporation followed suit in July 1998 when it sought license extensions for its Oconee nuclear units in South Carolina.

As the NRC considered its policies on license renewal, representatives of the nuclear industry expressed concern that the costs and uncertainties of the regulatory process would negate the potential advantages of plant life extension. This was consistent with strong industry criticism of the NRC's regulations or the ways in which they were implemented. A report prepared for an industry group, for example, concluded in 1994 that the NRC's policies and practices represented a "serious threat to America's nuclear energy resource" by distracting plant management, undermining public trust in nuclear power, and "pricing nuclear power out of the competitive energy marketplace." Industry protests about regulatory burdens were nothing new, of course, but they had taken on increased urgency and intensity by the early part of the 1990s. Industry officials complained that NRC regulations were in many cases intrusive, excessive, and potentially counterproductive. They particularly objected to the agency's numerical ratings of plant performance, which they found to be arbitrary and inconsistent. In September 1998, the Commission indefinitely suspended the "Systematic Assessment of Licensee Performance" program, which the agency had created in the wake of the Three Island accident to evaluate and score management practices in several different categories of plant operation. In June 1999, it began a pilot program to test methods of providing more consistent and predictable plant evaluations.

As a part of its reexamination of the regulatory process, the NRC evaluated the role of risk assessment and performance indicators. The benefits of risk assessment had been debated since the Rasmussen report without making a major impact on the formulation or enforcement of the NRC's rules. Nuclear industry representatives complained that the NRC relied too heavily on "prescriptive" regulations. They urged the agency to place greater emphasis on non-prescriptive performance-based assessments that would recognize the significant improvements that industry had achieved since Three Mile Island. This would allow licensees greater leeway to determine how to accomplish regulatory goals and presumably cut costs without sacrificing safety. In 1991, the Commission instructed the agency staff to investigate the feasibility of using more performance-based regulations that focused on a "result to be obtained, rather than prescribing to the licensee how the objective is to be obtained." This initiative received strong support from Ivan Selin, chairman of the NRC from 1992 to 1995, from his successor, Shirley Ann Jackson, chairman from 1995 to 1999, and from their colleagues on the Commission.

The effective employment of performance-based regulation was closely tied to informed analyses of risk. In 1995, the Commission unanimously approved a policy statement that encouraged the application of probabilistic risk assessment "as an extension and enhancement of traditional regulation." The agency believed that risk analysis would enable it to "focus on those regulated activities that pose the greatest risk to the public" and to ease "unnecessary burdens on licensees." The industry and the NRC agreed on this general objective, but many uncertainties about how to apply the concept of risk assessment in practice had not been resolved. The industry was concerned that the NRC gave unwarranted emphasis to the redundant "defense-in-depth" approach that had been applied since the earliest days of the nuclear power industry. Those concerns were magnified in 1997 when the Commission voted to require a containment spray system in a new Westinghouse plant design even though risk assessments indicated that the design was "safe enough" without the spray system. Despite this affirmation of the importance of defense-in-depth, the NRC continued to search for ways to use probabilistic risk assessment to improve the regulatory process.

Although risk-informed regulation offered many potential benefits for evaluating the technical performance of nuclear plants, it was not a reliable way to detect safety issues that could generate acute public concern. In that regard, it was not necessarily a useful means of building public confidence in nuclear power technology or the NRC. This was amply demonstrated when a series of problems arose at the Millstone nuclear station, which included three plants located on the northern side of Long Island Sound in Connecticut. The safety issues at Millstone required attention, but they were not so serious that risk analysis was likely to identify them as priority matters. As Commissioner Nils J. Diaz commented in 1997, of the many issues raised about Millstone, "only a handful appear to have been safety-significant." Nevertheless, the failures at Millstone created a great deal of controversy and a barrage of criticism of the NRC.

The uproar over Millstone began in the early 1990s when several plant employees claimed that they were harassed, intimidated, and/or dismissed from their jobs by the owner of the plants, Northeast Utilities, for calling attention to safety problems and violations of NRC regulations. The NRC investigated the concerns raised by the "whistle-blowers" and determined that the safety issues they raised were not of major significance and had been corrected. But the agency also concluded that the utility had harassed employees and assessed it a fine of $100,000, the maximum amount allowed by law. This did not satisfy the dissidents at Millstone and elsewhere, who insisted that the NRC was neither prompt nor firm in dealing with the issues they cited or in protecting them from retaliation by their employers. As a result of the complaints from Millstone and other plants, the agency reexamined and eventually tightened its policies in order to provide better protection to whistle-blowers who contacted it about safety issues.

Meanwhile, new revelations at Millstone generated increasing NRC scrutiny. It also commanded growing media attention, much of which was sharply critical of the NRC. In 1993 and again in 1994 the NRC fined Northeast Utilities for procedural violations that the agency viewed as serious lapses in the management of the Millstone units. The utility pledged to improve its performance and "to resolve issues raised by [its] employees." Nevertheless, another issue raised by company employees soon triggered new reservations about safety at Millstone and the effectiveness of the NRC's enforcement policies. In this case, the whistle-blowers objected to the company's practice of placing the entire nuclear core into the spent fuel pool at Millstone Unit 1 during refueling operations. The plant's "final safety analysis report," which provided the basis for the its operating license, specified that only one-third of the spent fuel rods would be moved into the pool. But Millstone-1 had performed "full-core off-loads" for years as an "emergency" procedure with the knowledge of the NRC. Finally, after employees questioned the practice, Northeast Utilities applied for a license amendment that expressly permitted full-core off-loading, and in November 1995 the NRC granted its approval.

By that time, the utility and the NRC were the subjects of extensive and unflattering coverage in the local media. In March 1996, the criticism reached a new level of visibility when *Time* magazine ran a cover story on the whistle-blowers who had "caught the Nuclear Regulatory Commission at a dangerous game." It suggested that an accident in a spent fuel pool posed the hazard of "releasing massive amounts of radiation and rendering hundreds of square miles uninhabitable." It charged that the NRC "may be more concerned with propping up an embattled, economically straitened industry than with ensuring public safety." NRC chairman Jackson conceded that the *Time* article demonstrated that "not all aspects of nuclear regulation or nuclear operations in certain places are as they should be," but she strongly denied the implication that "the Millstone situation borders on an impending TMI- or Chernobyl-type disaster."

Amid the growing criticism, the NRC conducted its own reviews to identify and correct errors that the Millstone experience brought to light. An internal task force reported in September 1996 that the "safety significance of Millstone's refueling practices was low." Nevertheless, it recommended a series of procedural, informational, and management improvements. The agency also undertook a careful study of a frequently-used provision in its regulations that allowed licensees to make changes in their plants without NRC permission under certain conditions. In 1999, after considerable debate over the threshold for permitting such changes, the Commission approved revisions designed to clarify the rule and provide guidance on when NRC consent was necessary within a risk-informed framework.

While the NRC examined its own regulations and procedures, it conducted an expanding probe of the Millstone plants. In May 1996 the NRC's inspector general faulted the agency for failing to recognize the problems at Millstone and impose corrective actions much earlier. When the NRC's investigations, along with those conducted by the utility, turned up hundreds of performance and procedural deficiencies, the agency took the unusual step of stipulating that the three plants, all of which had been shut down, would not be allowed to restart without a formal vote of the Commission. Eventually, after the utility made management changes, took a series of steps to address its shortcomings, and decided to permanently close Millstone-1, the Commission authorized the restart of units 2 (in 1999) and 3 (in 1998). The series of problems at Millstone underscored the general difficulties that the NRC had encountered with plants that did not perform up to standards and did not correct their deficiencies promptly or effectively. The Commission devoted a great deal of energy to dealing with the many aspects of encouraging or forcing improvements in plants that did not fully meet its requirements.

Although reactor safety issues captured a lion's share of public notice, the NRC also devoted substantial resources to a variety of complex matters in the area of nuclear materials safety and safeguards. The protection of nuclear materials from theft or diversion remained a major agency concern, though it did not command the level of public attention it had received in the 1970s. In cooperation and sometimes in conflict with other government agencies, the NRC evaluated the safety problems involved in building and operating repositories for high-level and low-level radioactive waste. Despite federal legislation that attempted to provide the means for establishing permanent waste sites and the efforts of federal and state officials, scientists, engineers, and other professionals, the disposal of radioactive wastes remained a source of intense public concern and bitter political controversy. The NRC also considered its role in regulating certain medical uses of radioactive materials. Although it exercised only limited responsibilities in the field of "radiation medicine," it sought to ensure that patients received the proper doses of radiation from procedures under its regulatory authority. Its rules elicited protests from medical practitioners and organizations who complained about regulatory overkill that intruded into physician-patient relationships.

The issues surrounding the regulation of nuclear materials, the problems at Millstone, and the use of risk assessment underscored patterns in the history of nuclear regulation over a period of four decades. The nuclear industry and materials licensees often asserted that regulatory requirements were too burdensome, too inflexible, and too strict. Nuclear critics, on the other hand, frequently lamented that regulatory requirements were too lax, too sympathetic to industry concerns, and too inattentive to public safety. The NRC, and the AEC before it, attempted to find a proper balance between essential and excessive regulation, but this was a difficult and uncertain task that usually elicited complaints from one side or all sides of regulatory issues. The NRC sought to separate valid criticisms from those that were exaggerated or ill-informed, but this process won few plaudits from its different (and frequently competing) constituencies. "The bane of the regulator," a senior agency official remarked in 1998, "is to feel unloved." The ongoing effort to promote the safe use of nuclear materials and the safe operation of nuclear power plants without imposing undue burdens on licensees ensured that nuclear regulation would remain a complex and controversial public policy issue.

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